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TU Graz research

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TU Graz
WISSEN
TECHNIK
LEIDENSCHAFT

TECHNIK FÜR DIE GESUNDHEIT

Seite 4

Liebe Kolleg*innen, sehr geehrte Forschungspartner*innen und an unserer Forschung Interessierte,

Andrea Höglinger
Vizerektorin für Forschung
Lunghammer – TU Graz

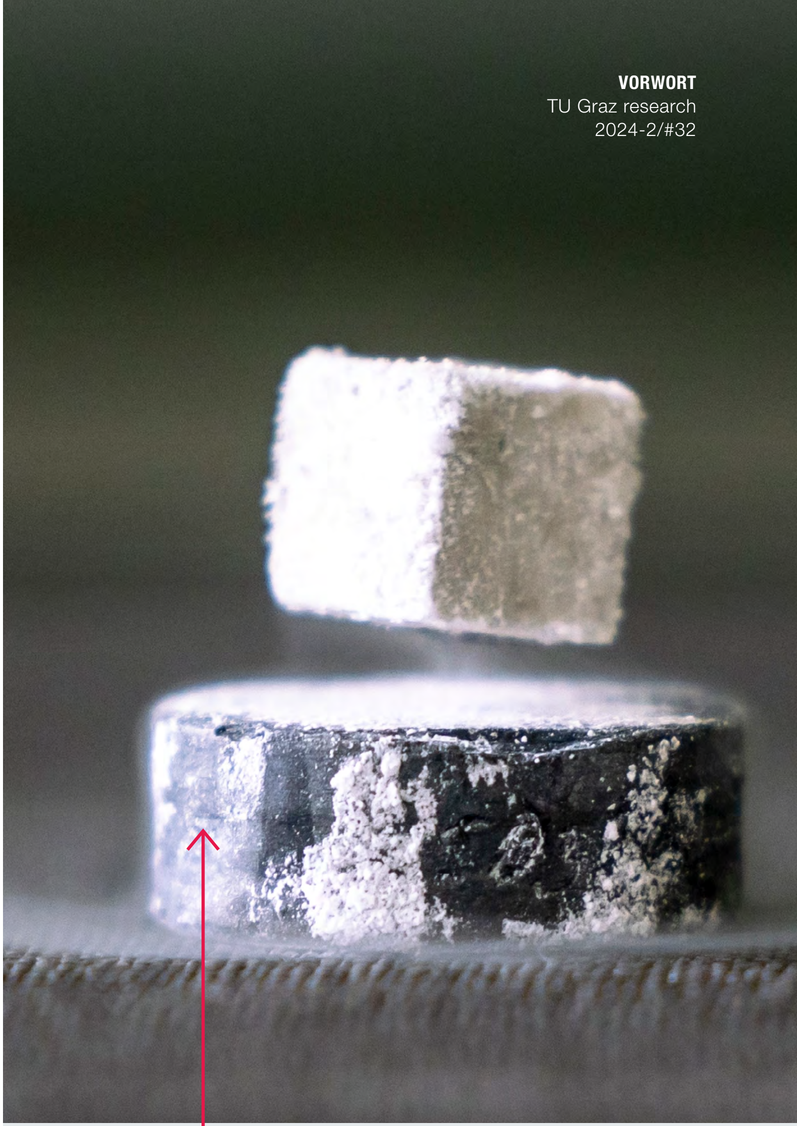
eine Universität lebt von Kooperationen in Lehre und Forschung. Seit 20 Jahren arbeiten TU Graz und Uni Graz eng im Bereich der Naturwissenschaft zusammen – sowohl in gemeinsamen Studien und Lehrveranstaltungen als auch in gemeinsam betriebener Infrastruktur und Forschung. NAWI Graz ist eine einzigartige Erfolgsgeschichte und wird es auch in Zukunft sein, denn die beiden Universitäten wachsen in den kommenden Jahren unter anderem mit dem Graz Center of Physics noch enger zusammen.

Zentrales Thema in dieser Ausgabe von TU Graz research ist die Biomedizinische Technik bzw. die biomedizinische Forschung. Hier steht der Mensch im Mittelpunkt, die Gesundheit und beste medizinische Versorgung. Verbesserung von MRT-Untersuchungen, Brain-Computer-Interfaces und eine optimierte Spracherkennung sind nur einige wenige Forschungsgebiete, denen sich die Forschenden an der TU Graz in diesem Bereich widmen.

Ganz besonders freut es mich, in dieser Ausgabe über gleich drei ERC Grants berichten zu dürfen, die der TU Graz verliehen wurden. Je ein ERC Starting Grant geht an Fariba Karimi und Maria Eichlseder. Gerhard A. Holzapfel wird in den kommenden Jahren mit einem ERC Synergy Grant forschen.

Alles in allem blicken wir auf ein äußerst erfolgreiches Forschungsjahr an der TU Graz zurück und ich wünsche Ihnen einen erholsamen Jahreswechsel.

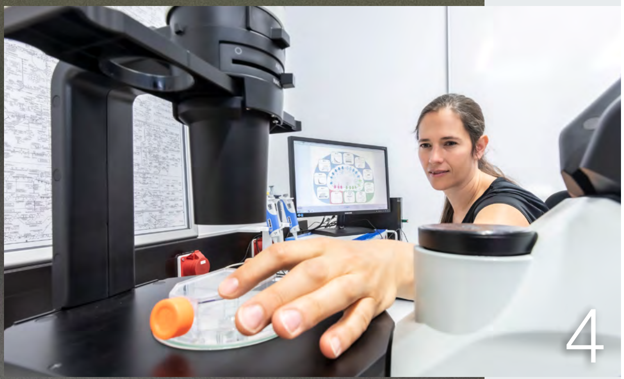
Mit besten Grüßen
Andrea Höglinger



SUPRALEITER

Ein Supraleiter ist ein Material, das unter bestimmten Bedingungen elektrischen Strom quasi widerstandsfrei transportieren kann. Bei heute bekannten Supraleitern – wie dem auf diesem Bild gezeigten – geschieht das bei extrem tiefen Temperaturen. Dazu wird der Leiter mit flüssigem Wasserstoff gekühlt, was derzeit nur bei Hightech-Anwendungen in Krankenhäusern oder Forschungseinrichtungen der Fall ist. Nun wird nach einem Supraleiter gesucht, der bei natürlicher Umgebungstemperatur und bei natürlichem Umgebungsdruck funktioniert.

I SPY SCIENCE
„Was ist ein Supraleiter?“



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Inhalt

Lunghammer – TU Graz

Technik für die Gesundheit

Krankheiten betreffen uns alle – in unterschiedlicher Form und mit unterschiedlichen Folgen. Medizinischer Fortschritt, unterstützt von technischer Forschung, hat Diagnose und Therapie in den vergangenen Jahren wesentlich treffsicherer, schneller und erfolgreicher gemacht.

Birgit Baustädter

Adobe Stock

Schwerpunkte wie die Biomedizinische Technik an der TU Graz zeigen, welchen Stellenwert dieses Thema in der Forschung hat. Hier wird an den Grundlagen genauso geforscht wie an ganz praktischen Diagnose- und Therapiemöglichkeiten. Das Thema „Mensch" ist ein vielfältiges und wird an der TU Graz so behandelt:

MEDIZINPRODUKTE

Prüfungen diverser Medizinprodukte bietet das Institut für Health Care Engineering bzw. die dort angesiedelte Europaprüfstelle für Medizinprodukte an. Sie ist die einzige akkreditierte Prüfstelle Europas an einer Universität. Hier werden Tests für Zertifizierungen durchgeführt. Aber natürlich auch Point-of-Care- und Sensortechnologien entwickelt, bewertet und validiert. In der Forschung geht es um die Analyse, Modellierung und Simulation von biophysikalischen, zellbiologischen und gewebespezifischen Prozessen sowie neuen technischen Ansätzen in Diagnose und Therapie.

Am Institut für Health Care Engineering, das räumlich mit der Prüfstelle verwoben ist, wird an unterschiedlichen Aspekten der Medizintechnik gearbeitet. Unter anderem an einem „Labor auf einem Chip". Das Labor ist ein kleiner Chip, und zwar ein Mikroelektroden-Array. „Wir züchten darauf Herzmuskelzellen", erklärt **Christian Baumgartner**, Leiter des Instituts. „Dieses System ermöglicht nichtinvasive Untersuchungen der Herzaktivität." Die Elektroden sind direkt an der Petrischale angebracht, in der die Herzmuskelzellen wachsen. Sie können dann sowohl die Herzzellen stimulieren als auch Daten messen. Die gezüchteten Herzmuskelzellen bilden in wenigen Tagen eine dichte Zellschicht und sogenannte Schrittmacherzellen, die Signale an ihre Umgebung aussenden. So „schlägt" das Herz künstlich in der Petrischale und Forschende können diverse Störungen simulieren und untersuchen.

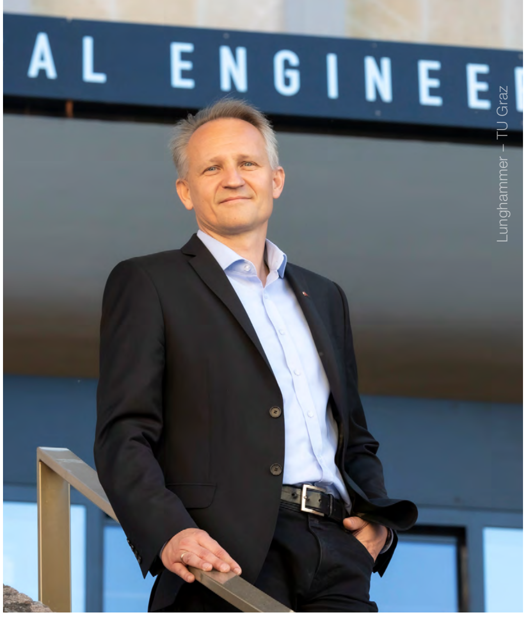
ERKRANKUNGEN DER AORTA

Ausgestattet mit einer Finanzierung aus dem TU Graz-Förderprogramm „Leadprojekte", untersuchen Gerhard A. Holzapfel (Institut für Biomechanik), Karin Ellermann (Institut für Mechanik) und ihr Forschungsteam die „Mechanik, Modellierung und Simulation von Aortendissektionen". Bei dieser Erkrankung unserer Hauptschlagader kommt es zu einem Einriss der Aorta. Aus dem Leadprojekt ging bereits ein Start-up hervor, in dem durch Machine-Learning-Ansätze die Diagnose von Aortendissektionen wesentlich erleichtert werden soll. Gerhard A. Holzapfel hat diesen Monat vom Europäischen Forschungsrat einen ERC Synergy Grant in der Höhe von 4,2 Millionen Euro erhalten. In diesem sechsjährigen Projekt werden experimentelle und KI-basierte Methoden entwickelt, die erstmals im Detail den Zusammenhang zwischen Transkriptomik, Mikrostruktur und mechanische Eigenschaften von weichem biologischem Gewebe zeigen. Übergeordnetes Ziel ist die Entwicklung eines bildgebenden Verfahrens zur nichtinvasiven Untersuchung der Gewebemikrostruktur, was die Diagnose und Behandlung der diastolischen Herzinsuffizienz im klinischen Alltag verbessert. Näheres auf Seite 10.

Zur Arbeit im Leadprojekt

DAS GENOM

Am Institut für Biomedical Informatics wird der Bauplan unseres Körpers untersucht – das menschliche Genom. Es rückte in den vergangenen Jahren vor allem in den Fokus der medizinischen Forschung, um personalisierte Medizin und individuelle Therapien möglich zu machen. Untersucht werden dabei vor allem die Abschnitte – Gene – , die Proteine kodieren; diese machen aber nur zwei Prozent des menschlichen Genoms aus. Der wesentlich größere Teil sind die sogenannten nicht-kodierende Sequenzen, die definieren, wie unsere Gene ausgeprägt sind. Damit haben diese nicht-codierten Sequenzen auch zentralen Einfluss auf die embryonale Entwicklung. Vor allem diesen Sequenzen widmet sich die Forschung am Institut für Biomedical Informatics, wo unter Zuhilfenahme von Methoden der künstlichen Intelligenz und Big Data am menschlichen Genom geforscht wird. Ein weiteres Forschungsfeld ist die Charakterisierung und Optimierung von Genomen von Mikroorganismen, die für die Herstellung von Biotherapeutika von großer Bedeutung sind. Dies erfolgt auch im Zusammenhang mit dem kürzlich gestarteten Leadprojekt "DigiBioTech".



Lunghammer – TU Graz

Christian Baumgartner

Lunghammer – TU Graz

Gernot Müller-Putz

MENSCHLICHE SPRACHE

Barbara Schuppler arbeitet mit Kindern und Jugendlichen, die aufgrund unterschiedlicher Sprachbeeinträchtigungen Probleme im Schulalltag haben. Sie untersucht mit ihrem Team am Institut für Signalverarbeitung und Sprachkommunikation speziell die menschliche Sprache, ihre Besonderheiten und Strukturen, wie menschliche Dialoge funktionieren, wie sehr sich Gesprächspartner*innen aneinander anpassen und wie dieses Verhalten modelliert werden kann. So schafft sie wichtige Daten für weitere Forschung: „Wir haben die größte Datenbank Österreichs zu spontansprachlichen Dialogen geschaffen. Anhand dieser Daten können wir analysieren, welche Eigenschaften spontane Sprache hat. Etwa wann die Dialogbeteiligten wissen, wann sie reden können, wie sie Zustimmung signalisieren und wie sich die Aussprache, Intonation und Rhythmik der Sprache verändern, zum Beispiel durch Demenz." So schafft sie die Grundlagen für die Verbesserung von Spracherkennungssystemen, die wieder unter anderem in medizinischen Hilfssystemen eingesetzt werden.

WIEDER BEWEGEN

Je nach Lage einer Rückenmarksverletzung haben betroffene Menschen unterschiedliche Einschränkungen im Alltag zu meistern. **Gernot Müller-Putz** und sein Team am Institut für Neurotechnologie möchten diesen Menschen das Leben erleichtern und zum Teil Kommunikation überhaupt erst möglich machen.

Bisher spezialisierten sich die Forschungsbemühungen vor allem auf nichtinvasive Messungen der Gehirnströme mittels EEG-Haube. Das EEG misst die elektrischen Impulse, die die Neuronen im Gehirn aussenden, ein Computer dekodiert sie und schickt die verstandenen Befehle an einen Roboterarm, ein Computerprogramm oder etwa ein Exoskelett. So können Proband*innen externe Prothesen bewegen, Muskeln benutzen, die über das Rückenmark nicht mehr angesteuert werden können, oder Wörter auf den Computerbildschirm „denken". „Unsere größte Herausforderung ist es, die richtigen Potenziale in den Gehirnströmen der richtigen Bewegung zuzuordnen", erklärt Müller-Putz. Aber auch die Proband*innen müssen sich mit der Nutzung der Maschine erst einmal vertraut machen.

Seit gut zwei Jahren geht das Team zusätzlich in Richtung implantierbarer Systeme und beteiligt sich an der Entwicklung eines völlig neuartigen Chips, der direkt ins Gehirn eingesetzt wird. „Der große Vorteil ist, dass die Signale wesentlich klarer sind als die einer EEG-Haube", erklärt Müller-Putz. Mit dem System möchte er zum Beispiel Menschen mit einem Locked-in-Syndrom oder Personen, die im Wachkoma liegen, die Kommunikation neu ermöglichen.

Talk Science To Me
TU Graz-Podcast

Podcast mit Gernot Müller-Putz

CYBATHLON

Im internationalen Studierendenwettbewerb Cybathlon treten Studierendenteams gegeneinander in unterschiedlichen Disziplinen rund um Brain-Computer-Interfaces an. Die Studierenden des Teams Mirage 91 der TU Graz nehmen regelmäßig daran teil, entwickeln Systeme, trainieren gemeinsam mit Pilot*innen und optimieren die Steuerung dann auf Basis des Trainings. Beim Bewerb selbst müssen die Pilot*innen – Personen mit Querschnittlähmung – via EEG-Messung ein Computerspiel schnellstmöglich durchlaufen. Die Herausforderung sei dabei vor allem, dass das System zu einem vorgegebenen Zeitpunkt auf vorgegebene Weise funktionieren muss, erklärt Gernot Müller-Putz. Aber auch die mentale Verfassung von Pilot*innen wirkt sich aus: „Diese Personen sind vor einem großen Publikum verständlicherweise aufgeregt. Das beeinflusst die Hirnsignale natürlich sehr."

Martin Uecker

MRT VERBESSERN

Martin Uecker und sein Team am Institut für Biomedical Imaging untersuchen, wie Aufnahmen und Messungen von Magnetresonanztomografen optimiert werden können. MRT-Untersuchungen dauern aufgrund ihrer Bildgebungsweise verhältnismäßig lange, kommen aber im Gegensatz etwa zur Computertomografie, die wesentlich schneller Bilder liefert, ohne ionisierte Strahlung aus. Die Länge der Untersuchung in einer relativ engen Röhre kann für manche Menschen unangenehm sein, ist aber notwendig, da bei einer MRT-Untersuchung viele einzelne Messungen vorgenommen werden, aus denen anschließend ein sehr genaues Gesamtbild zusammengesetzt wird.

Eine Möglichkeit, diese Untersuchungen zu verbessern, sind neue numerische Algorithmen für die Bildrekonstruktion. Sie können aus wesentlich weniger Daten – also wesentlich weniger einzelnen Messungen – akkurate Bilder erstellen. Einige aktuelle Ansätze beruhen auf maschinellem Lernen und brauchen daher für das Training perfekte MRT-Bilder. „Perfekte Daten sind aber schwer zu bekommen", beschreibt Martin Uecker. „Insbesondere von bewegten Organen, wie dem schlagenden Herzen." Am Institut erforscht man nun Möglichkeiten, die für die Algorithmen benötigten neuronalen Netzwerke aus den Daten selber und ohne perfekte Bilder zu trainieren.

Daneben ist das Institut sehr vielfältig in der Verbesserung von MRT-Untersuchungen engagiert. Etwa an der Entwicklung von quantitativen Bildgebungsbiomarkern, wie zum Beispiel auf Basis des Chemical Exchange Saturation Transfer (CEST) Effekts, oder an der Niedrigfeld-MRT.

A portable, small open-source MRI scanner

Christian Adams

MEDIKAMENTE

Ein wichtiger Teil der Behandlung von Krankheiten ist die Gabe von Medikamenten. TU Graz-Chemiker Rolf Breinbauer und sein Team engagieren sich in diesem Bereich. Sie entwickeln unter anderem Wirkstoffe, die den Fettsäurespiegel im Blut reduzieren. Dieser ist nämlich unter anderem für Typ-II-Diabetes mitverantwortlich, die nichtalkoholische Fettleber und einige Herzerkrankungen. Zentral ist dabei das Enzym ATGL (Adipozyten-Triglycerid-Lipase), das Fettsäuren im Blut freisetzt. Gemeinsam mit Forschenden der Uni Graz hat Breinbauer den Wirkstoff Atglistatin entwickelt, der das Enzym blockiert, aber keine anderen Vorgänge im Körper stört.

RCPE

Das an der TU Graz angesiedelte Kompetenzzentrum RCPE (Research Center Pharmaceutical Engineering) entwickelt gemeinsam mit dem eng verwobenen Institut für Prozess- und Partikeltechnik und in einer eigenen Pilotfabrik neue Methoden der Medikamentenerzeugung.

Link zum RCPE

GESUNDHEIT UND LÄRM

Christian Adams wiederum hat sich am Institut für Grundlagen und Theorie der Elektrotechnik auf unsere Ohren spezialisiert, genauer gesagt auf die Wahrnehmung von Lärm und dessen Auswirkungen auf unsere Gesundheit und unser Wohlbefinden. Lärm kann nämlich Krankheiten auslösen. Ausgestattet mit einer BMK-Stiftungsprofessur zur Lärmwirkungsforschung ist der Forscher in Kooperation mit Unternehmen dabei, eine Kompetenzstelle für Verkehrslärm und Gesundheit aufzubauen, die nicht nur eine intelligente Lärmkarte entwickeln, sondern auch technische Lösungen erforschen soll, die Lärm überhaupt verhindern. „Wichtigster Schritt ist es nämlich, den Lärm direkt an der Quelle zu beherrschen. Das muss unser erstes Ziel sein“, erklärt Adams. „In einem zweiten Schritt müssen wir den Lärm, der sich nicht verhindern lässt, an seiner Ausbreitung hindern. Etwa durch Lärmschutzmaßnahmen, die wir entweder verbessern wollen oder gänzlich neu entwickeln.“

NEUE PROJEKTE

Ansprechpersonen und an der Forschung rund um die biomedizinische Technik engagierte Personen finden Sie auf der Website des Field of Expertise „Human & Biotechnology“ der TU Graz. ■

Human & Biotechnology an der TU Graz

Alle Bilder von: Lunghammer – TU Graz

ERC Starting Grants für Maria Eichlseder & Fariba Karimi

Zwei TU Graz-Informatikerinnen haben die renommierten EU-Förderpreise in Höhe von je knapp 1,5 Millionen Euro für die Erforschung effizienterer Verschlüsselungssysteme und des Einflusses von künstlicher Intelligenz auf Diskriminierung in sozialen Netzwerken erhalten.

Philipp Jarke und Falko Schoklitsch

Die Verbesserung schlüsselloser Verschlüsselungen und die Verstärkung von Diskriminierung und sozialer Ungleichheit in sozialen Online-Netzwerken durch den Einsatz von KI: Das sind die beiden Forschungsthemen, mit denen die Spitzenforscherinnen Maria Eichlseder und Fariba Karimi hochdotierte Starting Grants des European Research Council an die TU Graz geholt haben. Die beiden Informatikerinnen erhalten für die kommenden fünf Jahre eine Förderung von jeweils knapp 1,5 Millionen Euro.

Von den insgesamt 494 vergebenen ERC Starting Grants gehen 24 an österreichische Einrichtungen. Österreich liegt damit europaweit auf Platz acht. „Die zwei ERC Starting Grants für Maria Eichlseder und Fariba Karimi unterstreichen die Position der TU Graz als eine der führenden Universitäten Europas in den Forschungsfeldern IT-Security, Künstliche Intelligenz und Data Science. Die Vorhaben in beiden Projekten – ressourcensparende, sichere IT-Systeme und faire Algorithmen – sind zukunftsweisend“, sagt Andrea Höglinger, Vizerektorin für Forschung der TU Graz. „Dass sich mit Maria Eichlseder und Fariba Karimi zwei Forscherinnen in diesem hoch kompetitiven Förderprogramm durchsetzen konnten, freut mich außerordentlich.“

MARIA EICHLSEDER

Maria Eichlseders ERC Starting Grant ist bereits der dritte, der seit 2016 an Forschende des Instituts für Angewandte Informationsverarbeitung und Kommunikationstechnologie der TU Graz gegangen ist. Ihr Projekt KEYLESS beschäftigt sich mit Verschlüsselung, allerdings ohne den namensgebenden Schlüssel. Der Fokus liegt auf dem Kernbauteil kryptograhischer Systeme, dem sogenannten Primitiv, das für die Sicherheit des ganzen Systems verantwortlich ist. Lange Zeit wurden vor allem Primitive mit Schlüssel, sogenannten Blockchiffren, genutzt und wissenschaftlich analysiert. Seit einigen Jahren sind Primitive ohne Schlüssel aber sehr populär geworden, da diese Bauteile einige Vorteile bieten. „Die neuesten kryptographischen Standards, beispielsweise für quantencomputersichere oder besonders effiziente Kryptographie, nutzen intern großteils solche schlüssellosen Bauteile“, sagt Maria Eichlseder. „Aber es gibt ein offenes Problem, nämlich die präzise Sicherheitsanalyse dieser Bauteile.“ Hier besteht noch Forschungsbedarf und Maria Eichlseders ERC-Projekt KEYLESS setzt genau da an. Die Anforderungen an die schlüssellosen Bauteile fußen derzeit noch auf idealisierten Annahmen. Diese Annahmen beeinflussen beispielsweise, wie oft eine kryptographische Funktion im Rahmen der Verschlüsselung wiederholt werden muss, bis diese nachweislich gegen Angreifende sicher ist. Die bisherige Lösung ist eine recht großzügige Anzahl von Wiederholungen, um Sicherheitsproblemen vorzubeugen. „Das kostet natürlich Ressourcen. Wenn ich etwa dreimal so viele Runden ausführe, wie ich eigentlich bräuchte, um mich gegen Angriffe abzusichern, dann verbrauche ich dreimal so viel Energie. Daher möchte ich mir alle Ebenen eines kryptographischen Systems ansehen, diese idealisierten Annahmen analysieren und herausfinden, ob man sie durch präzisere Annahmen, die der Realität näherkommen, ersetzen kann“, sagt Maria Eichlseder.

