# Thermal stability of γ-$Al_2O_3$ coatings

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Alumina coatings are widely used in high performance cutting applications, because of their high hardness, wear resistance, and high thermal and chemical stability [1]. In most cases, the thermodynamically stable α-alumina is desired, but recent theoretical and experimental research showed, that nanocrystallites of the metastable γ-$Al_2O_3$ exhibit a lower surface energy than α grains with the same specific surface area. This makes the nanocrystalline state of the γ-phase thermally even more stable than the one of the α-phase [2,3].

For our investigations of the thermal stability of γ-alumina, coatings were prepared using the Magnetron Sputter Ion Plating (MSIP) technique. They were deposited onto a WC-Co cutting insert and consisted of four different layers: a (Ti,Al)N bond coat, a ($Ti_{0.375}Al_{0.625}$)N interlayer, an (amorphous) transition layer and a γ-$Al_2O_3$ top layer (Fig. 1). Annealing experiments were carried out in vacuum and air at different temperatures and times in a furnace that allowed for temperatures up to 1200 °C.

From these samples, TEM lamellae were produced using the focused ion beam technique. TEM investigations were conducted on a FEI Tecnai F20 operated at 200 kV.

For the vacuum annealed samples, diffraction analysis revealed that even after heat treatment at 1200 °C for 4 hours the alumina layer stayed in the γ-phase (Fig. 2(a)). Analytical TEM images and EDX line scans, however, indicated slight Ti diffusion from the interlayer into the $Al_2O_3$ (Fig. 2(b)).

The samples annealed in air already showed changes in the layer structures at temperatures as low as 900 °C, because small pores formed in the amorphous transition zone. The $Al_2O_3$, however, still stayed in the γ-phase. With samples annealed at higher temperatures, the TEM investigations revealed much more severe modifications due to the formation and growth of α-grains and pores as well as Ti diffusion and its subsequent oxidation. However, even in several of the heavily transformed coatings, some parts of the $Al_2O_3$ layer still stayed in the γ-phase, showing the predicted high thermal stability of that phase.

In this contribution, we will present a model of the $\gamma \rightarrow \alpha$-$Al_2O_3$ transition in MSIP coatings with an amorphous transition zone that explains the experimental observations.

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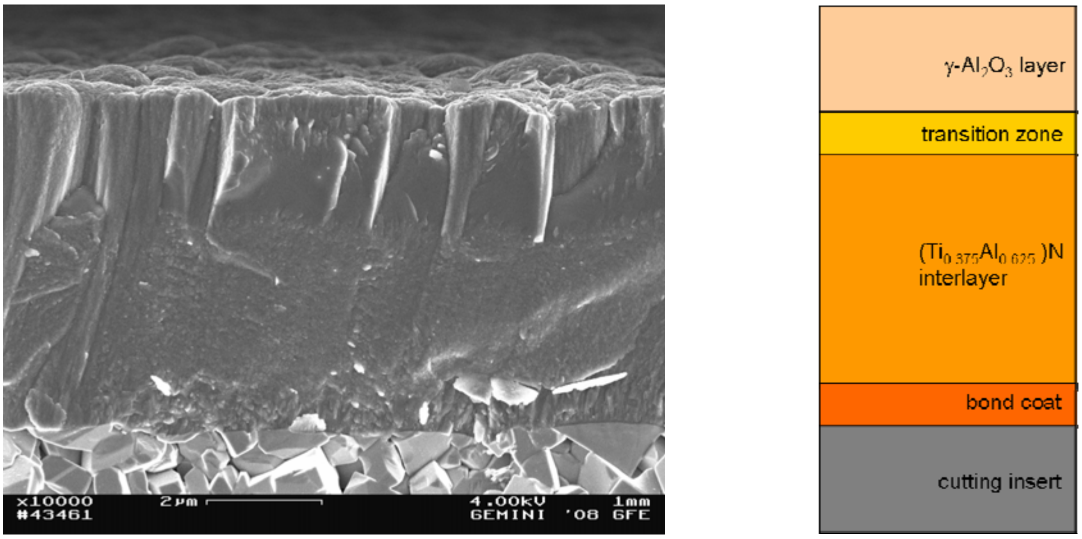
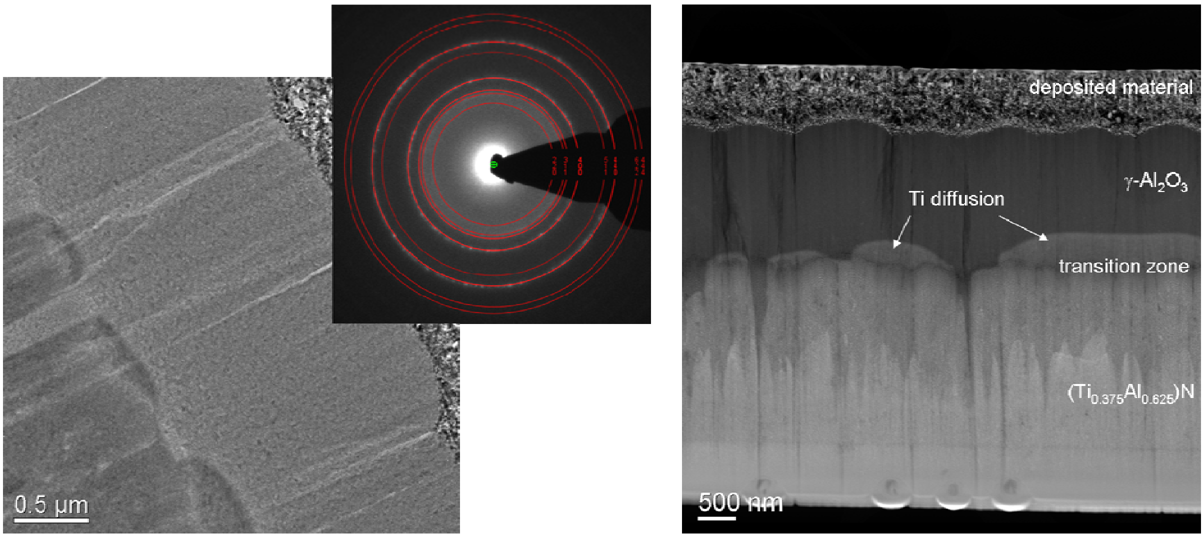


(a) (b)

**Figure 1.** (a) SEM image of a MSIP coating showing the described layer structure. (b) Sketch of the layer structure.



(a) (b)

**Figure 2.** MSIP coating annealed at 1200 °C for 4 h in vacuum. (a) TEM brightfield image of the alumina layer where the diffraction pattern was obtained. The simulation (red rings) shows that the phase is still γ-$Al_2O_3$. (b) STEM darkfield image of the same sample. Ti diffusion is clearly visible. The deposited material stems from remains in the furnace.