Comparison between X-ray tube based and synchrotron radiation based µCT

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Keywords: X-ray tube CT system, synchrotron radiation-based CT, comparison, nanofocus X-ray tube, bone architecture, composite microstructure

Nowadays, X-ray tube-based high-resolution CT systems are widely used in scientific research and industrial applications. But the potential, convenience and economy of these lab systems is often underestimated. The present paper shows the comparison of sophisticated conventional µCT with synchrotron radiation-based µCT (SRµCT). The different aspects and characteristics of both approaches like spatial and density resolution, penetration depth, scanning time or sample size is described in detail. The tube-based µCT measurements were performed with a granite-based phoenix|x-ray nanotom®-CT system (GE Sensing & Inspection Technologies, Wunstorf, Germany) equipped with a 180 kV – 15 W high-power nanofocus tube with tungsten or molybdenum targets. The tube offers a wide range of applications from scanning low absorbing samples in nanofocus mode with voxel sizes below 500 nm and highly absorbing objects in the high power mode with focal spot and voxel sizes of a few microns. The SRµCT measurements were carried out with the absorption contrast set-up at the beamlines W 2 and BW 2 at HASYLAB/DESY, operated by the GKSS Research Center. The range of samples examined covers materials of very different absorption levels and related photon energies for the CT scans. Both quantitative and qualitative comparisons of CT scans using biomedical specimens with rather low X-ray absorption such as parts of the human spine as well as using composites from the field of materials science are shown.

In the present study aimed to show a comprehensive comparison of CT scans obtained with a commercial high end CT scanner with a nanofocus X-ray tube and a absorption contrast synchrotron radiation based CT setup. Three samples with different absorption characteristics (a porous Al_2O_3 catalyst, sintered Ti_6Al_7Nb and part of human vertebra, see Fig. 1) have been scanned in a voxel size range between 2.3 and 10 µm. The chosen specimens are good examples for typical applications of both systems. In order to allow a direct and easy comparison of the results, the scan data has been registered to each other by a best fit algorithm. The analysis of the scans reveals that the nanotom® gives excellent data quality which in many cases can even compete with SRµCT data. For the shown examples the spatial resolution and also the signal to noise ration of the two systems was absolutely comparable. As the resolution limit of the current SRµCT setup at HASYLAB/DESY is limited to 2µm, it was not possible to compare nanotom® data with subµm voxelsize to corresponding SRµCT data right now.

In total the major advantages of the laboratory scanner are its large field of view, large scanning volume, high penetration power due to the 180kV tube, scanning speed (scanned volume per time), ease of use and overall cost effectiveness. The synchrotron radiation CT on the other hand provides an excellent contrast resolution, precisely adjustable monochromatic radiation and therefore no beam hardening artifacts. In conclusion state of the art conventional high resolution CT scanners like the nanotom® by phoenix|x-ray can adequately

DOI: 10.3217/978-3-85125-062-6-100, © Verlag der TU Graz 2009

support and complement research projects where high quality CT data is required. Due to its flexibility the nanotom® can be used for both, extreme high resolution scans with subµm voxelsize of small samples on the one side or also fast scans of high absorbing (or larger) specimen using the high power mode on the other. Thus an ideal situation for such projects is to use both systems. For subµm scans or studies where a lot of samples have to be scanned the nanotom® will be used. Whereas for situations in which optimal contrast resolution or artifact free data is needed, the synchrotron radiation based CT would be the system of choice.

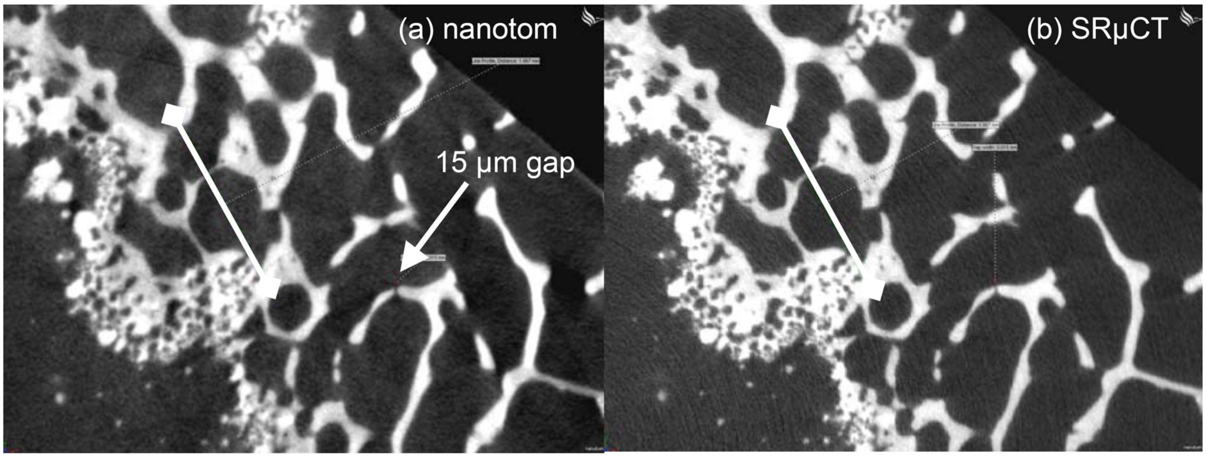

Figure 1. Part of a human vertebra. The size of the smallest detectable details in both datasets is roughly 10-12 µm. From the cross section images it can be seen that the SRµCT data shows slight rings which can not be found in the nanotom® scan. On the other hand the effect of the polychromatic source can be seen in Fig 1(a). The low absorbing soft tissue contains dark (apparently low absorbing) areas the high absorbing bony tissue. These so called streak artifacts can have two reasons: beam hardening and scattered radiation (Compton scattering). Scattering obviously can occur for both source types. However, for the X-ray energies used in this work the dominant reason for streak artifacts is beam hardening and the streaks are more obvious in the nanotom® scan. Nonetheless due to scattering they can also be found (much less pronounced) in the SRµCT data. Beam hardening effects can be reduced with algorithms implemented in the reconstruction software or by pre-hardening the source spectrum using metal sheets from e.g. Al, Cu, Sn or even Pb depending on the used X-ray energies.

G. Kothleitner, M. Leisch (Eds.): MC2009, Vol. 1: Instrumentation and Methodology,
DOI: 10.3217/978-3-85125-062-6-100, © Verlag der TU Graz 2009