Fariba Karimi

Oliver Wolf - TU Graz

FARIBA KARIMI

Es gibt Hinweise darauf, dass der Einsatz von künstlicher Intelligenz in sozialen Online-Netzwerken – etwa bei Empfehlungen und Timelines von Plattformen wie LinkedIn oder Google Scholar – zu Diskriminierung führt und soziale Ungleichheit verstärkt. Fariba Karimi vom Institute of Interactive Systems and Data Science will diesen Tendenzen in ihrem Projekt „NetFair – Network Fairness" auf den Grund gehen und Methoden entwickeln, um diese neuen Mechanismen der Ungleichheit und Diskriminierung zu analysieren und zu beseitigen.

Soziale Ungleichheit und Marginalisierung basieren auf einem komplexen Zusammenspiel verschiedener sozialer Merkmale wie Geschlecht, Herkunft oder Einkommen – die Sozialwissenschaften sprechen in diesem Zusammenhang von Intersektionalität. „Bislang gibt es nur qualitative Befunde zu intersektionaler Ungleichheit in gesellschaftlichen Netzwerken", sagt Fariba Karimi. In ihrem ERC-Projekt will sie Intersektionalität quantitativ messbar machen und dann auf KI-basierte soziale Online-Plattformen anwenden, um so mögliche Verzerrungen in deren Algorithmen aufzuzeigen.

Dafür wird Fariba Karimi zunächst verbesserte Modelle von gesellschaftlichen Netzwerken entwickeln und durch Datenanalysen und Experimente klären, welche Faktoren bei der Ausgestaltung der Netzwerke eine Rolle spielen und einander beeinflussen. „Aufbauend auf diesen verbesserten Netzwerkmodellen werden wir ihre Wirkungen auf Algorithmen und soziale Online-Plattformen untersuchen und die Effekte über einen längeren Zeitraum analysieren", sagt Fariba Karimi. Damit ist es aber nicht getan: Fariba Karimi möchte in ihrem Projekt Methoden entwickeln, die Ungleichheiten und Diskriminierungen in Online-Netzwerken nicht verstärken, sondern abbauen. „Das ist das große Ziel: faire Algorithmen für soziale Netzwerke." ■

KURZBIOGRAFIE

Fariba Karimi ist seit Oktober 2023 Professorin am Institute of Interactive Systems and Data Science der TU Graz, zudem leitet sie die Arbeitsgruppe Computational Social Science am Complexity Science Hub in Wien. Geboren 1981 in Teheran, Iran, studierte sie Physik an der Universität Schiras, der Schahid-Beheschti-Universität in Teheran und an der Universität Lund in Schweden. 2015 promovierte sie in Physik und Computerwissenschaften an der schwedischen Universität Umeå und war anschließend Postdoc am Leibniz-Institut für Sozialwissenschaften in Köln. Ihre Forschungsschwerpunkte sind computergestützte Sozialwissenschaften, die Analyse von Netzwerken und Algorithmen sowie die Modellierung menschlichen Verhaltens. 2023 erhielt sie den Young Scientist Award der Deutschen Physikalischen Gesellschaft für ihre Forschung über Ungleichheit in komplexen Netzwerken.

KURZBIOGRAFIE

Geboren wurde Maria Eichlseder im Februar 1988 in Graz. Aufgewachsen ist sie in Steyr und in Bayern, ehe sie 2006 am Akademischen Gymnasium in Graz maturierte. Darauf folgten die Bachelorstudien Informatik und Technische Mathematik sowie das Masterstudium und das Doktoratsstudium Informatik an der TU Graz. 2018 promovierte sie als eine der ersten beiden Frauen an der TU Graz sub auspiciis praesidentis und ist derzeit Assistenzprofessorin für Kryptographie am Institut für Angewandte Informationsverarbeitung und Kommunikationstechnologie (IAIK) der TU Graz. Ihre Dissertation mit dem Titel „Differential Cryptanalysis of Symmetric Primitives" wurde unter anderem mit dem Staatspreis für die besten Dissertationen 2018 des Bundesministeriums für Bildung, Wissenschaft und Forschung sowie dem Förderpreis 2019 für Dissertationen mit besonderer gesellschaftlicher Relevanz des Forums Technik und Gesellschaft ausgezeichnet. Zu ihren bisher größten Forschungserfolgen zählt die Wahl des von ihr mitentwickelten Algorithmus ASCON als neuen Standard für Lightweight Cryptography durch das National Institute of Standards and Technology (NIST) in den USA. Neben ihrer Forschungstätigkeit an der TU Graz hatte sie Gastaufenthalte an der Ruhr-Universität Bochum (2020) und der Radboud Universiteit Nijmegen (2022).

TU Graz holt hochdotierten ERC Synergy Grant für biomechanische Herzforschung

Der Europäische Forschungsrat fördert ein Konsortium aus Helmholtz-Zentrum Hereon, ETH Zürich und TU Graz mit 10 Millionen Euro. 4,2 Millionen Euro erhält TU Graz-Forscher Gerhard A. Holzapfel.

Lunghammer – TU Graz

Philipp Jarke

Veränderungen der mechanischen Eigenschaften von Organen sind die Ursache zahlreicher Erkrankungen, darunter der diastolischen Herzinsuffizienz (HFpEF), einer der weltweit häufigsten Ursachen für herzbedingte Krankheits- und Sterblichkeitsfälle. Die mechanischen Eigenschaften von weichem Gewebe ohne operativen Eingriff zu ermitteln, ist bislang jedoch nicht möglich. Ein internationales Forschungskonsortium bestehend aus TU Graz, Helmholtz-Zentrum Hereon und ETH Zürich will dies durch eine neuartige In-vivo-Gewebeanalyse ändern: In seinem Projekt „MechVivo“ wird das Forschungsteam experimentelle und KI-basierte Methoden entwickeln, die erstmals im Detail den Zusammenhang zwischen Transkriptomik, Mikrostruktur und mechanischen Eigenschaften von weichem biologischem Gewebe zeigen. Übergeordnetes Ziel ist die Entwicklung eines bildgebenden Verfahrens zur nichtinvasiven Untersuchung der Gewebemikrostruktur, die die Krankheitsdiagnose und Therapie im klinischen Alltag verbessert. Der Europäische Forschungsrat fördert das sechsjährige Forschungsvorhaben mit insgesamt 10 Millionen Euro, davon gehen rund 4,2 Millionen an das Institut für Biomechanik der TU Graz.

„Die TU Graz ist stolz auf Gerhard A. Holzapfel und sein Team und freut sich über ihren ersten ERC Synergy Grant“, sagt Andrea Höglinger, TU Graz-Vizerektorin für Forschung. „Der Bereich Biomedizinische Technik gehört zu den zentralen Stärkefeldern unserer Universität. Diese Forschung erhält durch die Zusammenarbeit mit hochkarätigen europäischen Partnern im Projekt „MechVivo“ zusätzliche internationale Sichtbarkeit. Mit diesem ERC Grant festigt die TU Graz einmal mehr ihre Position als führende Institution in der Steiermark im Rahmen von Horizon Europe.“

ETH ZÜRICH: MRT-FINGERABDRUCK DES GEWEBES

Im Rahmen des Projekts wird Sebastian Kozerke mit seinem Team am Institut für Biomedizinische Technik, das zur ETH Zürich und zur Universität Zürich gehört, in einem ersten Schritt ein neues Konzept für die Magnetresonanztomographie (MRT) entwickeln, deren detaillierte Auflösung es ermöglicht, einen Fingerabdruck der Zusammensetzung und Mikrostruktur des Gewebes im schlagenden Herzen zu ermitteln. Um ein zuverlässiges In-vivo-Bildgebungsinstrument zu entwickeln, sind erhebliche methodische Fortschritte bei der Simulation von MRT-Sequenzen, dem Design und der Datenrekonstruktion nötig.

TU GRAZ: TIEFGREIFENDES VERSTÄNDNIS DER BIOMECHANIK DES HERZENS

Um diesen Fingerabdruck des Gewebes richtig zu interpretieren, ist ein umfassendes Verständnis der Mikrostruktur und der mechanischen Eigenschaften von biologischem Gewebe erforderlich. Hier kommt die Forschungsgruppe von Gerhard A. Holzapfel am Institut für Biomechanik der TU Graz ins Spiel: Das Team wird dem Zusammenhang von Genexpression, Mikrostruktur und mechanischen Eigenschaften von weichem biologischem Gewebe im Labor auf den Grund gehen. Dazu kartiert das Team die Zusammensetzung des Gewebes bis in den Nanometerbereich, um so Rückschlüsse auf die mechanischen Eigenschaften des Herzens zu ziehen. Ex vivo werden an Schweineherzen von Schlachthöfen und menschlichen Spenderorganen verschiedene mechanische Tests und mikroskopische Untersuchungen durchgeführt. Die Testbelastungen sind den Bedingungen im lebenden Körper sehr ähnlich, wodurch sich die mechanischen Eigenschaften des Herzens außerordentlich realitätsnah ermitteln lassen.

HEREON: AI-BASIERTE SOFTWARE FÜR KLINISCHE ANWENDUNG

Am Helmholtz-Zentrum Hereon in Geesthacht wird ein Team um Christian Cyron vom Institut für Werkstoffsystem-Modellierung eine AI-basierte Software entwickeln, die auf Basis der in Zürich und Graz gesammelten Daten die Beziehung zwischen den mikrostrukturellen Fingerabdrücken des Gewebes und dessen mechanischen Gewebeeigenschaften entschlüsselt und Mediziner*innen zugänglich macht.

„Unsere drei Forschungsgruppen ergänzen sich durch ihre jeweilige Expertise optimal. Mit unserem innovativen Forschungsansatz in dieser Projektkonstellation wird es uns u. a. gelingen, ein bildgebendes Verfahren zur nichtinvasiven Untersuchung der Gewebemikrostruktur zu entwickeln“, sagt Gerhard A. Holzapfel. „Als Proof of Concept demonstrieren wir dann im Rahmen einer klinischen Studie am Universitätskrankenhaus Zürich, wie unsere neue Methode die Diagnose der diastolischen Herzinsuffizienz unterstützen kann. Unser Forschungsansatz in dieser Projektkonstellation verschafft uns weltweit ein Alleinstellungsmerkmal.“ ■

Cluster of Excellence

Mit den Clusters of Excellence fördert der Österreichische Wissenschaftsfonds FWF exzellente Forschende, die über die Grenzen ihrer Heimatinstitutionen und ihres Forschungsgebiets hinaus Spitzenforschung betreiben. Die TU Graz ist an zwei Clustern beteiligt.

Birgit Baustädter

Je fünf bis acht wissenschaftlich tätige Personen mit hochkarätiger Forschungsleistung aus mindestens drei österreichischen Forschungsinstitutionen sind an jedem der Cluster beteiligt. Das Ziel: gemeinsam in den kommenden fünf Jahren Großes in ihren jeweiligen Fachgebieten erreichen. Der FWF fördert die Cluster mit einer Gesamtsumme von 155 Millionen Euro, 104 Millionen Euro bringen die beteiligten Institutionen mit ein.

BILATERAL AI

Künstliche Intelligenz gilt als eine der bedeutendsten Technologien der Zukunft. Derzeit gibt es in der KI-Forschung zwei wichtige Stränge: die subsymbolische KI, die unter anderem maschinelles Lernen beinhaltet, und die symbolische KI, in der es um Wissenspräsentation und Reasoning geht. Der Cluster Bilateral AI möchte die beiden Stränge verbinden und so die Basis für sogenannte Broad AI schaffen – also eine künstliche Intelligenz, die Schlussfolgerungen ziehen können und umfassende kognitive Fähigkeiten besitzen soll. Derzeitige KI-Modelle werten lediglich vorhandene Daten aus. Die neuen Systeme sollen hingegen planen, schneller auf Änderungen reagieren und schlussendlich sogar selbst kreativ tätig sein können.
Neben der TU Graz ist die JKU Linz (Konsortiumsleiterin), die TU Wien, die Universität Klagenfurt, das ISTA und die WU Wien beteiligt.

CIRCULAR BIOENGINEERING

Ziel des Clusters Circular Bioengineering sind nachhaltige Materialkreisläufe, die das wirtschaftliche Wachstum vom Ressourcenverbrauch trennen. Gearbeitet wird hier an Plattformchemikalien und Materialien aus erneuerbaren Rohstoffen sowie an Möglichkeiten, diese Chemikalien effizient und zirkulär zu verwenden.

Gemeinsam mit der TU Graz arbeiten die BOKU Wien (Konsortiumsleiterin), die TU Wien, die Uni Graz und die Universität Wien im Cluster. ■

Ultrafast Science

Birgitta Schultze-Bernhardt, Institut für Experimentalphysik, hat den „Women in Ultrafast Science Global Award" erhalten.

Halil Kaya Gedik Award

Sergio Amancio, Professor am Institut für Werkstoffkunde, Fügetechnik und Umformtechnik der TU Graz, hat den Halil Kaya Gedik Award des International Institute of Welding in der Kategorie C: Aus- und Weiterbildung junger Menschen bekommen.

Wolfram Innovator Award

Thomas Wallek, Institut für Chemische Verfahrenstechnik und Umwelttechnik, hat den Wolfram Innovator Award für den Einsatz von Wolfram in der Lehre gewonnen.

Eurofusion Grant

Markus Markl, Institut für Theoretische Physik – Computational Physics hat das Nachwuchsforschenden-Stipendium Bernard Bigot Researcher Grants für Fusionsforschung gewonnen.

20 Jahre NAWI Graz

Kooperation statt Konkurrenz – Seit zwanzig Jahren bündeln TU Graz und Uni Graz Know-how und Ressourcen in der naturwissenschaftlichen Forschung und Lehre im Verbund von NAWI Graz. Ein österreichweit einzigartiges Vorzeigeprojekt.

Ines Hopfer-Pfister

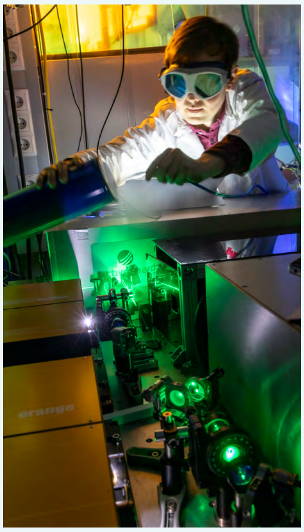
Gemeinsame Studien bildeten die Erfolgsbasis: Wurden vor 20 Jahren noch an jeder Universität getrennte Studien angeboten, werden mittlerweile 22 Studien gemeinsam betrieben. Rund 5.300 Studierende nutzen dieses breite Spektrum.
Die gemeinsame Doktoratsausbildung im Rahmen der NAWI Graz Advanced School of Science (GASS) genießt einen hohen Stellenwert, derzeit werden über 600 Doktoratsstudierende ausgebildet. Die Doktorand*innen sind universitätsübergreifend in Doktoratsschulen (Doctoral Schools) eingebunden und profitieren so von den Ressourcen und von der Betreuung durch Lehrende und Forschende beider Universitäten.

GEMEINSAME FORSCHUNG

Gemeinsame Lehre spart Zeit, die in Forschung investiert werden kann: Rund 450 Projekte werden im Verbund NAWI Graz betrieben. Die 36 beteiligten Institute werben 34,6 Millionen Euro an Drittmitteln ein, das entspricht einem Plus von rund 120 Prozent seit 2006. Auch gemeinsame NAWI Graz-Berufungen sind Usus geworden. Aktuell sind 36 §98-Professor*innen in einem gemeinsamen Verfahren berufen worden.

Darüber hinaus konzentriert sich NAWI Graz auch auf große interuniversitäre Verbundprojekte wie Spezialforschungsbereiche und Doktoratskollegs (DK). Das DK Molekulare Enzymologie war ein derartiges erfolgreiches Verbundprojekt, das von 2005 bis 2019 mit einem Fördervolumen von 13,5 Millionen Euro betrieben wurde. Mit Oktober startet nun ganz aktuell das FWF doc.funds-Projekt „Discrete Mathematics in Teams", das 12 Dissertant*innen ausbilden wird. Jeder*jede Doktorand*in wird dabei von zwei Forscher*innen gleichberechtigt betreut, 19 Betreuer*innen von TU Graz und Uni Graz sind involviert. „Durch den Zusammenschluss von Betreuer*innenpaaren können wir neue Forschungsrichtungen bearbeiten, die bislang in Graz nicht vorkommen", so Michael Kerber (Institut für Geometrie). Die Forschungsprojekte sind fakultäts-, aber auch universitätsübergreifend.

GEMEINSAME INFRASTRUKTUR



Aktuell wird in 28 Central Labs (Central Labs bündeln thematisch in einem Zusammenhang stehende Geräte an einem Ort) und Core Facilities (einzelne Großgeräte, die mehrere Forschungsgruppen benötigen) nach internationalen Maßstäben geforscht, rund 160 Geräte wurden angeschafft und partnerschaftlich genutzt. Eines der wohl ältesten gemeinsam genutzten Central Labs ist das Central Lab Water, Minerals und Rocks, das 2011 gestartet wurde.

Dorothee Hippler vom Institut für Angewandte Geowissenschaften leitet das Central Lab, „ein wertvoller Ort des wissenschaftlichen Zusammenarbeitens, des Entwickelns und des Austausches", so die Forscherin. „Durch das Central Lab können bisherige und aktuelle Forschungsvorhaben durch innovative und anspruchsvolle, aber auch ausgeklügelte Analysemethoden aus dem Bereich der Isotopen-Geochemie ergänzt werden", bekräftigt Dorothee Hippler.

GEMEINSAMER WEG IN DIE ZUKUNFT

Mit dem Bau des **GRAZ CENTER OF PHYSICS (GCP)** wurde die Kooperation nun auf ein neues Level gehoben: Im Juni 2024 erfolgte der Spatenstich dieses interuniversitären Zentrums, das ab 2030 die Physik-Institute von TU Graz und Uni Graz räumlich vereint. Neben dem GCP, das derzeit am Campus Uni Graz entsteht, werden in Zukunft auch vier weitere Institute von TU Graz und Uni Graz im **NAWI GRAZ GEOZENTRUM** (geplant am Campus Inffeldgasse) noch enger miteinander kooperieren. ■

Milena Stavric mit ihrem Team

Pilze als Baumeister

Milena Stavric möchte Baustoffe gänzlich neu denken. Sie erforscht, wie Myzelium im Bauwesen eingesetzt werden und umweltschädliche Stoffe ersetzen kann.

Birgit Baustädter

„Von Myzelium sagt man, es sei das größte biologische Gewächs überhaupt", ist Milena Stavric begeistert.

Myzelium ist das Pilzgeflecht, das sich in unserer Erde und anderen organischen Substraten ausbreitet. Es ist der wachsende Teil dessen, was wir an der Oberfläche als Pilze kennen. „Eine sehr gute Freundin von mir ist Expertin auf diesem Gebiet und ihre Arbeit hat mich immer schon fasziniert", erzählt Stavric. Sie selbst beschäftigte sich als Architektin vor allem mit nachhaltigen Baustoffen und Holz, war aber von der trotzdem notwendigen Menge an umweltschädlichen Kunststoffen abgeschreckt. Also wollte sie etwas sehr Grundsätzliches ändern. „Ich glaube, dass es nicht ausreicht, hier ein bisschen zu verbessern und dort ein bisschen zu optimieren", ist sie überzeugt.

„Wir müssen Baustoffe völlig neu denken."

Die Forscherin untersucht, wie Myzelium als Verstärkung für Ton eingesetzt werden kann. Der Ton – ein altbekannter und bewährter Baustoff – wird 3D-gedruckt und anschließend ein Nährsubstrat sowie das Myzelium eingebracht. „Wir nennen das impfen." Das Myzelium kann in die gewünschte Richtung und in der gewünschten Stärke wachsen und so entweder das Gebilde verstärken oder aber auch poröse Strukturen schaffen. Das Ziel: eine komplett neue, nachhaltige Bauweise. „Die Wand kann aus mit dem Myzelium verstärktem Ton bestehen. Dann kommt eine isolierende Schicht Ton, die porös ist. Dabei wird zuerst das Myzelium eingebracht und anschließend wird der Ton gebrannt – wo vorher das Myzelium war, entstehen tolle Poren", erklärt sie. Und nach außen wird die Wand abgeschlossen mit einer schützenden Schicht, etwa aus Alginat – einem anderen natürlichen Stoff, der am Institut erforscht wird.

NÄCHSTE SCHRITTE

Derzeit ist die Forschung in den Grundlagen angesiedelt. Die gedruckten Werke sind klein, aber beeindruckend. Die größte Herausforderung am Weg zur Umsetzung ist die Skalierbarkeit – wie kann die Methode vom cleanen Labor auf eine schmutzige und teils unberechenbare Baustelle überführt werden? „Wir starten gerade wieder ein vom FWF finanziertes Projekt, wo wir dieses Problem aufgreifen wollen. Und wo wir auch gemeinsam mit Geowissenschafter*innen weiter untersuchen, welche Tonmischungen sich gut für den Druck eignen. Wir denken daran, etwa mit Ton aus dem Neusiedler See zu arbeiten."■

Alle Bilder von Lunghammer - TU Graz

Lignum Test Center

Im Lignum Test Center an der TU Graz können unterschiedliche Holzbauteile auf Verformung und Bruch getestet werden. Nicht zuletzt das dort entwickelte Brettsperrholz, das Holzbauteile ermöglicht, die sich im Einsatz nicht verformen.

1 In der eigenen Holzwerkstatt werden die Proben für die umfassenden Tests selbst zurechtgeschnitten. Zahlreiche Kleingeräte ermöglichen die Herstellung unterschiedlichster Ausführungsformen und Geometrien.

LIGNUM

LIGNUM TEST CENTER ⟀ Reel

Andreas Ringhofer leitet das Lignum Test Center am Institut für Holzbau und Holztechnologie. Das Center steht wfür F&E-Kooperationen und Zertifizierungsprüfungen offen.

2 Mit den Prüfmaschinen lignum_uni_275 (Firma zwick, Belastungsbereich von 0 bis + oder −275 kN), lignum_z_850 (Firma Zum Wald, Belastungsbereich 0 bis 850 kN), lignum_dz_100 (Belastungsbereich −800 bis +1100 kN), einer Torsionsprüfmaschine und einer Fließmoment-Biegeeinheit können unterschiedlichste Stabversuche, Zugversuche und Torsionsversuche gemacht werden.

3 Im Lignum Test Center werden die Belastungsgrenzen der Holzbauteile ermittelt. Dabei gehen sie natürlich auch zu Bruch.

KONTAKT:

Lignum Test Center
Inffeldgasse 24
8010 Graz
Tel.: +43 316 873 4601
lignum@tugraz.at

⟀ Website

TU Graz research: Die Vielfalt der Forschung an der TU Graz

In jeder neuen Ausgabe widmet sich das Forschungsmagazin TU Graz research einem gesellschaftlich und wissenschaftlich relevanten Schwerpunktthema. Mit dem QR-Code neben der jeweiligen Ausgabe gelangen Sie direkt zum E-Paper.

Gedruckte Magazin-Exemplare können Sie beim Einkaufsservice der TU Graz kostenlos unter der E-Mail-Adresse **einkaufsservice@tugraz.at** bestellen.

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#31: BASIC RESEARCH

#30: RAILWAY SYSTEMS

#29: ENERGETIC

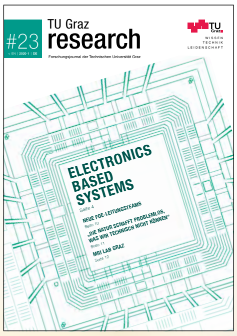
#28: SMARTE PRODUKTION

#27: NACHHALTIGES BAUEN

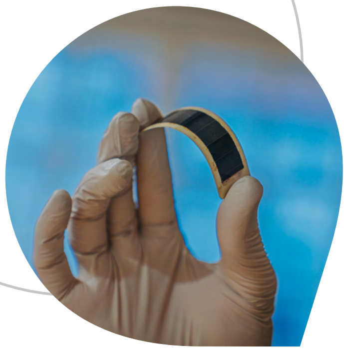
#26: LERNENDE MASCHINEN

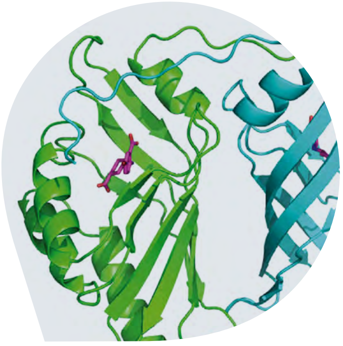
#25: BIOTECHNOLOGIE

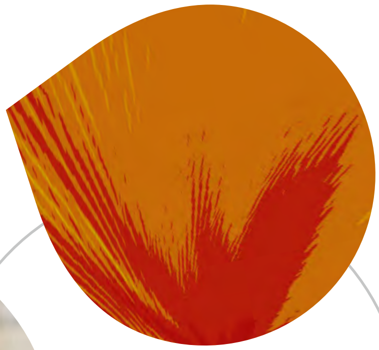
#24: WASSERSTOFF



#23: ELECTRONICS BASED SYSTEMS







Fields of Expertise

TU Graz's research activities are grouped into five strategic, forward-looking Fields of Expertise. Researchers engage in interdisciplinary cooperation and benefit from different approaches and methods, shared resources and international exchange.

Advanced Materials Science

Editorial: Karin Zojer, Gregor Trimmel & Sergio Amancio

Advancing a Sustainable Future with Research on Emerging Solar Cell Technologies

Thomas Rath

Human & Biotechnology

Editorial: Gabriele Berg and Christian Baumgartner

Controlling Protein Function by Small Molecules

Rolf Breinbauer

Information, Communication & Computing

Editorial: Kay Uwe Römer

Acoustics and Environmental Noise

Christian Adams

Mobility & Production

Editorial: Rudolf Pichler

Iron and Hydrogen – A Perfect Match

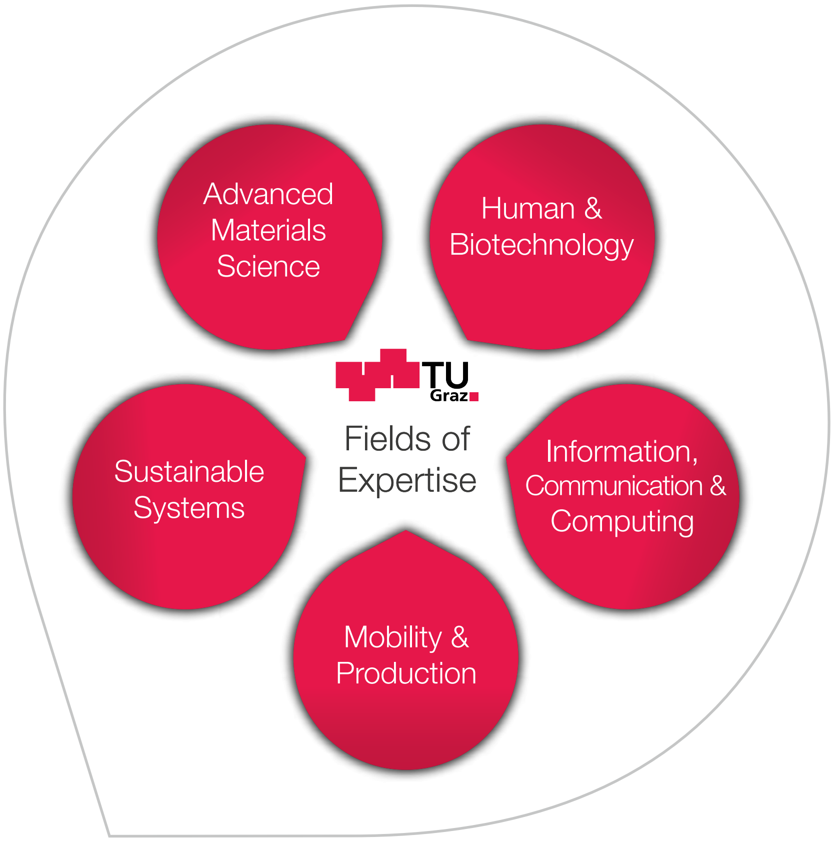
Susanne Lux and Viktor Hacker

Sustainable Systems

Editorial: Urs Leonhard Hirschberg

Towards a CO_2-Based Circular Economy

Regina Kratzer



TU Graz has divided its research into five innovative areas: the Fields of Expertise. Researchers in the Fields of Expertise break new ground in basic research. They take part in interdisciplinary cooperation, gain support for outstanding projects and are based in the region as well as part of international networks. They also develop key technologies for industry and commerce, and perform research in the framework of company shareholdings and partnerships.

Source: TU Graz

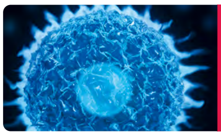
ADVANCED MATERIALS SCIENCE
Researchers aim to understand the smallest components in the structure and function of new materials, and develop and assemble them in special processes.

HUMAN & BIOTECHNOLOGY
Researchers develop devices and methods for medical applications and therapies, and focus on using enzymes and living microorganisms such as bacteria, fungi and yeast in technical applications.

INFORMATION, COMMUNICATION & COMPUTING
Researchers face challenges prompted by the information age, for example data security and efficient use of the ever-increasing volume of data.

MOBILITY & PRODUCTION
Researchers investigate novel vehicle technologies, new drive systems and more economical product manufacturing processes.

SUSTAINABLE SYSTEMS
Scientists focus on the complex challenges presented by a growing population and increasingly scarce natural resources.



ADVANCED MATERIALS SCIENCE

Fields of Expertise TU Graz

Source: istockphoto.com

This summer, extreme weather events demonstrated the tremendous power of the elements.

Our society faces enormous challenges minimizing and tackling the consequences of global warming and the changing economic landscape. Thus, new materials and concepts are needed for more efficient energy conversion and storage, for lightweight construction, for waste reduction, but also for analytical or biomedical applications. Materials must be designed to maximize their use, re-use and recyclability. More than ever, materials research is a central key to a better sustainable future. Members of the FoE Advanced Materials Science are actively working on these challenges.

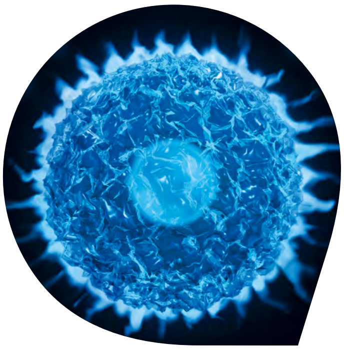
In the 21st call of the initial seed funding of TU Graz, we could finance six innovative project proposals in the areas of physics, chemistry and materials science: Oliver Hofmann, Institute of Solid State Physics; Mohan Tamilselvan, Institute of Chemistry and Technology of Biobased Systems; Anna Galler, Institute of Theoretical and Computational Physics; Francesco Carraro, Institute of Physical and Theoretical Chemistry; Caterina Czibula, Institute of Bioproducts and Paper Technology; and Gean Henrique Marcatto de Oliveira, Institute of Materials Science, Joining and Forming. The project ideas range from density functional theory studies to develop new materials, research on biomedical materials, new innovative analytical tools, organic frameworks, and 3D printing of new composite materials.

We wish all recipients good luck for their proposal submissions, and we look forward to more submissions at the next call. Finally, save the date for **Advanced Materials Poster Day 2025** taking place on **4 February 2025** at Campus Neue Technik, lecture hall H – "Ulrich Santner". We are looking forward to discussing your research with your poster.

Karin Zojer, Gregor Trimmel and Sergio Amancio

Source: Lunghammer – TU Graz

Advanced Materials Science



Thomas Rath

Advancing a Sustainable Future with Research on Emerging Solar Cell Technologies

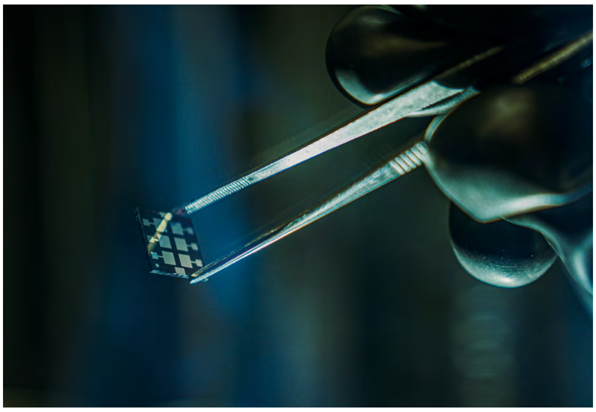
Photovoltaic solar energy conversion holds a central role in a clean and renewable energy supply of the future. While silicon solar cell modules are already well established, emerging solar cell technologies such as perovskite and organic solar cells can significantly broaden the possible applications of photovoltaics due to many advantages, ranging from flexibility, light weight, or semitransparency to a very low carbon footprint. >

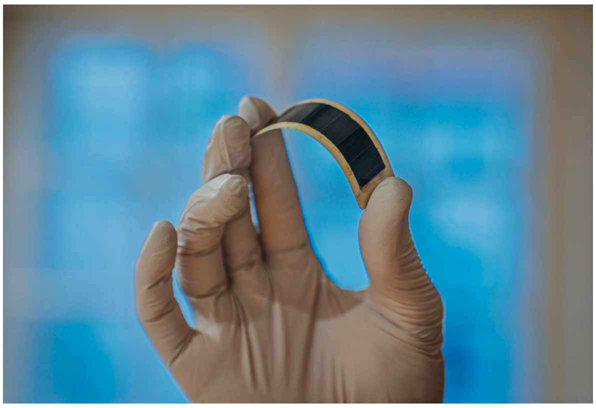
Perovskite solar cells are known for their high efficiencies, achieving up to 26%. However, the use of toxic lead in these highly efficient solar cells raises environmental concerns, pushing the need for a more sustainable alternative.

Thomas Rath coordinates the SMARTLINE-PV project, funded by the European Union's Horizon Europe Research and Innovation program. In this project, a consortium of 13 project partners, including universities, research organizations, and companies, develops efficient lead-free perovskite photovoltaics through innovative precursor solutions and a fast plasma-assisted crystallization process (Figure 1). This solar cell technology is targeted for applications in Internet of Things (IoT) devices and building-integrated photovoltaics (BIPV).

Figure 1: Thomas Rath at the Institute for Chemistry and Technology of Materials working in a glovebox, where perovskite solar cells are fabricated and characterized.

Source: Moritz Wehr, Horizon Films





TRANSITIONING TO TIN HALIDE PEROVSKITES

Tin halide perovskite solar cells and modules (Figure 2) offer a promising alternative to their lead-based analogs, but challenges in efficiency, stability and large area fabrication make further research in this field necessary. In SMARTLINE-PV, novel precursor chemistry is used to obtain precise control of the tin perovskite crystallization. Innovative crystallization mediators reduce the tin perovskite crystallization speed, allowing the growth of crystals with less defects in the perovskite films. This is expected to have a positive effect on the efficiency and stability of tin perovskite solar cells.

Furthermore, this approach enables, in combination with a plasma-assisted crystallization technique, to perform the crystallization without the typically used anti-solvent dripping process. Solvent-free crystallization makes the process more sustainable and opens up the possibility of homogeneous large area processing of tin perovskite films.

Figure 2: A tin perovskite solar cell and a flexible perovskite solar cell module.

Source: Moritz Wehr, Horizon Films

To improve the properties of the tin perovskite films, the SMARTLINE-PV team plans to explore non-oxidizing solvents for the tin perovskite precursor solutions as well as the effects of van der Waals interactions. Research on tailored interlayers will also assist the improvement of efficiency and stability.

SELECTABLE COLORS, SUSTAINABILITY AND DEMONSTRATORS

The MorphoColor® technology, inspired by the wings of a butterfly, comprises a photonic structure combining a geometrically structured substrate with an interference layer and offers customizable colors, ideal for BIPV. SMARTLINE-PV aims to achieve power conversion efficiencies above 20%, and by reducing energy consumption and costs in their fabrication through fast low-temperature processes, the tin-based perovskite solar cells will be a competitive alternative to other thin-film technologies.

Moreover, sustainability is at the core of SMARTLINE-PV. Through eco-design and circularity, the entire lifecycle of the solar cells – from production to recycling or disposal – is designed to minimize environmental impact.

In SMARTLINE-PV, BIPV as well as IoT demonstrators are fabricated and tested under real-world conditions. Solar cells embedded directly into building materials, such as facades and roof tiles (Figure 3), combine energy conversion with aesthetics, which well aligns with Europe's green transition goals.

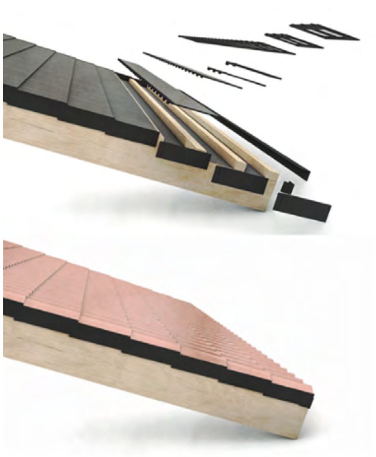


Figure 3: The envisaged application of solar roof tiles with selectable color.

Source: Viktor Karla, Silvester Filkorn, Filbau

A NEW ERA FOR PEROVSKITE SOLAR CELLS

By addressing efficiency, scalability, sustainability, and aesthetics, SMARTLINE-PV paves the way for a new generation of thin-film photovoltaics. These advancements will help Europe strengthen its role in renewable energy and contribute to global efforts to reduce the environmental impact of electricity generation.

Thomas Rath

is a senior scientist at the Institute for Chemistry and Technology of Materials (ICTM) at TU Graz and coordinator of the SMARTLINE-PV project. His research focuses on sustainable concepts for solar energy conversion, in particular materials for organic and lead-free perovskite solar cells. Recently, he received the Zero Emissions Award from the Austrian Science Fund (FWF) for his contributions to renewable energy research.

Source: Sabine Hoffmann, alpha+

HUMAN & BIOTECHNOLOGY

Fields of Expertise TU Graz

Source: fotolia.com

Source: Lunghammer – TU Graz

Gabriele Berg and Christian Baumgartner

Human & Biotechnology

The new semester has begun with a breath of fresh air, and major new research projects and initiatives in our FoE are picking up speed.

Biotechnological research is becoming increasingly digital and linked to the fields of data science and artificial intelligence. TU Graz is funding a new lead project called DigiBioTech, in which 17 scientists and ten doctoral students from the fields of biotechnology, biotechnological process engineering and computer science are working closely together to significantly improve the predictability and control of biochemical reactions and processes. The latter should not only enable production processes to be designed more sustainably, but should also be able to break down persistent environmental toxins such as perfluorinated and polyfluorinated alkyl compounds (PFAS).

The biotechnologists at TU Graz are also involved in the newly funded Austrian Science Fund Cluster of Excellence “Circular Bioengineering”. Here, scientists from various universities and research institutions are working together on the efficient production of platform chemicals and materials from renewable raw materials. The circular integration of biotechnological processes makes it possible to switch from petroleum-based to bio-based materials.

The tenure track professorship in biomedical engineering was filled by the first-ranked candidate out of 99 submissions in this year’s call for FoE tenure track positions. Debkalpa Goswami, assistant professor of medicine and biomedical engineering at the Cleveland Clinic Lerner College of Medicine at Case Western Reserve University, USA, will take up his teaching and research activities at the Institute of Health Care Engineering with Testing Center of Medical Devices in the field of soft robotics implants on 1 July 2025.

Change and continuity also ensure research. So we look forward to working together in our FoE and invite you once again to join us in shaping it.

We hope you enjoy reading our FoE’s contribution in this issue of the research magazine.

Rolf Breinbauer

Controlling Protein Function by Small Molecules

A major goal in modern biology is to understand how a cell and its various components are functioning. Various genetic tools (e.g. RNA interference, CRISPR/Cas9) have been developed, which have revolutionized this research. However, these tools have their limitations since they only interfere with the flow of information in a cell. In contrast, the use of small molecules which modulate protein function are a more direct way of controlling cell function, which offers the additional advantage that it can be carried out it in a time- and concentration-dependent way.

According to the "central dogma of molecular biology" the genetic information of a human cell is encoded in the DNA of the nucleus. A small region (gene) of the long DNA molecule will be transcribed into mRNA (messenger RNA), which ultimately gets translated into a certain protein (Figure 1). Proteins are the essential components of the cell, which are responsible for transport, communication ("signal transduction"), catalytic function (enzymes), and mechanical structure.

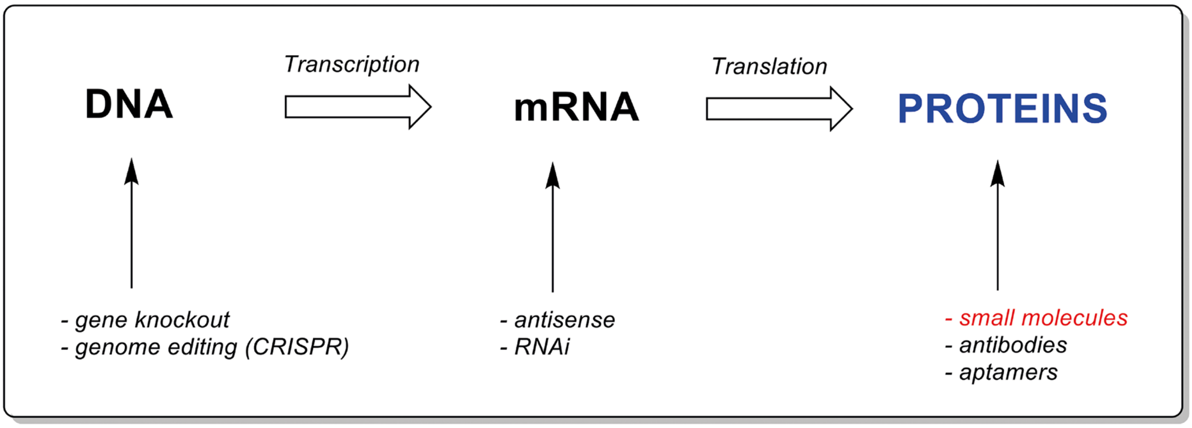


Figure 1: Organization of a cell and methods used to control the flow of information or the function of proteins in a cell.

SMALL MOLECULE INHIBITORS

In order to understand how the different components in a cell work, several tools have been developed which either delete a certain gene or prevent the production of the corresponding protein (Figure 1). Genetic methods such as gene knock out, CRISPR/Cas9 and RNA interference have proven to be powerful tools which are easy to design and show high specificity. However, they have certain limitations as they control only the flow of information in a cell (and not proteins directly), cause complete "on" or complete "off" events, or lead to problems regarding the delivery of the genetic tools into the cells.

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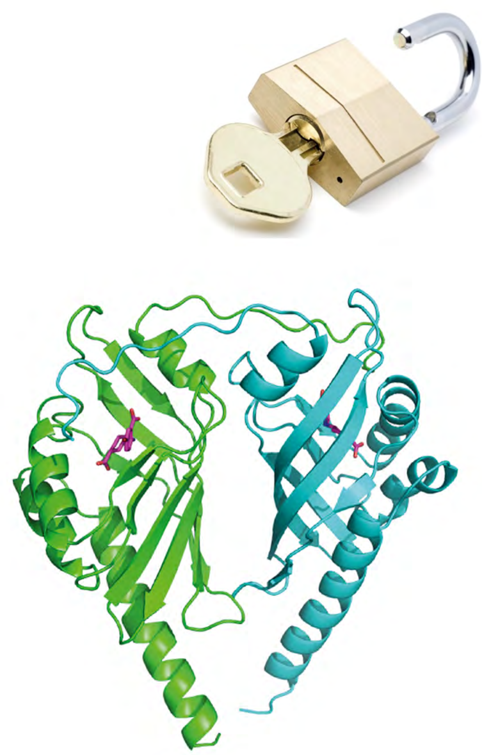
Figure 2: A small molecule inhibitor (depicted in magenta) inhibits protein function by binding to the active site of a protein (depicted in green and blue) according to the lock-key principle.



In contrast, small organic molecules can function as a molecular key (inhibitor) which binds directly to the protein in question. Additional advantages of small molecules are that they can easily reach the interior of a cell and control protein function in a dose- and time-dependent manner, which allow new levels of precision over genetic methods. However, there is one fundamental challenge: How can you find a specific key – a small molecule which binds selectively to just one out of the tens of thousands different proteins of a human cell?

Over the past 17 years my organic chemistry laboratory at TU Graz has collaborated with biochemists, structural biologists and cell biologists to develop the first small molecule inhibitors for several enzymes (Figure 3).

CONTROLLING LIPID METABOLISM

In 2004 the groups of Rudi Zechner and Robert Zimmermann at the Institute of Molecular Biosciences of the University of Graz published a study in the journal *Science* that demonstrated that a protein called ATGL (Adipose Triglyceride Lipase) is the rate-determining enzyme in the degradation of triglycerides in adipocytes (fat cells) of human fat tissue. Genetic studies performed in their lab revealed that a mouse which does not express the ATGL protein shows interesting features: it does not develop

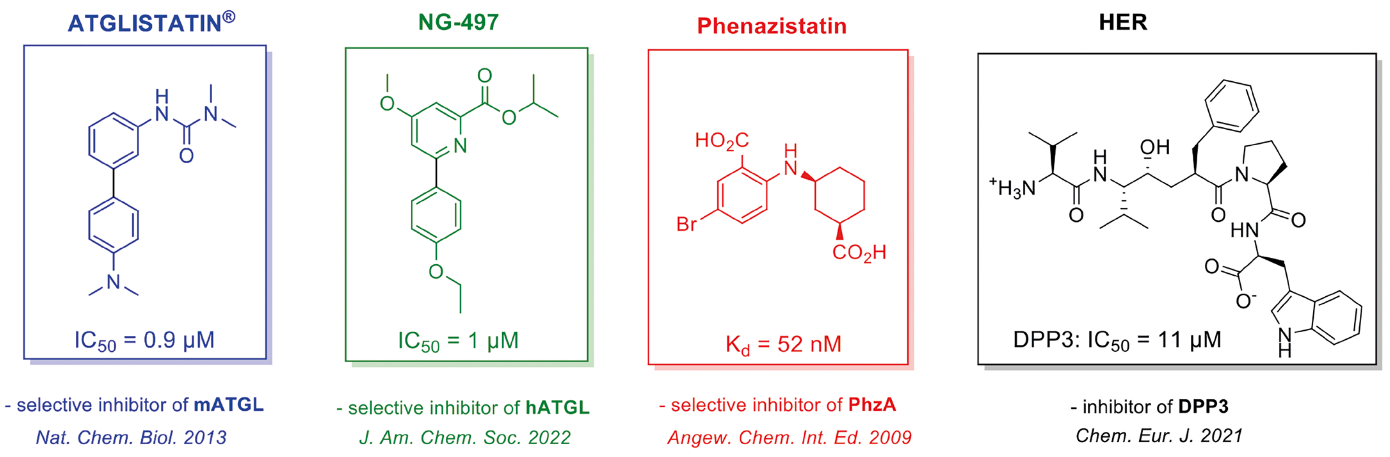


Figure 3: Small molecules inhibitors against adipose triglyceride lipase (ATGL), phenazine biosynthesis enzyme PhzA, dipeptidylpeptidase 3 (DPP3).

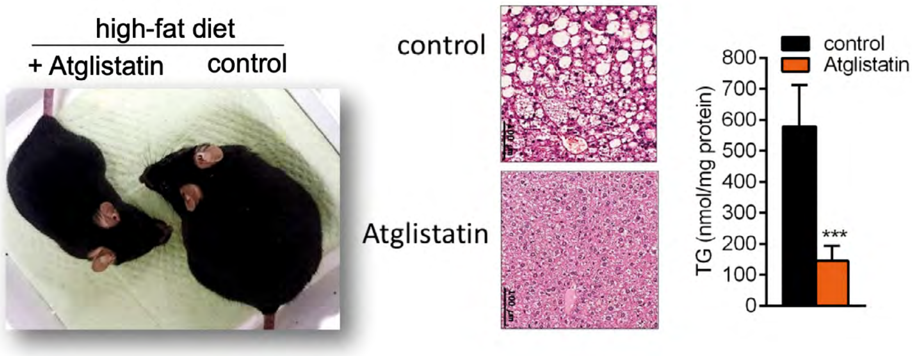


Figure 4: Atglistatin prevents metabolic-associated fatty liver disease (MAFLD) in mice as can be shown by the loss in body weight (left), the lack of white lipid droplets in liver tissue (middle) and the reduced content of triglycerides in liver tissue (right).

diabetes even on a high-fat diet, and it is resistant against tumor-induced cachexia. This motivated us to find a molecular key controlling ATGL function.

In a collaborative effort we have developed small molecule inhibitors of ATGL. It was necessary to synthesize and test almost 1,000 compounds before we could identify the first inhibitor of murine ATGL[1] with Atglistatin® and – more recently – the first inhibitor of human ATGL[2] with NG-497. Atglistatin has stimulated significant research activities worldwide, thus increasing our understanding of the physiological role of ATGL. The Zimmermann/Zechner lab could show that Atglistatin prevents metabolic-associated fatty liver disease (MAFLD) in mice (Figure 4). MAFLD affects ca. 25% of the Austrian population and in severe cases can lead to liver cirrhosis. With cardiologists in Edmonton (Canada) and at the Charité in Berlin (Germany) we could show that Atglistatin also prevents and cures heart failure in mice. These data have validated ATGL as an attractive drug target. We are currently investigating the preclinical development of ATGL inhibitors in collaboration with the wings4innovation-initiative. In addition, we are pursuing several other research programmes identifying small molecule inhibitors of various other proteins, especially transcription factors.

Rolf Breinbauer

has been head of the Institute of Organic Chemistry at TU Graz since 2007. His research interests encompass the development of tool compounds for chemical biology and the development of new methods for organic synthesis using biocatalysis, transition metal catalysis or electrochemistry.

Source: Christian Lembacher-Fadum – TU Graz

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Source: istockphoto.com

INFORMATION, COMMUNICATION & COMPUTING

Fields of Expertise TU Graz

Source: Lunghammer – TU Graz

Kay Uwe Römer,

Information, Communication & Computing

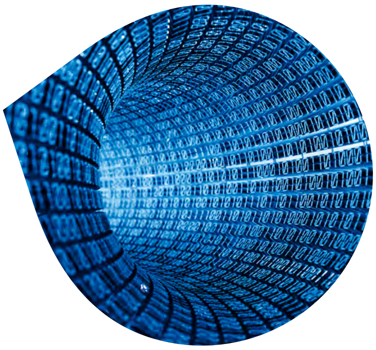
After a successful first round in 2020, this year the FoE ICC again had a tenure-track professorship to fill with a broad scope covering all areas of Information, Communication & Computing.

We received a staggering 179 applications from all over the world, including also many applications from former and current TU Graz members. The selection committee, composed of the deans, FoE leaders, and representatives of non-tenured staff of all three participating faculties as well as student representatives, had the challenging task of screening these applications and selecting the best 25 to be forwarded to three expert reviewers for a detailed assessment. Based on the reviews, the selection board invited nine candidates for interviews in early July. As part of the interviews, numerous meetings were arranged among the applicants and the institutes that would potentially host them. Impressed by the outstanding quality of these interviews, the selection board composed a short list of seven candidates, all of whom would have deserved to be offered a position. Unfortunately we had only one position to fill and were lucky enough that the top-ranking applicant accepted our offer of the tenure-track professorship. We will hear more from the winner of this competition as soon as he starts his work at TU Graz. With the application deadline set for the beginning of May and the shortlist being approved by the Rector in mid-July, the whole selection process was completed in a record time of just two and a half months. I am grateful to the selection board who were faced not just with a huge amount of work due to the large number of applicants, but also with the difficult task of comparing applicants from very different backgrounds – from mathematics and computer science to electrical engineering. A special thank you goes to Stephanie Mühlbacher from F&T House, who was instrumental in the organization of the whole process, paperwork, and communication.

In this edition of TU Graz research Christian Adams, professor at the Institute of Fundamentals and Theory in Electrical Engineering, gives us some insights into his research. Enjoy reading!

Christian Adams

Acoustics and Environmental Noise

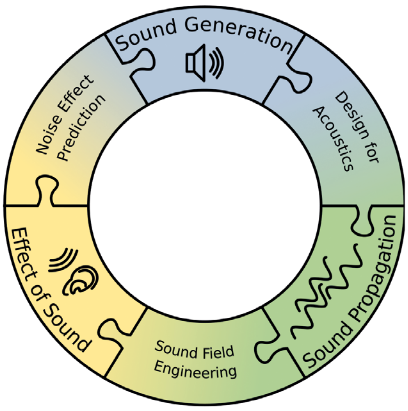


BMK endowed professorship on noise impact research: Competence Center for Traffic Noise and Health

Noise is a sound that an individual perceives as disturbing. In 2019, a third of Austrians stated that they were disturbed by noise at home and 48.5% said traffic was a significant source of noise. Across Europe, around 140 million people are exposed to harmful noise, with road (113 million), rail (22 million), and air traffic (4 million) being the primary sources of noise. Around one million people are affected by industrial noise. In addition, high noise pollution also threatens wildlife.

The Professorship for Acoustics and Environmental Noise is an endowed professorship and receives five years of funding from the Austrian Research Promotion Agency (Österreichische Forschungsförderungsgesellschaft mbH) and industry partners. Together with ÖBB-Infrastruktur AG, Linz AG Linien, Wiener Linien GmbH & Co KG, AVL List GmbH, ASFINAG, KTM F&E GmbH, and The Austrian Airports Association, we focus on transportation noise and its effects on humans. In the long term, we are opening up the application field of urban noise, and in particular noise in residential areas, with the goal of achieving a quiet city.

Figure 1: The Noise Effect Cycle – a holistic concept for noise impact research.
Source: Author's own illustration



THE NOISE EFFECT CYCLE

We aim to control noise as close to the source as possible. Ideally, unwanted noise should not be generated at all. We achieve this through Design for Acoustics of sound sources. Then, we need to understand how sound propagates into the environment to develop efficient noise protection measures through Sound Field Engineering. Finally, we want to understand better how noise affects people, including the health consequences of noise exposure. This knowledge will be fed back into the design of noise sources through Noise Effect Prediction. The result is a positive cycle that reduces the noise at the source, controls propagation and minimises harmful effects on humans – the noise effect cycle (Figure 1).

DESIGN FOR ACOUSTICS

Sound-absorbing materials can reduce noise from sound sources, but must be designed correctly during product development to be effective. These materials can be tested in an impedance tube. Figure 2 shows the setup and the absorption coefficient of acoustic foams, which is the ratio between the absorbed sound power and sound power at normal incidence. The red solid line (μ) and the black dashed line (μ±σ) represent the mean and one standard deviation from mean, respectively, while the grey lines illustrate the data set consisting of 980 individual measurements. Some data variation is intended and can be controlled through material type, density, or thickness. But a significant amount of variation is caused by the measurement procedure itself, such as the cutting technology and cutting precision of the specimens. We developed a machine learning framework that can distinguish between these variations and explain which frequencies have been decisive. Such knowledge is essential to selecting appropriate acoustic materials during product development so that our investigation can help to design acoustically optimised products more efficiently. >

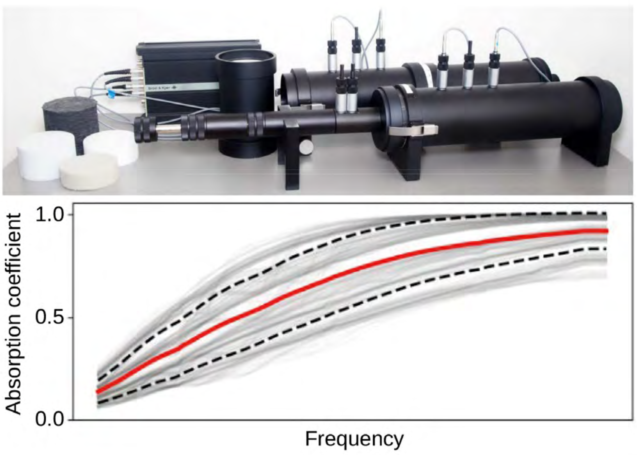


Figure 2: Impedance tube for sound absorption measurements (top).
Source: Gerald Maurer
Absorption coefficients versus frequency with several parameter variations (bottom).
Source: Alfonso Caiazzo

FIELDS OF EXPERTISE
TU Graz research
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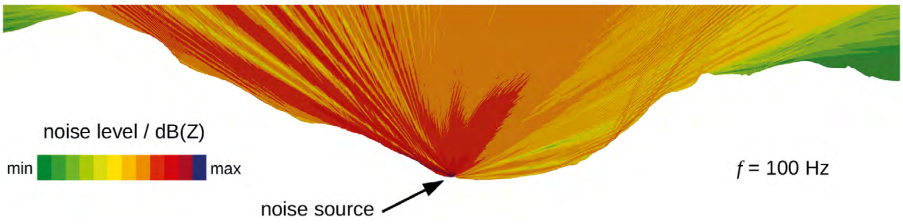

Figure 3: Sound level distribution at a frequency of 100 Hz in a valley near Wald am Schoberpass.

Source: Florian Kraxberger

SOUND FIELD ENGINEERING

Sound propagation into the environment must consider all physical effects to correctly predict noise, particularly at low frequencies (approximately 20 Hz–200 Hz). We research discontinuous Galerkin methods to efficiently and accurately predict noise immissions in large domains such as the environment. Our goal is to understand better how sound waves propagate into the environment and to predict the effects of noise reduction measures such as noise barriers or walls more accurately. Figure 3 is a cross-section through a valley near Wald am Schoberpass in Austria, where roads and rails cause traffic noise. It illustrates how noise levels are distributed at a frequency of 100 Hz if a noise barrier is set on the right-hand side of the sound sources. Noise is shielded in the right part of the valley, which highlights the effect of the noise barrier on noise immission even at 100 Hz, where noise barriers are usually less effective.

Christian Adams

is Professor of Acoustics and Environmental Noise at the Faculty of ETIT at TU Graz. He holds a newly established endowed professorship, which will be funded by the BMK and companies for the first five years. He is researching physical noise mechanisms at the source, simulation of the noise propagation into the environment and new approaches to noise impact and protection.

Source: Lunghammer – TU Graz

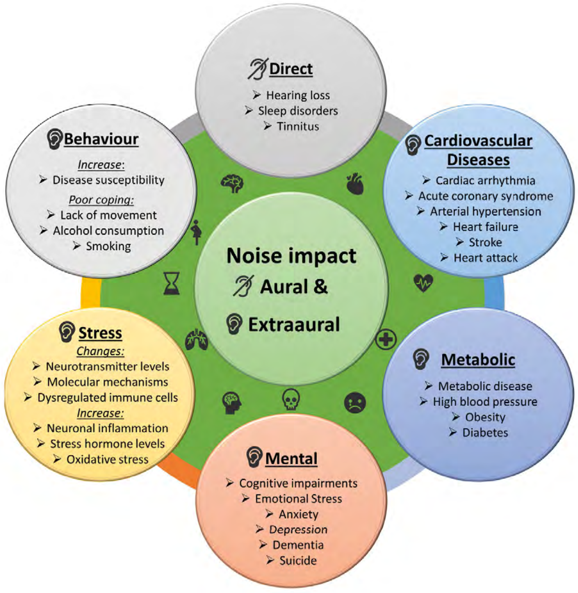

Figure 4: Summary of noise impacts on humans.

Source: Julia Donnerer

NOISE EFFECT PREDICTION

Noise protection measures are based on dose-effect relationships. They refer to the sound exposure and measure the effect on annoyance and health of those affected. Today, design and effects of noise sources are not connected. Knowledge about noise impacts is rather empirical, as the summary in Figure 4 illustrates. This is the starting point for our future noise impact research. We aim to connect the noise effects with the technical aspects of noise sources. Psychoacoustics provides us with the tools to translate empirical knowledge about noise effects for technical acoustics to improve noise source design.

Source: istockphoto.com/fotolia.com

MOBILITY & PRODUCTION

Fields of Expertise TU Graz

Source: Lunghammer – TU Graz

Rudolf Pichler

Mobility & Production

Industry and related business is currently suffering from a time of irritation, unclear perspectives and hesitation.

These days, we too often hear about workers being laid off, bankruptcies and other signs of an economy in fall. As a consequence of this, industry is presently disinclined to form alliances with and make contributions to universities. The major question now is: should science mimic the same dynamics of anxiety and paralysis as industry? The answer is a definite no! Times of recession are the best phases to make time for further education and for thinking about the future, because one thing is clear: when the order books of industry are full, nobody is willing to hear about future technologies. This means we have an opportunity to prepare our common future now! The future of industry is mainly in innovation and this depends on the input of universities. So we as a university undoubtedly do have the clout to encourage industry, to create feasible concepts and to assist industry in making good ideas for the future viable. We are happy to show an example of this in the current issue of our research magazine, namely how decarbonisation can work even in a highly traditional working environment. So please enjoy the report by Susanne Lux and stay deeply future oriented.

Susanne Lux, Viktor Hacker

Iron and Hydrogen – A Perfect Match

Iron and hydrogen, the first a typical heavy metal, the second a classical non-metal – two elements that could not be more different at first glance; and yet they form a perfect team giving access to a decarbonised future.

Iron – the first – has been the most important raw material since the iron age. The amount of pig iron produced is more than ten times greater than that of all other metals combined. In short, iron and steel are an integral part of our daily lives. However, their production is responsible for a major part of the industrial sector's CO_2 emissions. >

FIELDS OF EXPERTISE
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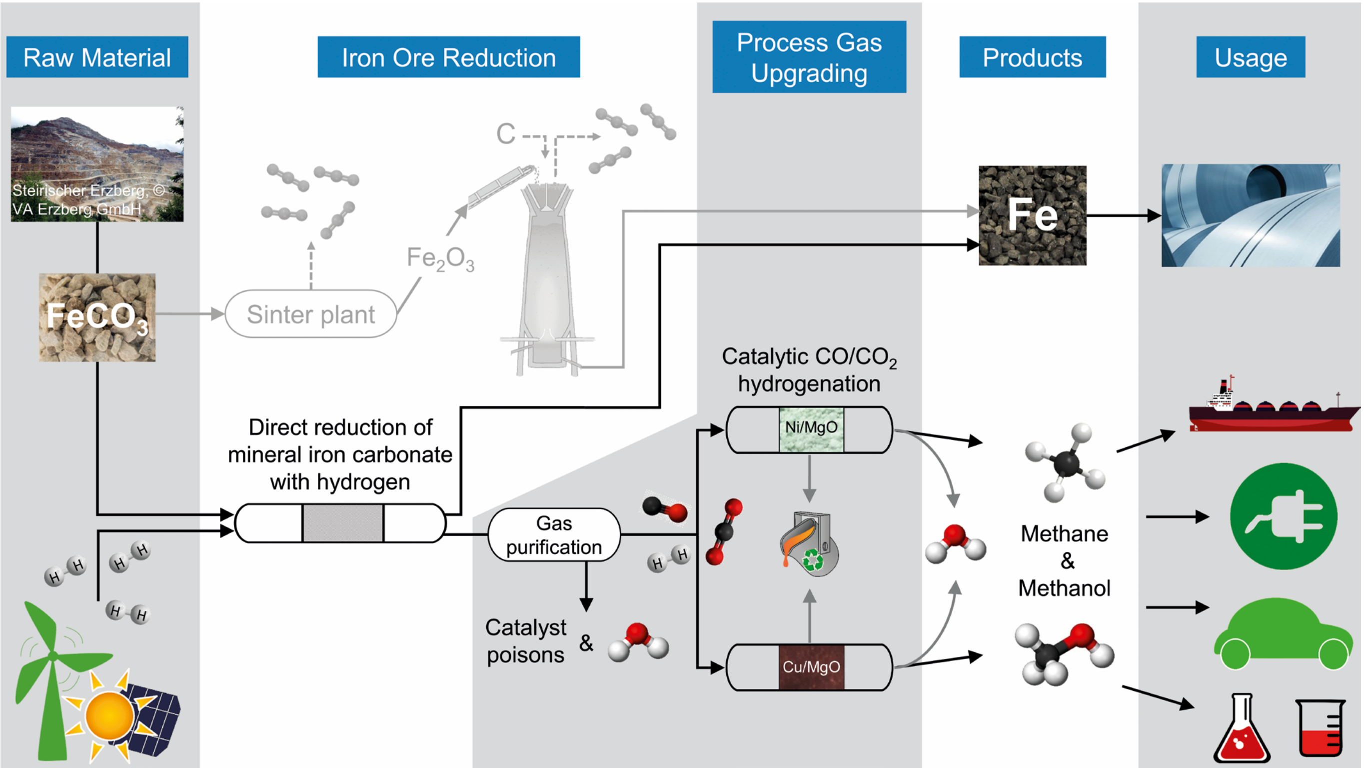

Figure 1: Process scheme of direct reduction of siderite ore with hydrogen combined with catalytic CO_2/CO hydrogenation for carbon neutral iron production.

Austrian mining and iron and steel production look back on a long tradition. Even though the Alps are considered to be "rich in poor deposits", for Austria, the mining and processing of iron ores and the subsequent production of steel have been an important cornerstone of economic and regional development over centuries. There is even a verse dedicated to mining in the Austrian national anthem ("Land der Hämmer, zukunftsreich!"). The most-used iron ores for pig iron production are iron oxides. In regions with large deposits of siderite ore such as Austria, this ore, which contains ferrous carbonate, is also used for pig iron production – although its iron content is lower and processing is more elaborate. Processing of siderite ore contributes to further CO_2 emissions due to the release of CO_2 from the carbonate. Thus, the search for measures to substantially reduce the high level of CO_2 emissions is a high priority task.

Hydrogen – the second – is the most common element in the cosmos. About two thirds of the total mass of the universe consists of hydrogen. In the earth's crust, every sixth atom is a hydrogen atom and, as is generally known, hydrogen can be produced from water. It is ideally suited as a chemical reducing agent and, as a versatile energy carrier, it is seen as playing a key role in the transformation process towards a decarbonised energy economy. However, hydrogen transport and storage are still the subject of debate.

Significant CO_2 emissions in iron production, especially from siderite ore, and complex and cost-intensive transport and storage of the promising energy carrier hydrogen; two pending questions, one of which could contribute to solving the other. Hydrogen may be the key to CO_2 emission-free iron production from siderite ore, where iron in turn shows potential to solve the storage and transport issue of hydrogen.

DIRECT REDUCTION OF SIDERITE ORE WITH HYDROGEN

Direct reduction of mineral metal carbonates with hydrogen, also termed “reductive calcination”, is a novel approach that was developed by the Chemical Reaction Engineering Research Group at the Institute of Chemical Engineering and Environmental Technology. It tackles the problem holistically and opens up a completely new pathway for metal carbonate processing in general and iron production in particular with the potential of becoming a CO_2 breakthrough technology. Direct hydrogen reduction of siderite ore does not need the conventional two-step route of roasting and reduction in the blast furnace, as elemental iron is directly formed from the iron carbonate in one process step; even at relatively moderate temperatures of 700–800°C. This results in a CO_2 emission reduction of more than 60%. Compared to siderite roasting (oxidation to hematite) followed by hematite reduction with hydrogen, 33% less reducing agent hydrogen is required for the direct reduction process. In addition, the process gas is upgraded by the formation of methane and carbon monoxide instead of simply releasing CO_2, thus further reducing overall CO_2 emissions [1].

Figure 2: Siderite ore from the Styrian Erzberg.

IRON AS A HYDROGEN CARRIER

Materials with high storage densities and efficient energy conversions are needed to transport hydrogen. The use of metals such as iron offers interesting prospects, as iron is readily available and can reversibly store and release hydrogen in a chemical cycle. >

Figure 3: Test stand for heterogeneous gas-phase reactions at the Institute of Chemical Engineering and Environmental Technology.

Source: Blendpunkt

In this novel approach, energy is stored by reducing iron oxide to metallic iron. This can even be done directly from natural ores, for instance siderite ore. Reoxidation of the iron-based oxygen carrier material with steam releases the stored chemical energy in the form of pure hydrogen and heat. A chemical looping hydrogen process with iron oxide as the contact mass, the so-called Reformer Steam Iron Cycle (RESC), was developed by the Hydrogen Research Group at the Institute of Chemical Engineering and Environmental Technology. A recent study revealed synergistic effects of mixed ionic electronic oxygen carriers in ceramic-structured environments with highest hydrogen storage capacity that effectively avoids sintering [2].

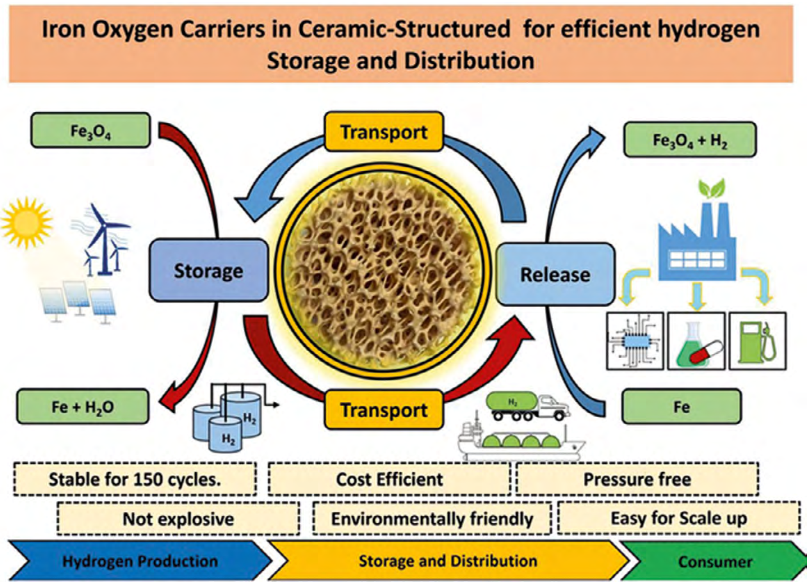

Figure 4: Iron oxide carriers in ceramic-structured environment for hydrogen storage and transportation.

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Viktor Hacker

is professor at and head of the Institute of Chemical Engineering and Environmental Technology and leads the Hydrogen Research Group with a focus on hydrogen production and hydrogen purification.

Source: Lunghammer – TU Graz

Susanne Lux

is associate professor at the Institute of Chemical Engineering and Environmental Technology and leads the Chemical Reaction Engineering Research Group. Her research focus lies in innovative process and apparatus design for multiphase reactions and reactive separations.

Source: Fotogenia – TU Graz

SUSTAINABLE SYSTEMS

Fields of Expertise TU Graz

Source: ymgerman – fotolia.com

Source: Lunghammer – TU Graz

Urs Leonhard Hirschberg
Sustainable Systems

In the 21st round of the initial funding program, a total of seven proposals were submitted in the Sustainable Systems category. The quality of the projects was high and we were able to fund six of them – more than ever before.

Daniel Gethman from the Institute of Architectural Theory, Art History and Cultural Studies is coordinating four institutes to apply for an FWF Special Research Area (SFB) grant, titled "Informed architectural acoustics in communication environments". Their proposal argues that communication and acoustics of architectural spaces are of crucial importance, today, and that, instead of treating communication and acoustics separately as is typically done, there is an urgent need for a new interdisciplinary approach that combines them.

Katharina Hengel from the Institute of Architecture and Landscape proposed the project with the short title "Cool GreenTec" to investigate the performative potential of integrated plant systems in building structures. Nature-based solutions are key in addressing the climate crisis and alternatives to mechanical ventilation systems that use the natural properties of plants to control the air quality in buildings are feasible. The project proposes analysing existing examples and then developing a working prototype of a software tool for creating and monitoring such solutions.

Matthias Rebhan from the Institute of Soil Mechanics, Foundation Engineering and Computational Geotechnics heads a team of researchers to apply for an FFG project to study "Wheel and soil interaction parameters". It turns out that current models used to compute the interaction between vehicle wheels and soil are rather rudimentary and not very good at dealing with dynamic phenomena. The project looks at ways how more complex computational approaches, already common in geo-engineering, could also be applied to vehicle technology.

Michael Kriechbaum from the Institute of Interactive Systems and Data Science proposes an FWF project with the short title HydroFair. He and his research team want to investigate how a sustainable and socially just global supply chain could be established for green hydrogen, which is increasingly seen as a corner stone of a transition towards a low-carbon economy. The challenge is not just technological, but lies in the complex interplay of multi-scalar governance and regional contexts.

Milica Tomic, Head of the Institute of Contemporary Art, proposes an FWF PEEK project that takes an interdisciplinary look at Brijuni, an archipelago off the Istrian coast. The famous islands have seen a multitude of governing powers in their history since Roman times and are a unique testament to the complex interplay between nature and human activity. The project "In stasis. Unravelling traces of potential worlds." wants to set up an international collaboration to investigate this entangled history, with many research activities, leading to an exhibition about Brijuni's history.

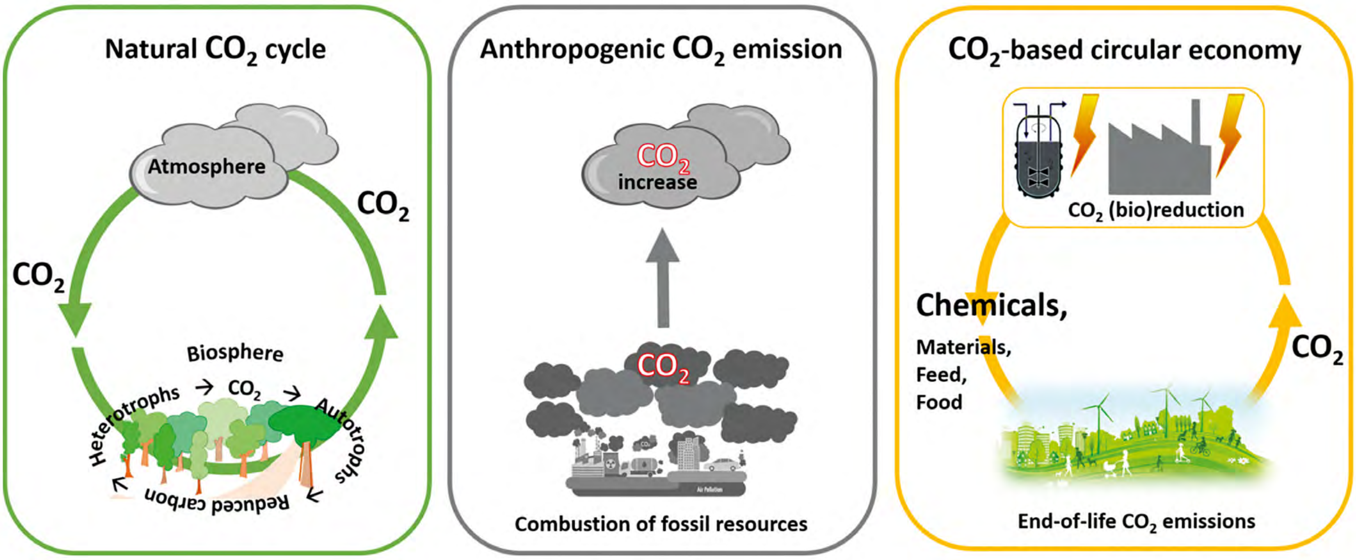
Oliver Pischler from the Institute of High Voltage Engineering and System Performance proposes an FFG project to pursue the "Development of a system for measuring space charges in HVDC cables". Europe's electricity infrastructure is transitioning to high-voltage direct current (HVDC) power lines, which can transport significantly more power over greater distances than high-voltage AC lines. While HVDC cables have already been used for years, there are still technical challenges. Space charges can limit the cables' durability and lead to expensive repairs, which the proposed system could help prevent.

We wish all applicants the best of luck with their proposals and hope that the resulting projects can one day be presented on these pages, just like the project on page 34.

Regina Kratzer

Towards a CO_2-Based Circular Economy

Carbon dioxide is an essential component of the Earth's biosphere and as such is part of the biological carbon cycle.



The biological or fast carbon cycle describes the movement of carbon as it is recycled between the biosphere and the atmosphere. In the biosphere, CO_2 is assimilated into organic compounds by so-called autotrophs and thus forms the basis of life for all organisms that are not able to fix CO_2. These heterotrophs in turn use reduced organic compounds as building blocks and obtain energy from the oxidation of organic molecules to CO_2 (Figure 1). Human activities have resulted in a significant alteration to the natural carbon cycle. The burning of fossil carbon sources such as coal, oil and gas has caused CO_2 in the atmosphere to rise by 50% (Figure 1). One strategy for reducing CO_2 emissions into the atmosphere is to use it as carbon source for the production of chemicals, materials, animal feed and even food. By doing so, excess CO_2 is removed and a framework for a CO_2-based circular economy is formed. The prerequisites for this are (bio)chemical reduction methods of CO_2 and the availability of cheap energy sources (Figure 1). The most important chemical reduction processes are based on transition metal-catalyzed hydrogenations. However, sulphur and nitrogen compounds in CO_2-rich gases poison transition metal catalysts, limiting their lifetime. A promising approach to avoiding frequent catalyst changes is the use of self-replicating, CO_2-assimilating biocatalysts. The main classes of autotrophic microorganisms are photoautotrophs, which rely on light as an energy source, and lithoautotrophs, which derive the energy required for CO_2 assimilation from chemical reactions. Aerobic hydrogen-oxidizing bacteria (lithoautotrophic HOBs) are able to assimilate CO_2 using H_2 as electron donor with O_2 as final electron acceptor. The advantage of aerobic HOBs compared to photoautotrophs or anaerobic lithoautotrophs is that the strongly exothermic oxyhydrogen reaction provides significantly more energy for metabolic processes.

Figure 1. As a field of science that utilizes biological systems for technological applications, biotechnology seeks to use HOBs (and other autotrophic organisms) for CO_2 conversion into various products. The main obstacle to the full exploitation of HOBs is the explosiveness of the substrate gas mixture consisting of H_2, O_2 and CO_2. Although several research groups were already cultivating HOBs successfully in the second half of the last century, stricter safety regulations at the beginning of the third millennium led to a decline in this field of research. In recent years, biotechnological strategies for the assimilation of CO_2 have once again come to the fore. Under the coordination of Regina Kratzer (Institute for Biotechnology and Biochemical Engineering), several working groups at Graz University of Technology have joined forces to develop lab-scale bioreactors for the cultivation of HOBs. The centrepiece is a standard lab-scale bioreactor, which was converted for operation with explosive gases under the supervision of Markus Raiber and Vanja Subotic from the Institute of Thermal Engineering (Figure 2). The first results obtained with the bioreactor were successfully published (Bioengineering Best Paper Award) and our (then) doctoral student Vera Lambauer won the dissertation prize of the Forum for Technology and Society at TU Graz. These activities are also supported by the start-up Econutri, which operates one of the world's few ATEX-compliant bioreactors on pilot scale at TU Graz/acib. (We want to emphasize that all gas fermenters were ATEX-certified by external bodies.) Currently, the gas fermentation process is implemented in a Digital Twin to facilitate safe processing by fully automated process control. The data obtained will be utilized in the new lead project DigiBioTech in order to facilitate predictive scale-up to the cubic meter scale using machine learning enhanced computational fluid dynamics (Stefan Radl, Institute of Process and Particle Engineering). This will allow for a better assessment of the potential of HOBs in the landscape of biological and chemical possibilities for the reduction of CO_2. In this context, the author wants to summarize her personal opinion on CO_2-based economies: (1) no single CO_2 reduction method will prevail as the only valid one, (2) each of the chemical and biochemical CO_2 reduction processes mentioned is energy intensive and complex, (3) the use of CO_2 as a future carbon source is unquestion.

FUNDING

LEAD project TU Graz "DigiBioTech Digitalization of Biotechnology", 2025 to 2027. H2020-MSCA-ITN-2020 "ConCO$_2$rde Training network on the conversion of CO_2 by smart autotrophic biorefineries", 2021 to 2024. Lighthouse project "Synthetic biology for efficient gas feedstock conversion to new protein sources", within the FFG Comet K2 ACIB, 2020 to 2023.

Figure 2. The team from the Institutes of Biotechnology and Biochemical Engineering and Thermal Engineering. From left to right Vera Lambauer (Biote), Markus Müller (IWT), Regina Kratzer (Biote) and Markus Raiber (IWT), in front of the newly designed bioreactor for use in oxyhydrogen fermentations. The bioreactor with medium and cell culture is shown on the right.

Regina Kratzer

is a researcher at the Institute of Biotechnology and Biochemical Engineering.

Source: Lunghammer - TU Graz

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TU Graz research

Research Journal of Graz University of Technology

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WISSEN
TECHNIK
LEIDENSCHAFT

TECHNOLOGY FOR HEALTH

Page 4

Dear colleagues, research partners and all those interested in our research,

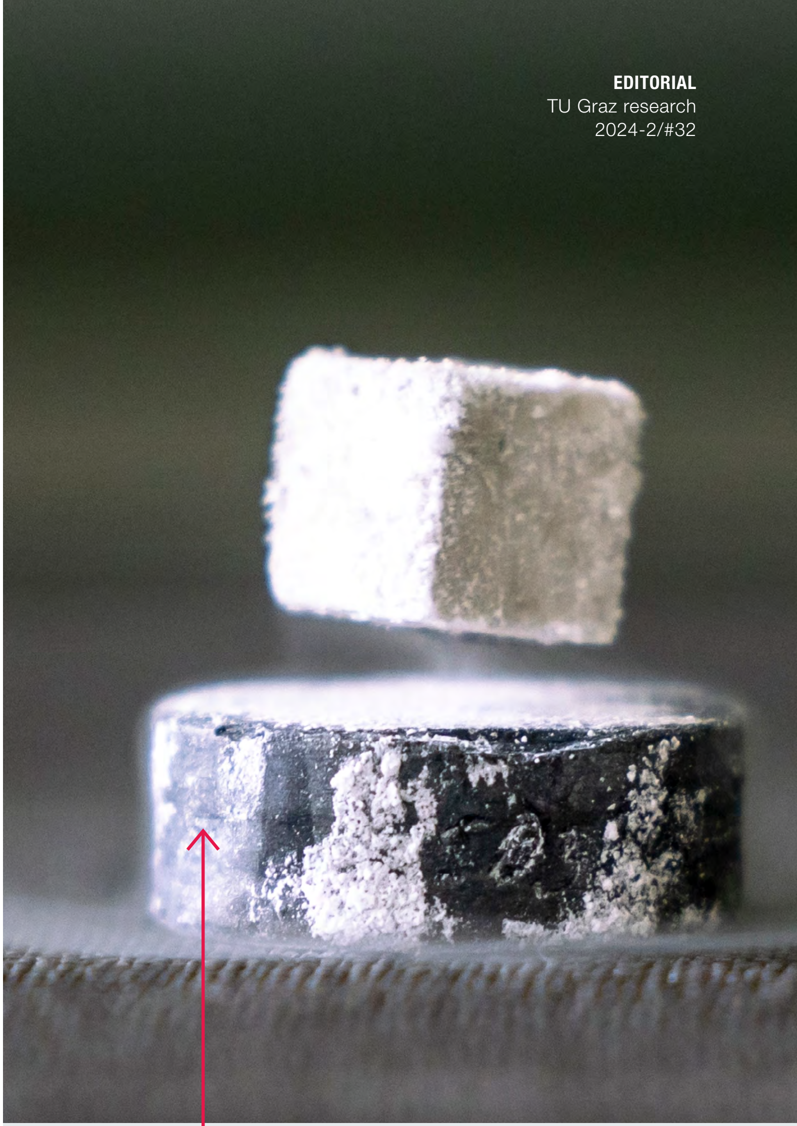
Andrea Höglinger
Vice Rector for Research
Lunghammer – TU Graz

a university thrives on collaboration in teaching and research. TU Graz and the University of Graz have been working closely together in the field of natural sciences for 20 years – both in joint study programmes and courses, as well as in jointly operated infrastructure and research projects. NAWI Graz is a unique success story and will continue to be so in the future, as the two universities will grow even closer together in the coming years, for example with the Graz Center of Physics.

The main theme of this issue of TU Graz research is biomedical engineering and biomedical research. Here, the focus is on people, health and the best medical care. Improving MRI examinations, brain-computer interfaces and optimised speech recognition are just a few of the research areas that researchers at TU Graz are working on in this field.
I am particularly pleased to be able to report in this issue on three ERC Grants awarded to TU Graz. One ERC Starting Grant each goes to Fariba Karimi and Maria Eichlseder. And Gerhard A. Holzapfel will be conducting research with an ERC Synergy Grant in the coming years.

All in all, we can look back on an extremely successful year of research at TU Graz. In the meantime, I wish you a relaxing New Year's break.

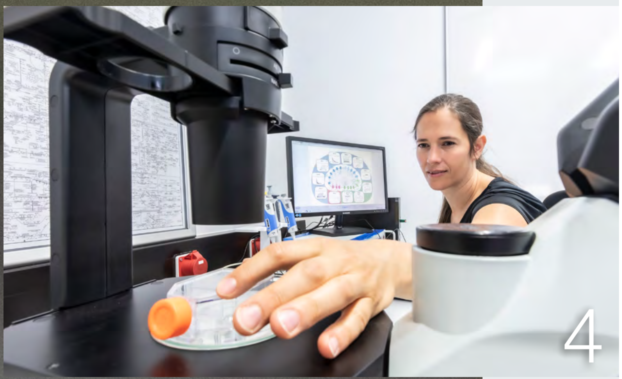
Best wishes,
Andrea Höglinger



SUPERCONDUCTOR

A superconductor is a material that, under certain conditions, can transport electrical current with virtually no resistance. In today's superconductors – like the one shown in this picture – this happens at extremely low temperatures. To achieve this, the conductor is cooled with liquid hydrogen – which is currently only the case in high-tech applications in hospitals or research facilities. But the search is on for a superconductor that works at natural ambient temperature and pressure.

I SPY SCIENCE
„Was ist ein Supraleiter?“



All Images by: Lunghammer – TU Graz

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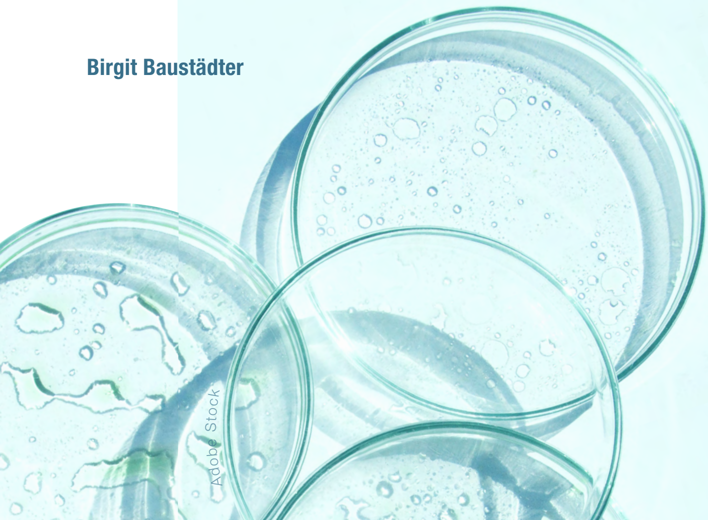
Lunghammer – TU Graz

Technology for Health

Diseases affect us all – in different forms and with different consequences. Medical advances supported by technical research have made diagnosis and therapy much more accurate, faster and more successful in recent years.

Birgit Baustädter



Adobe Stock

Focus areas such as biomedical engineering at TU Graz show the importance of this topic in research. Here, research is carried out on the fundamentals as well as on very practical diagnostic and therapeutic options. The topic of "people" is a multifaceted one and is treated in exactly the same way at TU Graz:

MEDICAL DEVICES

The Institute for Health Care Engineering and its European Testing Centre for Medical Devices offer testing of various medical devices. It is the only accredited testing centre in Europe the institute. Tests for certifications are carried out here. But of course we also develops, evaluates and validates point-of-care and sensor technologies. Research focuses on the analysis, modelling and simulation of biophysical, cell biological and tissue-specific processes as well as new technical approaches in diagnosis and therapy.

The Institute of Health Care Engineering, which is located right next door, is working on various aspects. One of these is a lab on a chip". The lab is a small chip, which is a microelectrode array. "We grow heart muscle cells on it," explains Christian Baumgartner, head of the institute. "This system enables non-invasive examinations of cardic activity." The electrodes are attached directly to the petri dish in which the heart muscle cells grow. They can then both stimulate the heart cells and measure data. Within a few days, the cultivated heart muscle cells form a dense cell layer and so-called pacemaker cells that send signals to their environment. In this way, the heart "beats" artificially in the Petri dish and researchers can simulate and analyse various disorders.

AORTIC DISSECTIONS

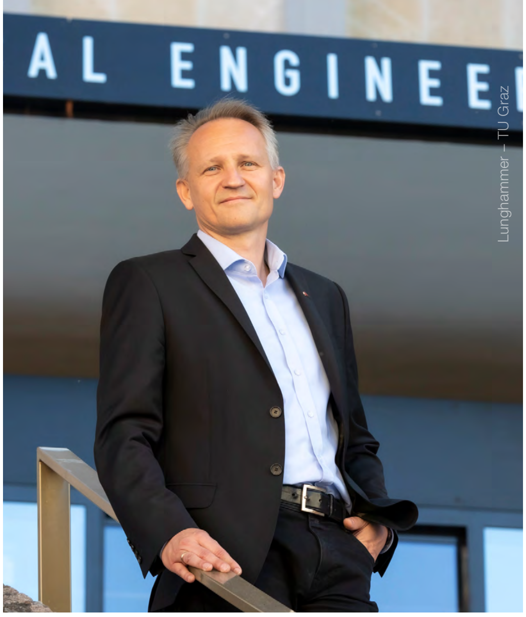
Gerhard A. Holzapfel (Institute of Biomechanics), Karin Ellermann (Institute of Mechanics) and their research team are investigating the "mechanics, modelling and simulation of aortic dissections" with funding from the TU Graz Lead Projects funding programme. This disease of our aorta results in a tear in the aorta. A start-up has already emerged from the lead project, which aims to significantly facilitate the diagnosis of aortic dissections using machine learning approaches.

Gerhard A. Holzapfel was awarded an ERC Synergy Grant worth 4.2 million euros by the European Research Council this month. In this six-year project will develop experimental and AI-based methods to analyse in detail for the first time the relationship between transcriptomics, microstructure and mechanical properties of soft biological tissue. The overarching aim is to develop an imaging method for the non-invasive investigation of tissue microstructure, which will improve the diagnosis and treatment of diastolic heart failure in everyday clinical practice. More details on page 10.

About the work in the lead project

THE GENOME

The Institute of Biomedical Informatics analyses the blueprint of our body – the human genome. In recent years, it have become the focus of medical research in order to make personalised



Lunghammer – TU Graz

Christian Baumgartner

medicine and individual therapies possible. The main focus is on the sections – genes – that code for proteins; however, these only make up two per cent of the human genome. The much larger part is made up of so-called non-coding sequences, which define whether and how strongly our genes are characterised. They therefore also have a central influence on embryonic development. Research at the Institute of Biomedical Informatics, where artificial intelligence and big data methods are used to study the human genome, is primarily focused on these sequences. Another field of research is the characterisation and optimisation of microorganism genomes, which are of great importance for the production of biotherapeutics. This is also being done in connection with the recently launched lead project "DigiBioTech".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Gernot Müller-Putz

HUMAN LANGUAGE

At the Institute of Signal Processing and Speech Communication, Barbara Schuppler works with children and young people with different language impairments and helps them to participate better in everyday school life. She looks at human speech. She investigates how human dialogues work, how much interlocutors adapt to each other and how this behaviour can be modelled. She is primarily involved in basic research and generates important data for further research: "We have created Austria's largest database of spontaneous language dialogues. We can use this data to analyse the characteristics of spontaneous speech. For example, when the dialogue participants know when they can speak, how they signal agreement and how the pronunciation, intonation and rhythm of the language changes for example because of dementia." In this way, she is laying the foundations for improving speech recognition systems, which are used in medical assistance systems, among other things.

MOVING IT AGAIN

Depending on the location of a spinal cord injury, affected people have to cope with different restrictions in everyday life. Gernot Müller-Putz and his team at the Institute of Neural Engineering want to make life easier for these people and, in some cases, make communication possible in the first place.

Until now, research efforts have mainly specialised in non-invasive measurements of brain waves using an EEG cap. The EEG measures the electrical impulses emitted by the neurons in the brain, a computer decodes them and sends the understood commands to a robotic arm, a computer programme or an exoskeleton, for example. This enables test subjects to move external prostheses, use muscles that could no longer be controlled via the spinal cord, or "think" words on the computer screen. "Our biggest challenge is to assign the right potentials in the brain waves to the right movement," explains Müller-Putz. But the test subjects first have to familiarise themselves with using the machine.

For a good two years now, the team has also been working on implantable systems and is involved in the development of a completely new type of chip that is implanted directly into the brain. "The main advantage is that the disturbing noise is reduced and the signals are much clearer than those from an EEG cap," explains Müller-Putz. He wants to use the system to enable people with locked-in syndrome or people in a vegetative state to communicate in a new way.

Talk Science To Me
TU Graz-Podcast

Podcast interview with Gernot Müller-Putz

CYBATHLON

In the international student competition Cybathlon, teams of students compete against each other in various disciplines related to brain-computer interfaces. The students of the Mirage 91 team at TU Graz regularly take part, develop systems, train together with pilots and optimise their systems. In the competition itself, the pilots – people with spinal cord injuries – have to complete a computer game as quickly as possible via EEG measurement. The main challenge here is that the system has to function in a predetermined way at a predetermined time, explains Gernot Müller-Putz. But the mental state of pilots also has an impact: "These people are understandably excited in front of a large audience. Of course, this has a huge impact on the brain signals."

Martin Uecker

IMPROVING MRI

Martin Uecker and his team at the Institute of Biomedical Imaging are investigating how images and measurements from magnetic resonance tomographs can be optimised. MRI examinations take a relatively long time due to their imaging method, but in contrast to computer tomography, for example, which delivers images much faster, they do not require ionised radiation. The length of the examination in a relatively narrow tube can be uncomfortable for some people, but it is necessary as many individual measurements are taken during an MRI examination, from which a very precise overall image is then compiled.

One way to improve these analyses is to use new numerical algorithms for image reconstruction. They can create accurate images from significantly less data – i.e. significantly fewer individual measurements. Some current approaches are based on machine learning and therefore require perfect MRI images for training. "However, perfect data is difficult to obtain," explains Martin Uecker. "Especially from moving organs, such as the beating heart." The institute is now researching ways to train the neural networks required for the algorithms from the data itself and without perfect images.

The institute is also involved in a wide range of activities to improve MRI examinations. For example, in the development of quantitative imaging biomarkers, such as those based on the Chemical Exchange Saturation Transfer (CEST) effect, or in low-field MRI.

A portable, small open-source MRI scanner

Christian Adams

MEDICATION

An important method of dealing with illness is to administer medication. TU Graz chemist Rolf Breinbauer and his team are involved in this area. They are developing active substances that reduce fatty acid levels in the blood. Among other things, fatty acid levels are partly responsible for type II diabetes, non-alcohol related fatty liver and some heart diseases. The enzyme ATGL (adipose triglyceride lipase), which releases fatty acids into the blood, is central to this process. Together with researchers from the University of Graz, Breinbauer is developing the active ingredient Atglistatin, which blocks the enzyme but does not interfere with any other processes in the body of an animal model.

RCPE

The competence centre RCPE (Research Center Pharmaceutical Engineering) located at TU Graz is developing new methods of drug production together with the closely interwoven Institute of Process and Particle Technology.

Link to RCPE

HEALTH AND NOISE

Christian Adams, on the other hand, specialises in ears at the Institute of Fundamentals and Theory in Electrical Engineering. More precisely, the perception of noise and its effects on our health and well-being. Noise can trigger illnesses. Holding an endowed professorship (from the ministry of climate action) for noise impact research, the researcher is in the process of setting up a competence centre for traffic noise and health, which will not only develop an intelligent noise map, but also carry out research on technical solutions that prevent noise in the first place. “The most important step is to control noise directly at the source. That has to be our first goal,” explains Adams. “In a second step, we have to prevent noise that cannot be stopped at source from spreading. For example, through noise protection measures that we either want to improve or develop from scratch.”

NEW PROJECTS

Contact persons and people involved in biomedical engineering research can be found on the website of the Field of Expertise Human & Biotechnology at TU Graz. ■

Human & Biotechnology at TU Graz

All Images by: Lunghammer – TU Graz

ERC Starting Grants for Maria Eichlseder & Fariba Karimi

Two TU Graz computer scientists have been awarded the prestigious EU funding prize of almost 1.5 million euros each for their research into more efficient encryption systems and the influence of artificial intelligence on discrimination in online social networks.

Philipp Jarke and Falko Schoklitsch

Improvements to keyless encryption and the increasing discrimination and social inequality in online social networks through the use of AI – these are the two research topics with which the top researchers Maria Eichlseder and Fariba Karimi are bringing highly endowed Starting Grants from the European Research Council to Graz University of Technology (TU Graz). The two computer scientists will each receive funding of almost 1.5 million euros over the next five years, the European Research Council announced today.

Of the 494 Starting Grants awarded across the EU, a total of 24 went to researchers from Austrian institutions. This puts Austria in eighth place in Europe. "The two ERC Starting Grants for Maria Eichlseder and Fariba Karimi underline TU Graz's position as one of Europe's leading universities in the research fields of IT security, artificial intelligence and data science. The plans in both projects – resource-saving, secure IT systems and fair algorithms – are pioneering," says Andrea Höglinger, Vice Rector for Research at TU Graz. "I am extremely pleased that two women researchers, Maria Eichlseder and Fariba Karimi, have come out on top in this highly competitive funding programme."

MARIA EICHLSEDER

Maria Eichlseder's ERC Starting Grant is the third to be awarded to researchers from the Institute of Applied Information Processing and Communications at TU Graz since 2016. Her project – KEYLESS – deals with encryption, but without the eponymous key. The focus is on the core component of cryptographic systems, the so-called primitive, which is responsible for the security of the entire system. For a long time, it was mainly primitives with keys, so-called block ciphers, that were used and scientifically analysed. In recent years, however, primitives without keys have become very popular, as these components offer a number of advantages. "The latest cryptographic standards, for example for quantum computer-secure or particularly lightweight cryptography, largely use such keyless components internally," says Maria Eichlseder. "But there is an open problem, namely the precise safety analysis of these components." There is still a need for research in this area and Maria Eichlseder's ERC project KEYLESS addresses precisely this. The requirements for keyless components are currently still based on idealised assumptions. These assumptions influence, for example, how often a cryptographic function has to be repeated as part of the encryption process until it is demonstrably secure against attackers. The current solution is a fairly generous number of repetitions to prevent security problems. "That costs resources, of course. If I carry out three times as many rounds as I actually need to protect myself against attacks, then I use three times as much energy. That's why I want to look at all levels of a cryptographic system, analyse these idealised assumptions and find out whether they can be replaced by more precise assumptions that come closer to reality, " says Maria Eichlseder.

Oliver Wolf - TU Graz

SHORT BIOGRAPHY

Fariba Karimi has been a full professor at the Institute of Interactive Systems and Data Science at TU Graz since October 2023 and also heads the Computational Social Science working group at the Complexity Science Hub in Vienna. Born in Tehran, Iran, in 1981 she studied physics at Shiraz University, Shahid Beheshti University in Tehran and Lund University in Sweden. in 2015, she completed her doctorate in physics and computer science at Umeå University in Sweden and was subsequently a post-doc at the Leibniz Institute for the Social Sciences in Cologne. Her research focuses on computational social sciences, the analysis of networks and algorithms and the modelling of human behaviour. In 2023, she received the Young Scientist Award from the German Physical Society for her research on inequality in complex networks.

FARIBA KARIMI: FAIR ALGORITHMS FOR SOCIAL NETWORKS

There is evidence that the use of artificial intelligence in online social networks – for example in recommendations and timelines on platforms such as LinkedIn or Google Scholar – leads to discrimination and increases social inequality. Fariba Karimi from the Institute of Interactive Systems and Data Science wants to get to the bottom of these trends in her project NetFair – Network Fairness and develop methods to analyse and eliminate these new mechanisms of inequality and discrimination.

Social inequality and marginalisation are based on a complex interplay of different social characteristics such as gender, origin and income – the social sciences speak of intersectionality in this context. “So far, there have only been qualitative findings on intersectional inequality in social networks,” says Fariba Karimi. In her ERC project, she wants to make intersectionality quantitatively measurable and then apply it to AI-based online social platforms in order to identify possible biases in their algorithms.

To this end, Fariba Karimi will first develop improved models of social networks and use data analyses and experiments to clarify which factors play a role in the design of the networks and influence each other. “Building on these improved network models, we will investigate their effects on algorithms and online social platforms and analyse the effects over a longer period of time,” says Fariba Karimi. But that is not the end of the story. In her project, Fariba Karimi wants to develop methods that reduce rather than reinforce inequalities and discrimination in online networks. “That’s the big goal: fair algorithms for social networks.” ■

SHORT BIOGRAPHY

Maria Eichlseder was born in Graz in February 1988. She was brought up in Steyr and Bavaria before she matriculated in Graz in 2006. This was followed by a bachelor’s degree in computer science and technical mathematics as well as the master’s and doctoral degree in computer science at TU Graz. In 2018, she was one of the first two women at TU Graz to receive her doctorate sub auspiciis praesidentis and is currently assistant professor of cryptography at the Institute of Applied Information Processing and Communications (IAIK) at TU Graz. Her doctoral thesis entitled “Differential cryptanalysis of symmetric primitives” was awarded a State Prize for the Best Doctoral Theses in 2018 by the Federal Ministry of Education, Science and Research and the 2019 Sponsorship Prize for Doctoral Theses of Special Social Relevance by the Technology and Society Forum. One of her greatest research successes to date is the selection of the algorithm ASCON, which she co-developed, as the new standard for lightweight cryptography by the National Institute of Standards and Technology (NIST) in the USA. In addition to her research activities at TU Graz, she was a visiting researcher at Ruhr University Bochum (2020) and Radboud University Nijmegen (2022).

ERC Synergy Grant for Biomechanical Heart Research

Lunghammer – TU Graz

The European Research Council is also funding a consortium consisting of the Helmholtz-Zentrum Hereon, ETH Zurich and TU Graz with a total of 10 million euros for developing new methods to determine the mechanical properties of living human tissue. TU Graz researcher Gerhard A. Holzapfel receives 4.2 million euros.

Philipp Jarke

Changes in the mechanical properties of organs are the cause of numerous diseases, including diastolic heart failure (HFpEF), one of the leading causes of heart-related disease and mortality worldwide. However, it is not yet possible to determine the mechanical properties of soft tissue without surgical intervention. An international research consortium from Graz University of Technology (TU Graz), the Helmholtz-Zentrum Hereon and ETH Zurich wants to change this with a new type of in vivo tissue analysis. In the project MechVivo, the research team will develop experimental and AI-based methods that for the first time show in detail the relationship between transcriptomics, microstructure and mechanical properties of soft biological tissue. The overarching aim is to develop an imaging procedure for the non-invasive examination of tissue microstructure that improves disease diagnosis and therapy in everyday clinical practice. The European Research Council is funding the six-year research project to the sum of 10 million euros, around 4.2 million of which will go to the Institute of Biomechanics at TU Graz.

"TU Graz is proud of Gerhard A. Holzapfel and his team and is delighted with their first ERC Synergy Grant," says Andrea Höglinger, TU Graz Vice Rector for Research. "Biomedical engineering is one of our university's key areas of strength. This research receives additional international visibility through collaboration with high-calibre European partners in the MechVivo project. With this ERC grant, TU Graz is once again consolidating its position as a leading institution in Styria within the framework of Horizon Europe."

ETH ZURICH: MRI FINGERPRINT OF THE TISSUE

In the course of the project, Sebastian Kozerke and his team at the Institute of Biomedical Engineering, which is run by ETH Zurich and the University of Zurich, will develop a new concept for magnetic resonance imaging (MRI), whose detailed resolution makes it possible to determine a fingerprint of the composition and microstructure of the tissue in the beating heart. In order to develop a reliable in vivo imaging instrument, considerable methodological progress is required in the simulation of MRI sequences, design and data reconstruction.

TU GRAZ: IN-DEPTH UNDERSTANDING OF THE BIOMECHANICS OF THE HEART

In order to correctly interpret this fingerprint of the tissue, a comprehensive understanding of the microstructure and mechanical properties of biological tissue is required. This is where Gerhard A. Holzapfel's research group at the Institute of Biomechanics at TU Graz comes into play. The team will investigate the relationship between gene expression, microstructure and mechanical properties of soft biological tissue in the laboratory. To do this, the team will map the composition of the tissue down to the nanometre range in order to draw conclusions about the mechanical properties of the heart. Various mechanical tests and microscopic examinations will be carried out ex vivo on pig hearts from abattoirs and human donor organs. The test loads are very similar to the conditions in the living body, which means that the mechanical properties of the heart can be determined extremely realistically.

HEREON: AI-BASED SOFTWARE FOR CLINICAL APPLICATIONS

At Helmholtz-Zentrum Hereon in Geesthacht, a team led by Christian Cyron from the Institute of Materials Systems Modeling will develop AI-based software that uses the data collected in Zurich and Graz to decipher the relationship between the microstructural fingerprints of the tissue and its mechanical tissue properties and make it accessible to medical professionals.
"Our three research groups complement each other perfectly with their respective expertise. With our innovative research approach in this project constellation, we will succeed, among other things, in developing an imaging procedure for the non-invasive examination of tissue microstructure," says Gerhard A. Holzapfel. "As a proof of concept, we will then demonstrate how our new method can support the diagnosis of diastolic heart failure as part of a clinical study at the University Hospital Zurich. Our research approach in this project constellation gives us a unique selling point worldwide". ■

Cluster of Excellence

With the Clusters of Excellence, the Austrian Science Fund FWF supports researchers of excellence who conduct cutting-edge research beyond the boundaries of their home institutions and research fields. TU Graz is involved in two clusters.

Birgit Baustädter

Five to eight scientists with high-calibre research achievements from at least three Austrian research institutions are involved in each of the clusters. The goal is to achieve great things together in their respective fields over the next five years. The Austrian Science Fund (FWF) is funding the clusters to the tune of 155 million euros, with the participating institutions contributing 104 million euros.

BILATERAL AI

Artificial intelligence is regarded as the most important and ground-breaking technology of the future. There are currently two important strands in AI research: sub-symbolic AI, which includes machine learning, and symbolic AI, which is concerned with knowledge presentation and reasoning. The Bilateral AI cluster aims to connect the two strands and thus create the basis for so-called broad AI – in other words, artificial intelligence that is able to draw conclusions and possess comprehensive cognitive abilities. Current AI models only analyse existing data. The new systems, on the other hand, should be able to plan, react more quickly to changes and ultimately even be creative themselves.
The Institute of Theoretical Computer Science at TU Graz is involved in the cluster and its research focuses primarily on sub-symbolic AI. In addition to TU Graz, Johannes Kepler University Linz (consortium leader), TU Vienna, the University of Klagenfurt, ISTA and Vienna University of Economics and Business are also part of the cluster.

CIRCULAR BIOENGINEERING

The aim of the Circular Bioengineering cluster is to create sustainable material cycles that separate economic growth from resource consumption. Work is being carried out here on platform chemicals and materials made from renewable raw materials as well as ways of using these chemicals efficiently and in a circular manner.

BOKU Vienna (consortium leader), TU Vienna, the University of Graz and the University of Vienna work together with TU Graz in this cluster. ■

Ultrafast Science

Birgitta Schultze-Bernhardt, Institute of Experimental Physics, has received the 'Women in Ultrafast Science Global Award'.

Halil Kaya Gedik Award

Sergio Amancio, Professor at the Institute of Materials Science, Joining and Forming Technology at TU Graz, has received the Halil Kaya Gedik Award from the International Institute of Welding in Category C: Education and Training of Young People.

Wolfram Innovator Award

Thomas Wallek, Institute of Chemical Process Engineering and Environmental Technology, has won the Wolfram Innovator Award for the use of tungsten in teaching.

Eurofusion Grant

Markus Markl, Institute of Theoretical and Computational Physics has won the Bernard Bigot Researcher Grant for fusion research.

20 Years of NAWI Graz

Cooperation instead of Competition – For twenty years, TU Graz and the University of Graz have been pooling expertise and resources in natural science research and teaching in the NAWI Graz network. A showcase project that is unique in Austria.

Ines Hopfer-Pfister

Joint studies formed the basis for success. Whereas 20 years ago each university offered separate degree programmes, 22 degree programmes are now run jointly. Around 5,300 students make use of this broad spectrum.

The joint doctoral programme within the NAWI Graz Advanced School of Science (GASS) enjoys a high status, with over 600 doctoral students currently being taught. Doctoral candidates are integrated in the inter-university doctoral schools and profit from supervision from the teaching staff of both universities.

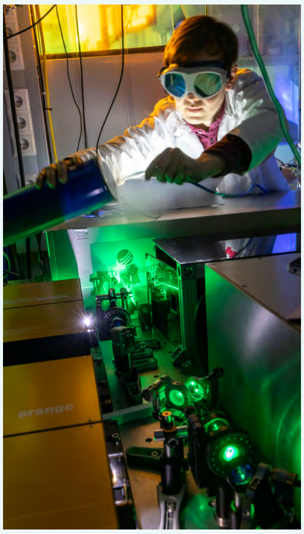
CONDUCTING RESEARCH TOGETHER

Joint teaching saves time that can be invested in research, and around 450 research projects are run in the NAWI Graz network. The 36 participating institutes raise 34.6 million euros in third-party funding, which corresponds to an increase of around 120 per cent since 2006. Joint NAWI Graz professorial appointments have also become common practice. Currently, 36 Section-98 professors have been appointed in joint procedures.

In addition, NAWI Graz also focuses on large inter-university collaborative projects such as special research programmes and doctoral programmes (DK). The doctoral programme Molecular Enzymology was one such successful joint project; it ran from 2005 to 2019 with a funding volume of 13.5 million euros.

The Austrian Science Fund doc.funds project Discrete Mathematics in Teams, which will train 12 doctoral students, will start in October. Each doctoral student is supervised by two researchers on an equal footing, with 19 supervisors from TU Graz and the University of Graz involved. “By bringing together pairs of supervisors, we can work on new areas of research that have not previously been available in Graz,” says Michael Kerber (Institute of Geometry). The research projects are cross-faculty, but also cross-university.

SHARED INFRASTRUCTURE



Research is currently being conducted in 28 “central labs” (central labs pool thematically related equipment in one place) and core facilities (individual large-scale appliances that several research groups need) in accordance with international standards; around 160 appliances have been purchased and utilised in partnership. One of the oldest shared central labs is the Central Lab for Water, Minerals and Rocks, which was launched in 2011. Dorothee Hippler from the Institute of Applied Geosciences heads this central lab: “A valuable place for scientific collaboration, development and exchange,” says the researcher. “Through this central lab, previous and current research projects can be supplemented by innovative and challenging, but also sophisticated analytical methods from the field of isotope geochemistry,” she emphasises.

A SHARED PATH INTO THE FUTURE

With the construction of the GRAZ CENTER OF PHYSICS (GCP), the cooperation project has now been taken to a new level. The ground-breaking ceremony for this inter-university centre, which will unite the physics institutes of TU Graz and the University of Graz from 2030, took place in June 2024. In addition to the GCP, which is currently being built on the University of Graz campus, four other institutes of TU Graz and the University of Graz will also cooperate even more closely with each other in the NAWI GRAZ GEOCENTER (planned for Campus Inffeldgasse). ■

Milena Stavric and her team

Fungi as Master Builder

Milena Stavric wants to completely rethink building materials. She conducts research into how mycelium can be used in the construction industry and replace environmentally harmful substances.

Birgit Baustädter

> *“Mycelium is said to be the largest organic plant of all,” says Milena Stavric enthusiastically.*

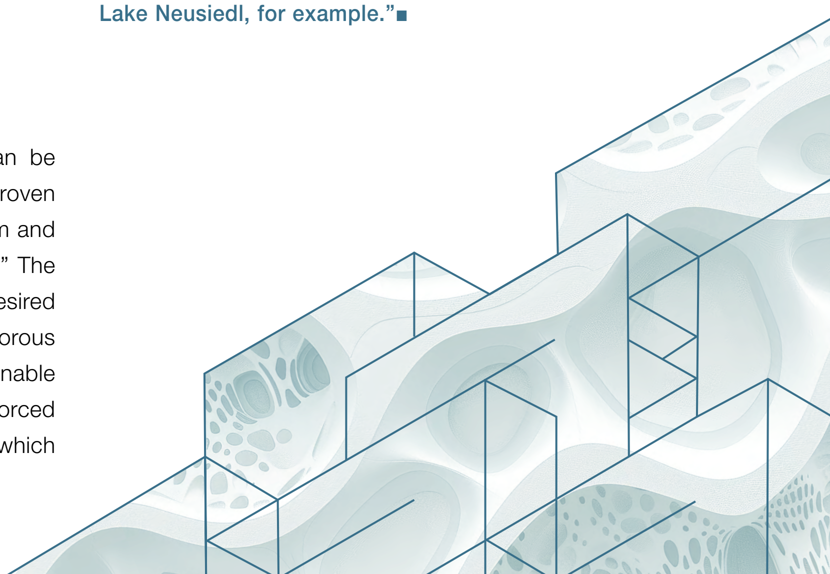
Mycelium is the fungal network that spreads in our soil and other organic substrates. It is the growing part of what we know on the surface as fungi. “A very good friend of mine is an expert in this field and her work has always fascinated me,” says Stavric. As an architect herself, Stavric is primarily concerned with sustainable building materials and wood, but was put off by the amount of environmentally harmful plastics that were still necessary. So she wanted to change something very fundamental. “I believe that it is not enough to improve a little here and optimise a little there,” she says with conviction.

> *“We have to completely rethink building materials.”*

The researcher has been investigating how mycelium can be used to strengthen clay. Clay – a well-known and well-proven building material – is 3D-printed and then a nutrient medium and the mycelium are added. “We call this process inoculating.” The mycelium can grow in the desired direction and in the desired thickness and thus either reinforce the structure or create porous structures. The goal is to achieve a completely new, sustainable construction method. “The wall can be made of clay reinforced with the mycelium. Then comes an insulating layer of clay, which is porous. The mycelium is introduced first and then the clay is fired – pores are created where the mycelium was before,” she explains. And the wall is sealed on the outside with a protective layer, for example of alginate – another natural material being researched at the institute.

NEXT STEP

Research is currently focusing on the fundamentals. The printed results are small but impressive. The biggest challenge on the road to implementation is scalability – how can the method be transferred from a clean laboratory to a dirty and sometimes unpredictable construction site? “We are currently starting a project funded by the Austrian Science Fund where we want to address this problem, and where we are also working with geoscientists to further investigate which clay mixtures are suitable for printing. We are thinking of working with clay from Lake Neusiedl, for example.”■



Lignum Test Centre

Various timber components can be tested for deformation and breakage at the Lignum Test Centre at Graz University of Technology. Not least the cross laminated timber developed there, which enables economical solutions in the field of multi-storey timber construction.

1 The samples for the comprehensive tests are cut to size in the in-house wood workshop. Numerous small devices make the production of a wide variety of designs and geometries

LIGNUM

LIGNUM TEST CENTRE

↙ Reel

Andres Ringhofer heads the Lignum Test Centre at the Institute of Timber Construction and Wood Technology. The centre is open for R&D collaborations and certification tests.

2 The testing machines lig- num_uni_275 (company zwick, load range from 0 to + or –275 kN), lignum_z_850 (company Zum Wald, load range 0 to 850 kN), lignum_dz_100 (load range –800 to +1100 kN), a torsion testing machine and a flexion-torsion unit can be used to carry out a wide range of bar tests, tensile tests and torsion tests.

3 The load limits of the timber components are determined in the Lignum Test Centre. Of course, they also break in the process.

CONTACT:

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Phone.: +43 316 873 4601
lignum@tugraz.at

↙ Website

TU Graz research: The Variety of Research Topics at TU Graz

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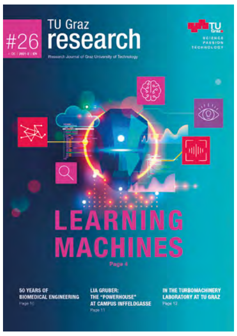
#31: BASIC RESEARCH

#30: RAILWAY SYSTEMS

#29: ENERGETIC

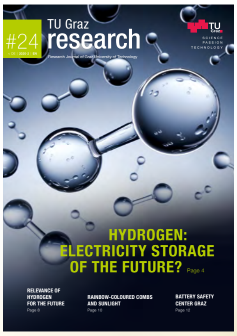
#28: SMART PRODUCTION

#27: SUSTAINABLE CONSTRUCTION

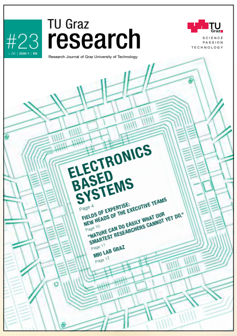


#26: LEARNING MACHINES

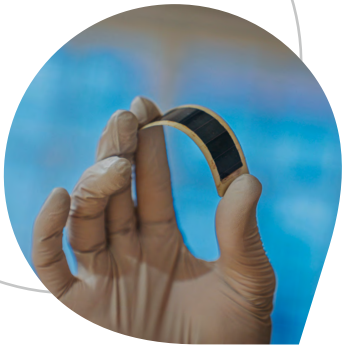
#25: BIOTECHNOLOGY

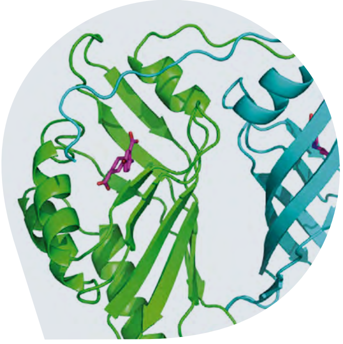


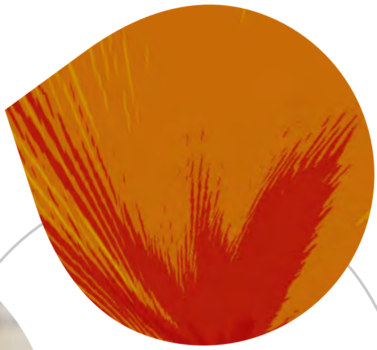
#24: HYDROGEN



#23: ELECTRONICS BASED SYSTEMS







Fields of Expertise

TU Graz's research activities are grouped into five strategic, forward-looking Fields of Expertise. Researchers engage in interdisciplinary cooperation and benefit from different approaches and methods, shared resources and international exchange.

Advanced Materials Science

Editorial: Karin Zojer, Gregor Trimmel & Sergio Amancio

Advancing a Sustainable Future with Research on Emerging Solar Cell Technologies

Thomas Rath

Human & Biotechnology

Editorial: Gabriele Berg and Christian Baumgartner

Controlling Protein Function by Small Molecules

Rolf Breinbauer

Information, Communication & Computing

Editorial: Kay Uwe Römer

Acoustics and Environmental Noise

Christian Adams

Mobility & Production

Editorial: Rudolf Pichler

Iron and Hydrogen – A Perfect Match

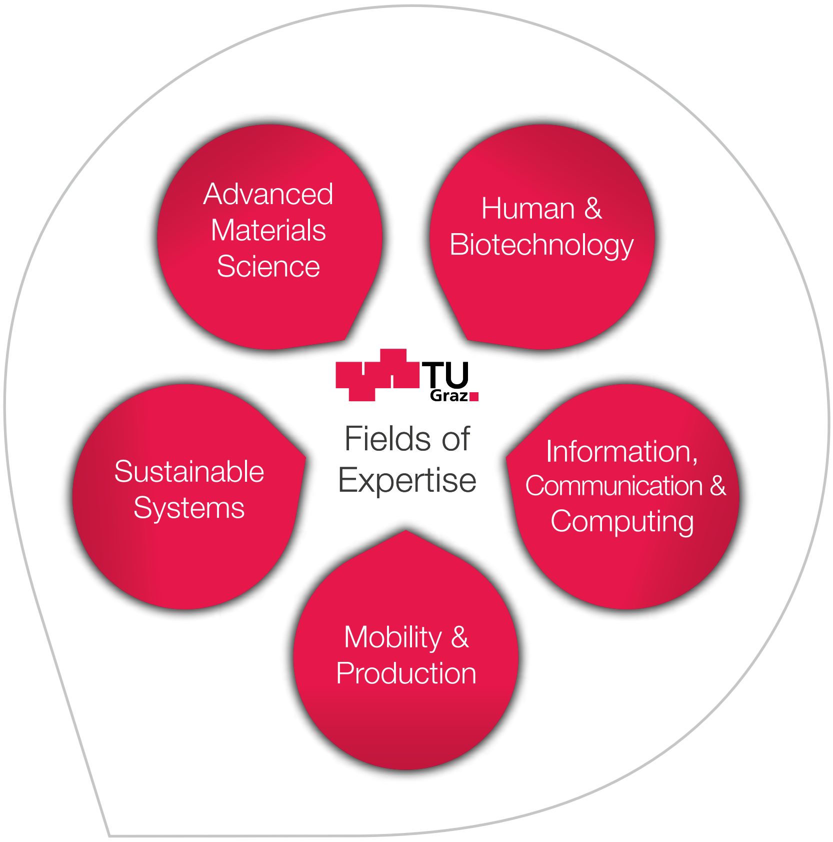
Susanne Lux and Viktor Hacker

Sustainable Systems

Editorial: Urs Leonhard Hirschberg

Towards a CO_2-Based Circular Economy

Regina Kratzer



TU Graz has divided its research into five innovative areas: the Fields of Expertise. Researchers in the Fields of Expertise break new ground in basic research. They take part in interdisciplinary cooperation, gain support for outstanding projects and are based in the region as well as part of international networks. They also develop key technologies for industry and commerce, and perform research in the framework of company shareholdings and partnerships.

Source: TU Graz

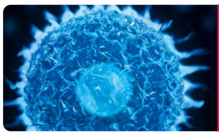
ADVANCED MATERIALS SCIENCE
Researchers aim to understand the smallest components in the structure and function of new materials, and develop and assemble them in special processes.

HUMAN & BIOTECHNOLOGY
Researchers develop devices and methods for medical applications and therapies, and focus on using enzymes and living microorganisms such as bacteria, fungi and yeast in technical applications.

INFORMATION, COMMUNICATION & COMPUTING
Researchers face challenges prompted by the information age, for example data security and efficient use of the ever-increasing volume of data.

MOBILITY & PRODUCTION
Researchers investigate novel vehicle technologies, new drive systems and more economical product manufacturing processes.

SUSTAINABLE SYSTEMS
Scientists focus on the complex challenges presented by a growing population and increasingly scarce natural resources.



ADVANCED MATERIALS SCIENCE

Fields of Expertise TU Graz

Source: istockphoto.com

This summer, extreme weather events demonstrated the tremendous power of the elements.

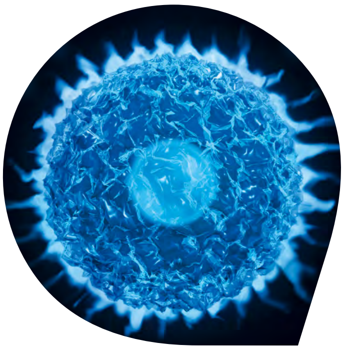
Our society faces enormous challenges minimizing and tackling the consequences of global warming and the changing economic landscape. Thus, new materials and concepts are needed for more efficient energy conversion and storage, for lightweight construction, for waste reduction, but also for analytical or biomedical applications. Materials must be designed to maximize their use, re-use and recyclability. More than ever, materials research is a central key to a better sustainable future. Members of the FoE Advanced Materials Science are actively working on these challenges.

In the 21st call of the initial seed funding of TU Graz, we could finance six innovative project proposals in the areas of physics, chemistry and materials science: Oliver Hofmann, Institute of Solid State Physics; Mohan Tamilselvan, Institute of Chemistry and Technology of Biobased Systems; Anna Galler, Institute of Theoretical and Computational Physics; Francesco Carraro, Institute of Physical and Theoretical Chemistry; Caterina Czibula, Institute of Bioproducts and Paper Technology; and Gean Henrique Marcatto de Oliveira, Institute of Materials Science, Joining and Forming. The project ideas range from density functional theory studies to develop new materials, research on biomedical materials, new innovative analytical tools, organic frameworks, and 3D printing of new composite materials.

We wish all recipients good luck for their proposal submissions, and we look forward to more submissions at the next call. Finally, save the date for **Advanced Materials Poster Day 2025** taking place on **4 February 2025** at Campus Neue Technik, lecture hall H – "Ulrich Santner". We are looking forward to discussing your research with your poster.

Karin Zojer, Gregor Trimmel and Sergio Amancio
Source: Lunghammer – TU Graz

Advanced Materials Science



Thomas Rath

Advancing a Sustainable Future with Research on Emerging Solar Cell Technologies

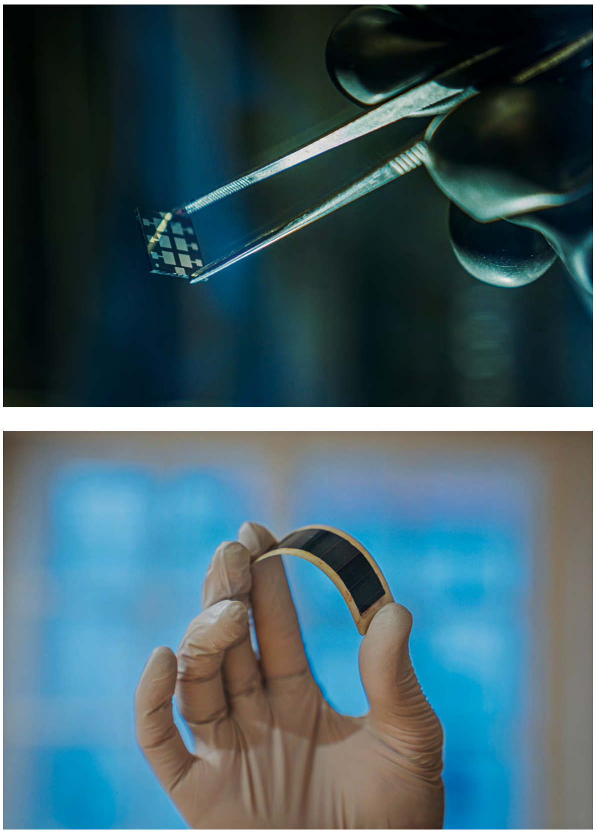
Photovoltaic solar energy conversion holds a central role in a clean and renewable energy supply of the future. While silicon solar cell modules are already well established, emerging solar cell technologies such as perovskite and organic solar cells can significantly broaden the possible applications of photovoltaics due to many advantages, ranging from flexibility, light weight, or semitransparency to a very low carbon footprint. >

Perovskite solar cells are known for their high efficiencies, achieving up to 26%. However, the use of toxic lead in these highly efficient solar cells raises environmental concerns, pushing the need for a more sustainable alternative.

Thomas Rath coordinates the SMARTLINE-PV project, funded by the European Union's Horizon Europe Research and Innovation program. In this project, a consortium of 13 project partners, including universities, research organizations, and companies, develops efficient lead-free perovskite photovoltaics through innovative precursor solutions and a fast plasma-assisted crystallization process (Figure 1). This solar cell technology is targeted for applications in Internet of Things (IoT) devices and building-integrated photovoltaics (BIPV).

Figure 1: Thomas Rath at the Institute for Chemistry and Technology of Materials working in a glovebox, where perovskite solar cells are fabricated and characterized.

Source: Moritz Wehr, Horizon Films



TRANSITIONING TO TIN HALIDE PEROVSKITES

Tin halide perovskite solar cells and modules (Figure 2) offer a promising alternative to their lead-based analogs, but challenges in efficiency, stability and large area fabrication make further research in this field necessary. In SMARTLINE-PV, novel precursor chemistry is used to obtain precise control of the tin perovskite crystallization. Innovative crystallization mediators reduce the tin perovskite crystallization speed, allowing the growth of crystals with less defects in the perovskite films. This is expected to have a positive effect on the efficiency and stability of tin perovskite solar cells.

Furthermore, this approach enables, in combination with a plasma-assisted crystallization technique, to perform the crystallization without the typically used anti-solvent dripping process. Solvent-free crystallization makes the process more sustainable and opens up the possibility of homogeneous large area processing of tin perovskite films.

Figure 2: A tin perovskite solar cell and a flexible perovskite solar cell module.

Source: Moritz Wehr, Horizon Films

To improve the properties of the tin perovskite films, the SMARTLINE-PV team plans to explore non-oxidizing solvents for the tin perovskite precursor solutions as well as the effects of van der Waals interactions. Research on tailored interlayers will also assist the improvement of efficiency and stability.

SELECTABLE COLORS, SUSTAINABILITY AND DEMONSTRATORS

The MorphoColor® technology, inspired by the wings of a butterfly, comprises a photonic structure combining a geometrically structured substrate with an interference layer and offers customizable colors, ideal for BIPV. SMARTLINE-PV aims to achieve power conversion efficiencies above 20%, and by reducing energy consumption and costs in their fabrication through fast low-temperature processes, the tin-based perovskite solar cells will be a competitive alternative to other thin-film technologies.

Moreover, sustainability is at the core of SMARTLINE-PV. Through eco-design and circularity, the entire lifecycle of the solar cells – from production to recycling or disposal – is designed to minimize environmental impact.

In SMARTLINE-PV, BIPV as well as IoT demonstrators are fabricated and tested under real-world conditions. Solar cells embedded directly into building materials, such as facades and roof tiles (Figure 3), combine energy conversion with aesthetics, which well aligns with Europe's green transition goals.

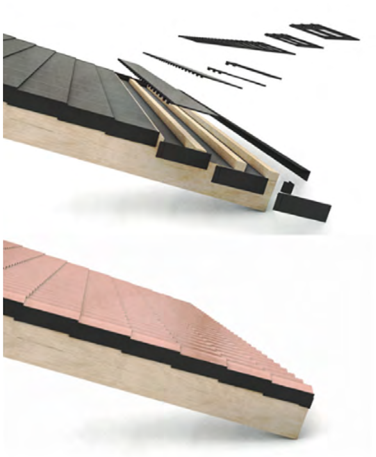


Figure 3: The envisaged application of solar roof tiles with selectable color.

Source: Viktor Karla, Silvester Filkorn, Filbau

A NEW ERA FOR PEROVSKITE SOLAR CELLS

By addressing efficiency, scalability, sustainability, and aesthetics, SMARTLINE-PV paves the way for a new generation of thin-film photovoltaics. These advancements will help Europe strengthen its role in renewable energy and contribute to global efforts to reduce the environmental impact of electricity generation.

Thomas Rath

is a senior scientist at the Institute for Chemistry and Technology of Materials (ICTM) at TU Graz and coordinator of the SMARTLINE-PV project. His research focuses on sustainable concepts for solar energy conversion, in particular materials for organic and lead-free perovskite solar cells. Recently, he received the Zero Emissions Award from the Austrian Science Fund (FWF) for his contributions to renewable energy research.

Source: Sabine Hoffmann, alpha+

Source: fotolia.com

HUMAN & BIOTECHNOLOGY

Fields of Expertise TU Graz

Source: Lunghammer – TU Graz

Gabriele Berg and Christian Baumgartner

Human & Biotechnology

The new semester has begun with a breath of fresh air, and major new research projects and initiatives in our FoE are picking up speed.

Biotechnological research is becoming increasingly digital and linked to the fields of data science and artificial intelligence. TU Graz is funding a new lead project called DigiBioTech, in which 17 scientists and ten doctoral students from the fields of biotechnology, biotechnological process engineering and computer science are working closely together to significantly improve the predictability and control of biochemical reactions and processes. The latter should not only enable production processes to be designed more sustainably, but should also be able to break down persistent environmental toxins such as perfluorinated and polyfluorinated alkyl compounds (PFAS).

The biotechnologists at TU Graz are also involved in the newly funded Austrian Science Fund Cluster of Excellence "Circular Bioengineering". Here, scientists from various universities and research institutions are working together on the efficient production of platform chemicals and materials from renewable raw materials. The circular integration of biotechnological processes makes it possible to switch from petroleum-based to bio-based materials.

The tenure track professorship in biomedical engineering was filled by the first-ranked candidate out of 99 submissions in this year's call for FoE tenure track positions. Debkalpa Goswami, assistant professor of medicine and biomedical engineering at the Cleveland Clinic Lerner College of Medicine at Case Western Reserve University, USA, will take up his teaching and research activities at the Institute of Health Care Engineering with Testing Center of Medical Devices in the field of soft robotics implants on 1 July 2025.

Change and continuity also ensure research. So we look forward to working together in our FoE and invite you once again to join us in shaping it.

We hope you enjoy reading our FoE's contribution in this issue of the research magazine.

Rolf Breinbauer

Controlling Protein Function by Small Molecules

A major goal in modern biology is to understand how a cell and its various components are functioning. Various genetic tools (e.g. RNA interference, CRISPR/Cas9) have been developed, which have revolutionized this research. However, these tools have their limitations since they only interfere with the flow of information in a cell. In contrast, the use of small molecules which modulate protein function are a more direct way of controlling cell function, which offers the additional advantage that it can be carried out it in a time- and concentration-dependent way.

According to the "central dogma of molecular biology" the genetic information of a human cell is encoded in the DNA of the nucleus. A small region (gene) of the long DNA molecule will be transcribed into mRNA (messenger RNA), which ultimately gets translated into a certain protein (Figure 1). Proteins are the essential components of the cell, which are responsible for transport, communication ("signal transduction"), catalytic function (enzymes), and mechanical structure.

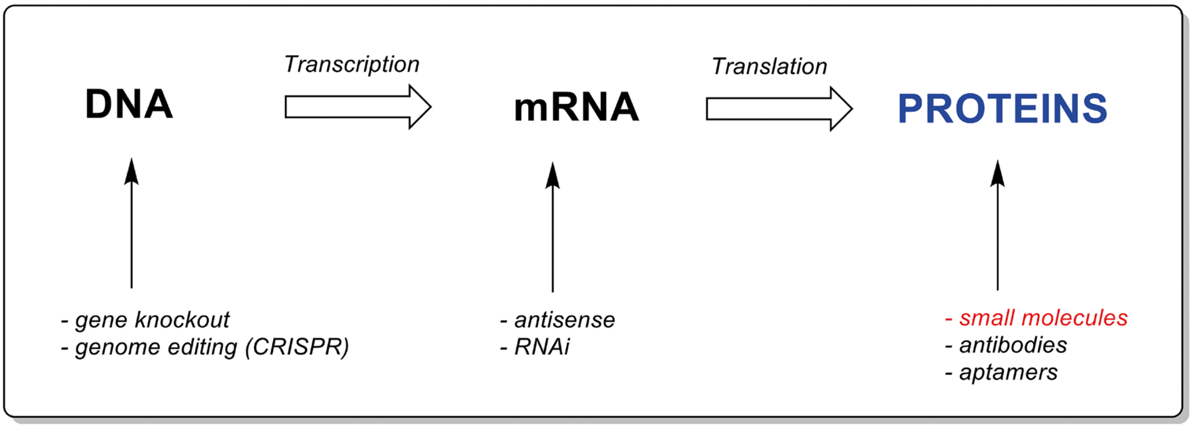


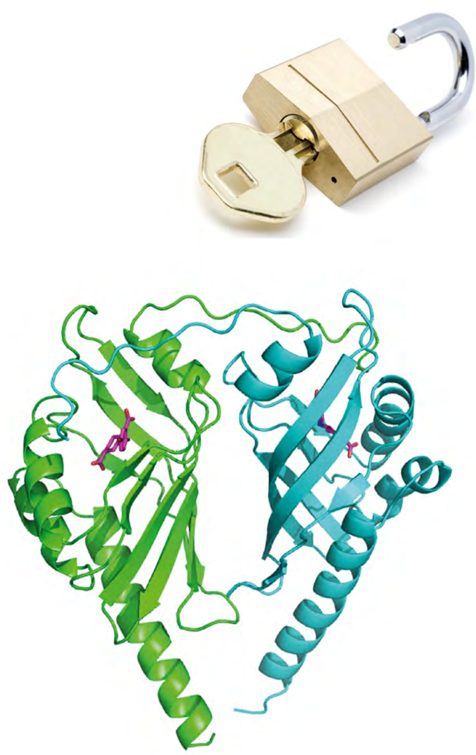
Figure 1: Organization of a cell and methods used to control the flow of information or the function of proteins in a cell.

SMALL MOLECULE INHIBITORS

In order to understand how the different components in a cell work, several tools have been developed which either delete a certain gene or prevent the production of the corresponding protein (Figure 1). Genetic methods such as gene knock out, CRISPR/Cas9 and RNA interference have proven to be powerful tools which are easy to design and show high specificity. However, they have certain limitations as they control only the flow of information in a cell (and not proteins directly), cause complete "on" or complete "off" events, or lead to problems regarding the delivery of the genetic tools into the cells.

>

Figure 2: A small molecule inhibitor (depicted in magenta) inhibits protein function by binding to the active site of a protein (depicted in green and blue) according to the lock-key principle.



In contrast, small organic molecules can function as a molecular key (inhibitor) which binds directly to the protein in question. Additional advantages of small molecules are that they can easily reach the interior of a cell and control protein function in a dose- and time-dependent manner, which allow new levels of precision over genetic methods. However, there is one fundamental challenge: How can you find a specific key – a small molecule which binds selectively to just one out of the tens of thousands different proteins of a human cell?

Over the past 17 years my organic chemistry laboratory at TU Graz has collaborated with biochemists, structural biologists and cell biologists to develop the first small molecule inhibitors for several enzymes (Figure 3).

CONTROLLING LIPID METABOLISM

In 2004 the groups of Rudi Zechner and Robert Zimmermann at the Institute of Molecular Biosciences of the University of Graz published a study in the journal *Science* that demonstrated that a protein called ATGL (Adipose Triglyceride Lipase) is the rate-determining enzyme in the degradation of triglycerides in adipocytes (fat cells) of human fat tissue. Genetic studies performed in their lab revealed that a mouse which does not express the ATGL protein shows interesting features: it does not develop

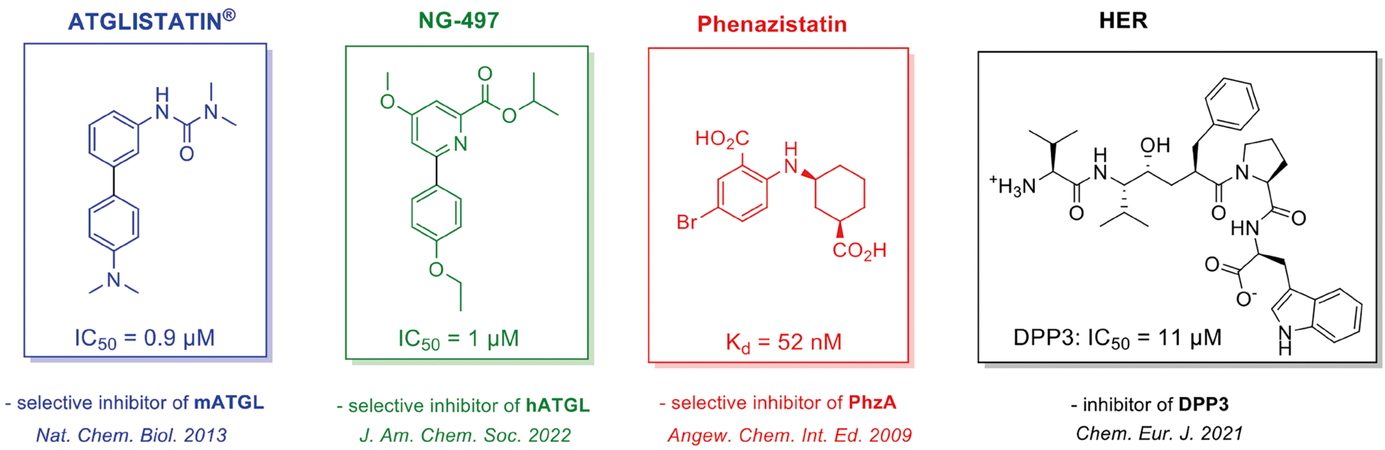


Figure 3: Small molecules inhibitors against adipose triglyceride lipase (ATGL), phenazine biosynthesis enzyme PhzA, dipeptidylpeptidase 3 (DPP3).

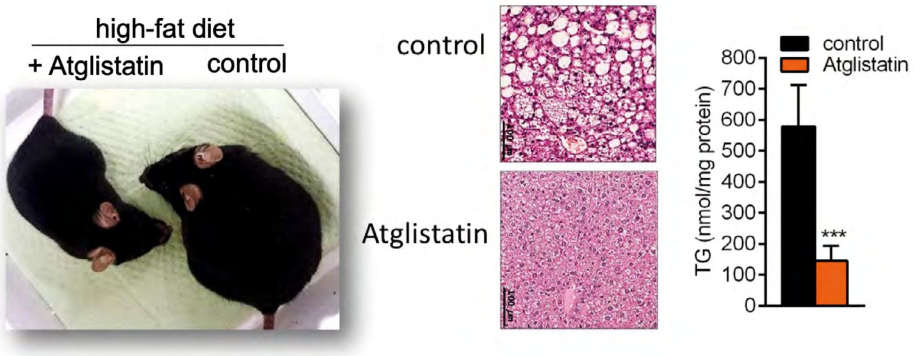


Figure 4: Atglistatin prevents metabolic-associated fatty liver disease (MAFLD) in mice as can be shown by the loss in body weight (left), the lack of white lipid droplets in liver tissue (middle) and the reduced content of triglycerides in liver tissue (right).

diabetes even on a high-fat diet, and it is resistant against tumor-induced cachexia. This motivated us to find a molecular key controlling ATGL function.

In a collaborative effort we have developed small molecule inhibitors of ATGL. It was necessary to synthesize and test almost 1,000 compounds before we could identify the first inhibitor of murine ATGL[1] with Atglistatin® and – more recently – the first inhibitor of human ATGL[2] with NG-497. Atglistatin has stimulated significant research activities worldwide, thus increasing our understanding of the physiological role of ATGL. The Zimmermann/Zechner lab could show that Atglistatin prevents metabolic-associated fatty liver disease (MAFLD) in mice (Figure 4). MAFLD affects ca. 25% of the Austrian population and in severe cases can lead to liver cirrhosis. With cardiologists in Edmonton (Canada) and at the Charité in Berlin (Germany) we could show that Atglistatin also prevents and cures heart failure in mice. These data have validated ATGL as an attractive drug target. We are currently investigating the preclinical development of ATGL inhibitors in collaboration with the wings4innovation-initiative. In addition, we are pursuing several other research programmes identifying small molecule inhibitors of various other proteins, especially transcription factors.

Rolf Breinbauer

has been head of the Institute of Organic Chemistry at TU Graz since 2007. His research interests encompass the development of tool compounds for chemical biology and the development of new methods for organic synthesis using biocatalysis, transition metal catalysis or electrochemistry.

Source: Christian Lembacher-Fadum – TU Graz

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Source: istockphoto.com

INFORMATION, COMMUNICATION & COMPUTING

Fields of Expertise TU Graz

Source: Lunghammer – TU Graz

Kay Uwe Römer,

Information, Communication & Computing

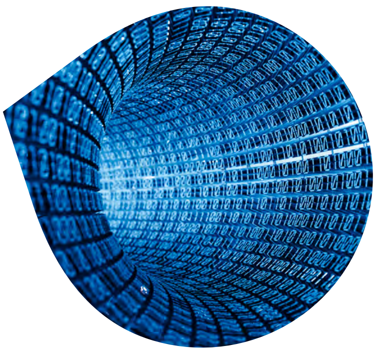
After a successful first round in 2020, this year the FoE ICC again had a tenure-track professorship to fill with a broad scope covering all areas of Information, Communication & Computing.

We received a staggering 179 applications from all over the world, including also many applications from former and current TU Graz members. The selection committee, composed of the deans, FoE leaders, and representatives of non-tenured staff of all three participating faculties as well as student representatives, had the challenging task of screening these applications and selecting the best 25 to be forwarded to three expert reviewers for a detailed assessment. Based on the reviews, the selection board invited nine candidates for interviews in early July. As part of the interviews, numerous meetings were arranged among the applicants and the institutes that would potentially host them. Impressed by the outstanding quality of these interviews, the selection board composed a short list of seven candidates, all of whom would have deserved to be offered a position. Unfortunately we had only one position to fill and were lucky enough that the top-ranking applicant accepted our offer of the tenure-track professorship. We will hear more from the winner of this competition as soon as he starts his work at TU Graz. With the application deadline set for the beginning of May and the shortlist being approved by the Rector in mid-July, the whole selection process was completed in a record time of just two and a half months. I am grateful to the selection board who were faced not just with a huge amount of work due to the large number of applicants, but also with the difficult task of comparing applicants from very different backgrounds – from mathematics and computer science to electrical engineering. A special thank you goes to Stephanie Mühlbacher from F&T House, who was instrumental in the organization of the whole process, paperwork, and communication.

In this edition of TU Graz research Christian Adams, professor at the Institute of Fundamentals and Theory in Electrical Engineering, gives us some insights into his research. Enjoy reading!

Christian Adams

Acoustics and Environmental Noise

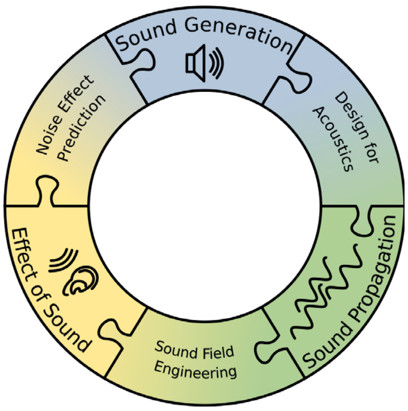


BMK endowed professorship on noise impact research: Competence Center for Traffic Noise and Health

Noise is a sound that an individual perceives as disturbing. In 2019, a third of Austrians stated that they were disturbed by noise at home and 48.5% said traffic was a significant source of noise. Across Europe, around 140 million people are exposed to harmful noise, with road (113 million), rail (22 million), and air traffic (4 million) being the primary sources of noise. Around one million people are affected by industrial noise. In addition, high noise pollution also threatens wildlife.

The Professorship for Acoustics and Environmental Noise is an endowed professorship and receives five years of funding from the Austrian Research Promotion Agency (Österreichische Forschungsförderungsgesellschaft mbH) and industry partners. Together with ÖBB-Infrastruktur AG, Linz AG Linien, Wiener Linien GmbH & Co KG, AVL List GmbH, ASFINAG, KTM F&E GmbH, and The Austrian Airports Association, we focus on transportation noise and its effects on humans. In the long term, we are opening up the application field of urban noise, and in particular noise in residential areas, with the goal of achieving a quiet city.

Figure 1: The Noise Effect Cycle – a holistic concept for noise impact research.
Source: Author's own illustration



THE NOISE EFFECT CYCLE

We aim to control noise as close to the source as possible. Ideally, unwanted noise should not be generated at all. We achieve this through Design for Acoustics of sound sources. Then, we need to understand how sound propagates into the environment to develop efficient noise protection measures through Sound Field Engineering. Finally, we want to understand better how noise affects people, including the health consequences of noise exposure. This knowledge will be fed back into the design of noise sources through Noise Effect Prediction. The result is a positive cycle that reduces the noise at the source, controls propagation and minimises harmful effects on humans – the noise effect cycle (Figure 1).

DESIGN FOR ACOUSTICS

Sound-absorbing materials can reduce noise from sound sources, but must be designed correctly during product development to be effective. These materials can be tested in an impedance tube. Figure 2 shows the setup and the absorption coefficient of acoustic foams, which is the ratio between the absorbed sound power and sound power at normal incidence. The red solid line (μ) and the black dashed line (μ±σ) represent the mean and one standard deviation from mean, respectively, while the grey lines illustrate the data set consisting of 980 individual measurements. Some data variation is intended and can be controlled through material type, density, or thickness. But a significant amount of variation is caused by the measurement procedure itself, such as the cutting technology and cutting precision of the specimens. We developed a machine learning framework that can distinguish between these variations and explain which frequencies have been decisive. Such knowledge is essential to selecting appropriate acoustic materials during product development so that our investigation can help to design acoustically optimised products more efficiently. >

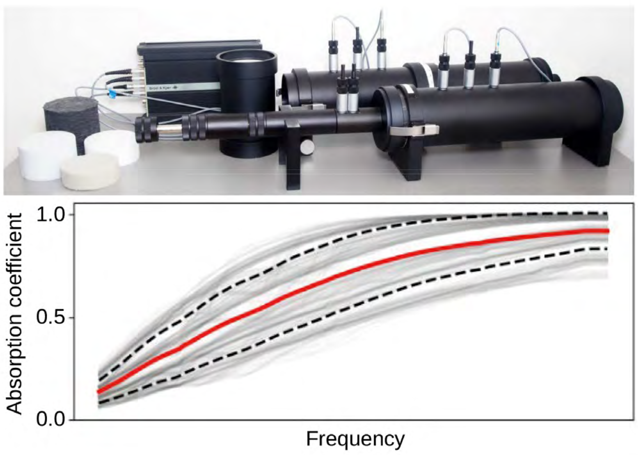


Figure 2: Impedance tube for sound absorption measurements (top).
Source: Gerald Maurer
Absorption coefficients versus frequency with several parameter variations (bottom).
Source: Alfonso Caiazzo

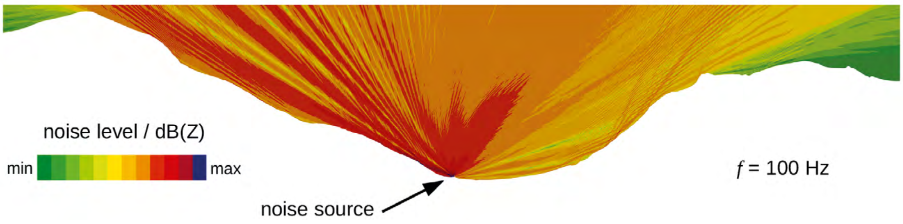


Figure 3: Sound level distribution at a frequency of 100 Hz in a valley near Wald am Schoberpass.

Source: Florian Kraxberger

SOUND FIELD ENGINEERING

Sound propagation into the environment must consider all physical effects to correctly predict noise, particularly at low frequencies (approximately 20 Hz–200 Hz). We research discontinuous Galerkin methods to efficiently and accurately predict noise immissions in large domains such as the environment. Our goal is to understand better how sound waves propagate into the environment and to predict the effects of noise reduction measures such as noise barriers or walls more accurately. Figure 3 is a cross-section through a valley near Wald am Schoberpass in Austria, where roads and rails cause traffic noise. It illustrates how noise levels are distributed at a frequency of 100 Hz if a noise barrier is set on the right-hand side of the sound sources. Noise is shielded in the right part of the valley, which highlights the effect of the noise barrier on noise immission even at 100 Hz, where noise barriers are usually less effective.

Christian Adams

is Professor of Acoustics and Environmental Noise at the Faculty of ETIT at TU Graz. He holds a newly established endowed professorship, which will be funded by the BMK and companies for the first five years. He is researching physical noise mechanisms at the source, simulation of the noise propagation into the environment and new approaches to noise impact and protection.

Source: Lunghammer – TU Graz

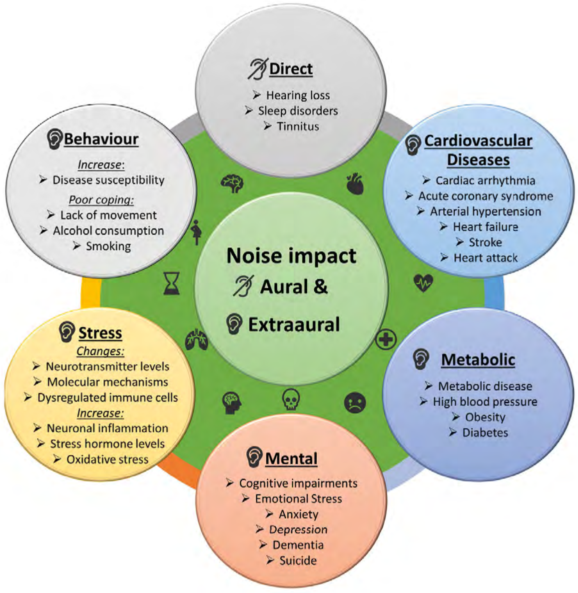


Figure 4: Summary of noise impacts on humans.

Source: Julia Donnerer

NOISE EFFECT PREDICTION

Noise protection measures are based on dose-effect relationships. They refer to the sound exposure and measure the effect on annoyance and health of those affected. Today, design and effects of noise sources are not connected. Knowledge about noise impacts is rather empirical, as the summary in Figure 4 illustrates. This is the starting point for our future noise impact research. We aim to connect the noise effects with the technical aspects of noise sources. Psychoacoustics provides us with the tools to translate empirical knowledge about noise effects for technical acoustics to improve noise source design.

MOBILITY & PRODUCTION

Fields of Expertise TU Graz

Source: istockphoto.com/fotolia.com

Source: Lunghammer – TU Graz

Rudolf Pichler

Mobility & Production

Industry and related business is currently suffering from a time of irritation, unclear perspectives and hesitation.

These days, we too often hear about workers being laid off, bankruptcies and other signs of an economy in fall. As a consequence of this, industry is presently disinclined to form alliances with and make contributions to universities. The major question now is: should science mimic the same dynamics of anxiety and paralysis as industry? The answer is a definite no! Times of recession are the best phases to make time for further education and for thinking about the future, because one thing is clear: when the order books of industry are full, nobody is willing to hear about future technologies. This means we have an opportunity to prepare our common future now! The future of industry is mainly in innovation and this depends on the input of universities. So we as a university undoubtedly do have the clout to encourage industry, to create feasible concepts and to assist industry in making good ideas for the future viable. We are happy to show an example of this in the current issue of our research magazine, namely how decarbonisation can work even in a highly traditional working environment. So please enjoy the report by Susanne Lux and stay deeply future oriented.

Susanne Lux, Viktor Hacker

Iron and Hydrogen – A Perfect Match

Iron and hydrogen, the first a typical heavy metal, the second a classical non-metal – two elements that could not be more different at first glance; and yet they form a perfect team giving access to a decarbonised future.

Iron – the first – has been the most important raw material since the iron age. The amount of pig iron produced is more than ten times greater than that of all other metals combined. In short, iron and steel are an integral part of our daily lives. However, their production is responsible for a major part of the industrial sector's CO_2 emissions. >

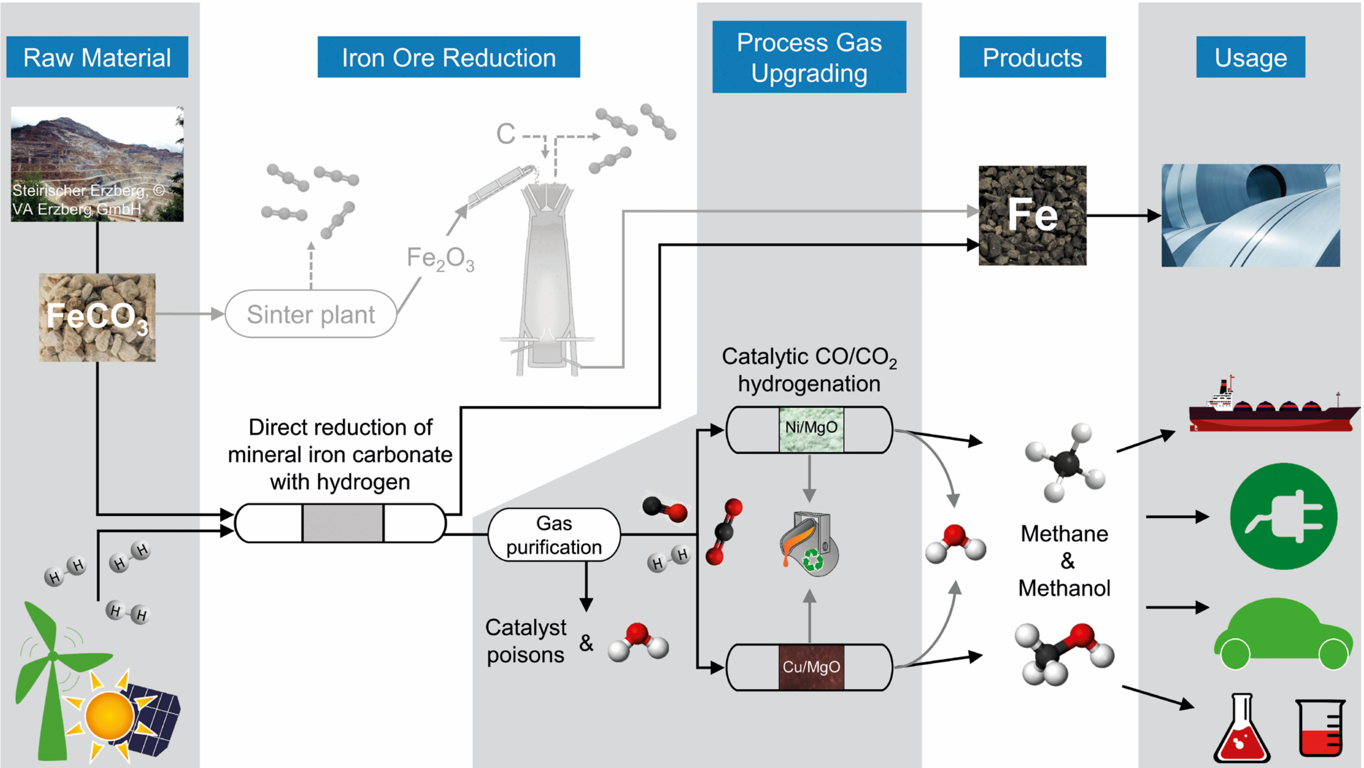


Figure 1: Process scheme of direct reduction of siderite ore with hydrogen combined with catalytic CO_2/CO hydrogenation for carbon neutral iron production.

Austrian mining and iron and steel production look back on a long tradition. Even though the Alps are considered to be "rich in poor deposits", for Austria, the mining and processing of iron ores and the subsequent production of steel have been an important cornerstone of economic and regional development over centuries. There is even a verse dedicated to mining in the Austrian national anthem ("Land der Hämmer, zukunftsreich!"). The most-used iron ores for pig iron production are iron oxides. In regions with large deposits of siderite ore such as Austria, this ore, which contains ferrous carbonate, is also used for pig iron production – although its iron content is lower and processing is more elaborate. Processing of siderite ore contributes to further CO_2 emissions due to the release of CO_2 from the carbonate. Thus, the search for measures to substantially reduce the high level of CO_2 emissions is a high priority task.

Hydrogen – the second – is the most common element in the cosmos. About two thirds of the total mass of the universe consists of hydrogen. In the earth's crust, every sixth atom is a hydrogen atom and, as is generally known, hydrogen can be produced from water. It is ideally suited as a chemical reducing agent and, as a versatile energy carrier, it is seen as playing a key role in the transformation process towards a decarbonised energy economy. However, hydrogen transport and storage are still the subject of debate.

Significant CO_2 emissions in iron production, especially from siderite ore, and complex and cost-intensive transport and storage of the promising energy carrier hydrogen; two pending questions, one of which could contribute to solving the other. Hydrogen may be the key to CO_2 emission-free iron production from siderite ore, where iron in turn shows potential to solve the storage and transport issue of hydrogen.

DIRECT REDUCTION OF SIDERITE ORE WITH HYDROGEN

Direct reduction of mineral metal carbonates with hydrogen, also termed “reductive calcination”, is a novel approach that was developed by the Chemical Reaction Engineering Research Group at the Institute of Chemical Engineering and Environmental Technology. It tackles the problem holistically and opens up a completely new pathway for metal carbonate processing in general and iron production in particular with the potential of becoming a CO_2 breakthrough technology. Direct hydrogen reduction of siderite ore does not need the conventional two-step route of roasting and reduction in the blast furnace, as elemental iron is directly formed from the iron carbonate in one process step; even at relatively moderate temperatures of 700–800°C. This results in a CO_2 emission reduction of more than 60%. Compared to siderite roasting (oxidation to hematite) followed by hematite reduction with hydrogen, 33% less reducing agent hydrogen is required for the direct reduction process. In addition, the process gas is upgraded by the formation of methane and carbon monoxide instead of simply releasing CO_2, thus further reducing overall CO_2 emissions [1].

Figure 2: Siderite ore from the Styrian Erzberg.

IRON AS A HYDROGEN CARRIER

Materials with high storage densities and efficient energy conversions are needed to transport hydrogen. The use of metals such as iron offers interesting prospects, as iron is readily available and can reversibly store and release hydrogen in a chemical cycle. >

Figure 3: Test stand for heterogeneous gas-phase reactions at the Institute of Chemical Engineering and Environmental Technology.

Source: Blendpunkt

In this novel approach, energy is stored by reducing iron oxide to metallic iron. This can even be done directly from natural ores, for instance siderite ore. Reoxidation of the iron-based oxygen carrier material with steam releases the stored chemical energy in the form of pure hydrogen and heat. A chemical looping hydrogen process with iron oxide as the contact mass, the so-called Reformer Steam Iron Cycle (RESC), was developed by the Hydrogen Research Group at the Institute of Chemical Engineering and Environmental Technology. A recent study revealed synergistic effects of mixed ionic electronic oxygen carriers in ceramic-structured environments with highest hydrogen storage capacity that effectively avoids sintering [2].

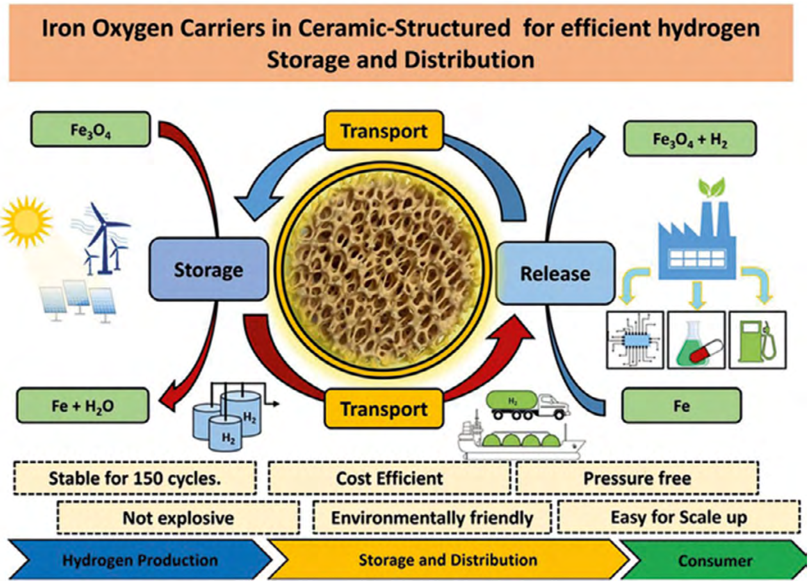


Figure 4: Iron oxide carriers in ceramic-structured environment for hydrogen storage and transportation.

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[1] Kleiber, S.; Böhm, A.; Lux, S. Effect of pressure on direct reduction of mineral iron carbonate with hydrogen. Chemical Engineering Journal 2024, 494, 152985, doi:10.1016/j.cej.2024.152985.

[2] Blaschke, F.; Hasso, R.; Hacker, V. Unlocking synergistic effects of mixed ionic electronic oxygen carriers in ceramic-structured environments for efficient green hydrogen storage. International Journal of Hydrogen Energy 2024, doi:10.1016/j.ijhydene.2024.08.508.

Viktor Hacker

is professor at and head of the Institute of Chemical Engineering and Environmental Technology and leads the Hydrogen Research Group with a focus on hydrogen production and hydrogen purification.

Source: Lunghammer – TU Graz

Susanne Lux

is associate professor at the Institute of Chemical Engineering and Environmental Technology and leads the Chemical Reaction Engineering Research Group. Her research focus lies in innovative process and apparatus design for multiphase reactions and reactive separations.

Source: Fotogenia – TU Graz

Source: ymgerman – fotolia.com

SUSTAINABLE SYSTEMS

Fields of Expertise TU Graz

Source: Lunghammer – TU Graz

Urs Leonhard Hirschberg

Sustainable Systems

In the 21st round of the initial funding program, a total of seven proposals were submitted in the Sustainable Systems category. The quality of the projects was high and we were able to fund six of them – more than ever before.

Daniel Gethman from the Institute of Architectural Theory, Art History and Cultural Studies is coordinating four institutes to apply for an FWF Special Research Area (SFB) grant, titled “Informed architectural acoustics in communication environments”. Their proposal argues that communication and acoustics of architectural spaces are of crucial importance, today, and that, instead of treating communication and acoustics separately as is typically done, there is an urgent need for a new interdisciplinary approach that combines them.

Katharina Hengel from the Institute of Architecture and Landscape proposed the project with the short title “Cool GreenTec” to investigate the performative potential of integrated plant systems in building structures. Nature-based solutions are key in addressing the climate crisis and alternatives to mechanical ventilation systems that use the natural properties of plants to control the air quality in buildings are feasible. The project proposes analysing existing examples and then developing a working prototype of a software tool for creating and monitoring such solutions.

Matthias Rebhan from the Institute of Soil Mechanics, Foundation Engineering and Computational Geotechnics heads a team of researchers to apply for an FFG project to study “Wheel and soil interaction parameters”. It turns out that current models used to compute the interaction between vehicle wheels and soil are rather rudimentary and not very good at dealing with dynamic phenomena. The project looks at ways how more complex computational approaches, already common in geo-engineering, could also be applied to vehicle technology.

Michael Kriechbaum from the Institute of Interactive Systems and Data Science proposes an FWF project with the short title HydroFair. He and his research team want to investigate how a sustainable and socially just global supply chain could be established for green hydrogen, which is increasingly seen as a corner stone of a transition towards a low-carbon economy. The challenge is not just technological, but lies in the complex interplay of multi-scalar governance and regional contexts.

Milica Tomic, Head of the Institute of Contemporary Art, proposes an FWF PEEK project that takes an interdisciplinary look at Brijuni, an archipelago off the Istrian coast. The famous islands have seen a multitude of governing powers in their history since Roman times and are a unique testament to the complex interplay between nature and human activity. The project “In stasis. Unravelling traces of potential worlds.” wants to set up an international collaboration to investigate this entangled history, with many research activities, leading to an exhibition about Brijuni’s history.

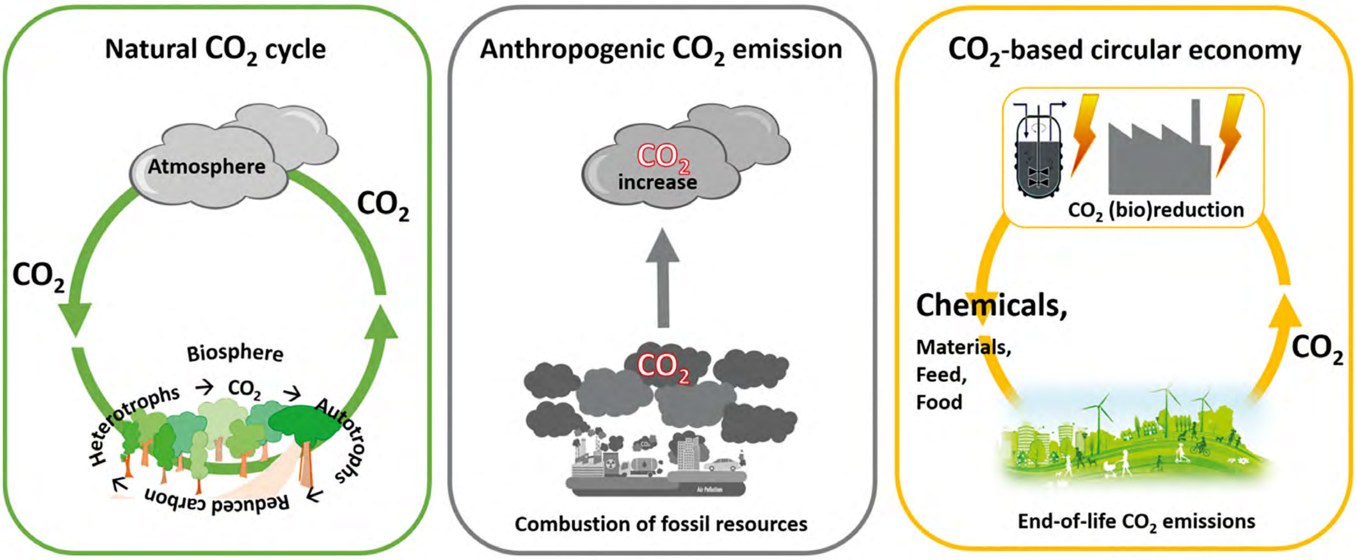
Oliver Pischler from the Institute of High Voltage Engineering and System Performance proposes an FFG project to pursue the “Development of a system for measuring space charges in HVDC cables”. Europe’s electricity infrastructure is transitioning to high-voltage direct current (HVDC) power lines, which can transport significantly more power over greater distances than high-voltage AC lines. While HVDC cables have already been used for years, there are still technical challenges. Space charges can limit the cables’ durability and lead to expensive repairs, which the proposed system could help prevent.

We wish all applicants the best of luck with their proposals and hope that the resulting projects can one day be presented on these pages, just like the project on page 34.

Regina Kratzer

Towards a CO_2-Based Circular Economy

Carbon dioxide is an essential component of the Earth's biosphere and as such is part of the biological carbon cycle.



The biological or fast carbon cycle describes the movement of carbon as it is recycled between the biosphere and the atmosphere. In the biosphere, CO_2 is assimilated into organic compounds by so-called autotrophs and thus forms the basis of life for all organisms that are not able to fix CO_2. These heterotrophs in turn use reduced organic compounds as building blocks and obtain energy from the oxidation of organic molecules to CO_2 (Figure 1). Human activities have resulted in a significant alteration to the natural carbon cycle. The burning of fossil carbon sources such as coal, oil and gas has caused CO_2 in the atmosphere to rise by 50% (Figure 1). One strategy for reducing CO_2 emissions into the atmosphere is to use it as carbon source for the production of chemicals, materials, animal feed and even food. By doing so, excess CO_2 is removed and a framework for a CO_2-based circular economy is formed. The prerequisites for this are (bio)chemical reduction methods of CO_2 and the availability of cheap energy sources (Figure 1). The most important chemical reduction processes are based on transition metal-catalyzed hydrogenations. However, sulphur and nitrogen compounds in CO_2-rich gases poison transition metal catalysts, limiting their lifetime. A promising approach to avoiding frequent catalyst changes is the use of self-replicating, CO_2-assimilating biocatalysts. The main classes of autotrophic microorganisms are photoautotrophs, which rely on light as an energy source, and lithoautotrophs, which derive the energy required for CO_2 assimilation from chemical reactions. Aerobic hydrogen-oxidizing bacteria (lithoautotrophic HOBs) are able to assimilate CO_2 using H_2 as electron donor with O_2 as final electron acceptor. The advantage of aerobic HOBs compared to photoautotrophs or anaerobic lithoautotrophs is that the strongly exothermic oxyhydrogen reaction provides significantly more energy for metabolic processes.

Figure 1. As a field of science that utilizes biological systems for technological applications, biotechnology seeks to use HOBs (and other autotrophic organisms) for CO_2 conversion into various products. The main obstacle to the full exploitation of HOBs is the explosiveness of the substrate gas mixture consisting of H_2, O_2 and CO_2. Although several research groups were already cultivating HOBs successfully in the second half of the last century, stricter safety regulations at the beginning of the third millennium led to a decline in this field of research. In recent years, biotechnological strategies for the assimilation of CO_2 have once again come to the fore. Under the coordination of Regina Kratzer (Institute for Biotechnology and Biochemical Engineering), several working groups at Graz University of Technology have joined forces to develop lab-scale bioreactors for the cultivation of HOBs. The centrepiece is a standard lab-scale bioreactor, which was converted for operation with explosive gases under the supervision of Markus Raiber and Vanja Subotic from the Institute of Thermal Engineering (Figure 2). The first results obtained with the bioreactor were successfully published (Bioengineering Best Paper Award) and our (then) doctoral student Vera Lambauer won the dissertation prize of the Forum for Technology and Society at TU Graz. These activities are also supported by the start-up Econutri, which operates one of the world's few ATEX-compliant bioreactors on pilot scale at TU Graz/acib. (We want to emphasize that all gas fermenters were ATEX-certified by external bodies.) Currently, the gas fermentation process is implemented in a Digital Twin to facilitate safe processing by fully automated process control. The data obtained will be utilized in the new lead project DigiBioTech in order to facilitate predictive scale-up to the cubic meter scale using machine learning enhanced computational fluid dynamics (Stefan Radl, Institute of Process and Particle Engineering). This will allow for a better assessment of the potential of HOBs in the landscape of biological and chemical possibilities for the reduction of CO_2. In this context, the author wants to summarize her personal opinion on CO_2-based economies: (1) no single CO_2 reduction method will prevail as the only valid one, (2) each of the chemical and biochemical CO_2 reduction processes mentioned is energy intensive and complex, (3) the use of CO_2 as a future carbon source is unquestion.

FUNDING

LEAD project TU Graz "DigiBioTech Digitalization of Biotechnology", 2025 to 2027. H2020-MSCA-ITN-2020 "ConCO$_2$rde Training network on the conversion of CO_2 by smart autotrophic biorefineries", 2021 to 2024. Lighthouse project "Synthetic biology for efficient gas feedstock conversion to new protein sources", within the FFG Comet K2 ACIB, 2020 to 2023.

Figure 2. The team from the Institutes of Biotechnology and Biochemical Engineering and Thermal Engineering. From left to right Vera Lambauer (Biote), Markus Müller (IWT), Regina Kratzer (Biote) and Markus Raiber (IWT), in front of the newly designed bioreactor for use in oxyhydrogen fermentations. The bioreactor with medium and cell culture is shown on the right.

Regina Kratzer

is a researcher at the Institute of Biotechnology and Biochemical Engineering.

Source: Lunghammer - TU Graz

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