INDUSTRIAL PILOT PROJECT

Synchrotron nano-diffraction aiding development of advanced CVD coatings for increased cutting tool performance

THE INDUSTRIAL CHALLENGE

The application of a thin (~10 µm) coating on a cemented carbide tool for metal machining can lead to improvements in tool performance of more than 100 times. $Al_xTi_{1-x}N$ grown by chemical vapour deposition (CVD) is a new coating system within the metal cutting industry and at present only a few companies offer CVD $Al_xTi_{1-x}N$-coated products. The residual stress state in the coating is believed to be a key parameter for performance and tool life, why the ability to tailor the residual stress profiles could allow further enhancements. However, residual stress measurements with standard in-house methods have spatial limitations and cannot resolve gradients through the CVD coating thickness.

WHY USING A LARGE SCALE FACILITY

Through the technical developments associated with the third and fourth generation synchrotron sources it is today possible to perform X-ray diffraction experiments with a spatial resolution well below 100 nm, so called nano-diffraction. In this case the beam size is much smaller than the coating thickness, which allows measurement of stress profile.

HOW THE WORK WAS DONE

Sandvik Coromant and Chalmers jointly performed transmission X-ray nano-diffraction experiments at the NanoMAX beamline at MAX IV, which used an energy of 14 keV and a beam size of ~60 nm. Samples were machined from cutting tools, and carefully prepared through focused ion beam (FIB) milling to preserve the stress state in the coating (Fig. 1a-c). The coating thickness was around 5 µm and the probed width (in the beam direction) in the order of 60-100 µm. Diffraction patterns were collected by a downstream area detector (Fig. 1d-e), which allowed subsequent calculation of the residual stresses as a function of position using the traditional $\sin^2\Psi$ method.

THE RESULTS AND EXPECTED IMPACT

Even in challenging industrial materials, such as coarse-grained CVD AlTiN, synchrotron X-ray nano-diffraction enabled accurate and reliable measurements of residual stresses with sufficient spatial resolution (~100-300 nm) to capture the through-thickness gradient. It also provides simultaneous information of the phase composition, which is extremely important for multilayer coatings (Fig. 2). This provides a unique tool to further understand the relationships between process, structure, stress state, and performance in cutting applications. Several coatings with different processing conditions were investigated, and the results can be correlated with performance measurements to allow knowledge-based design of processes for optimal properties.

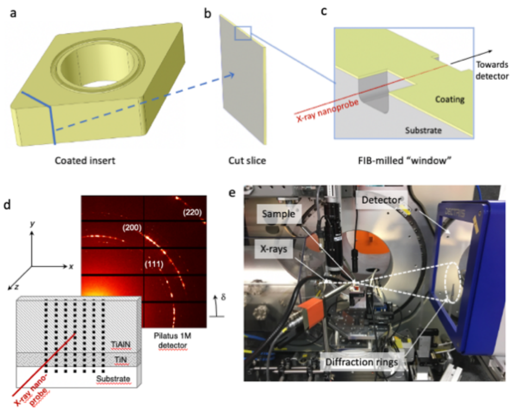

Figure 1. a-c: Sample preparation. d: Schematic of the set-up. e: Photograph of the experimental station at NanoMAX.

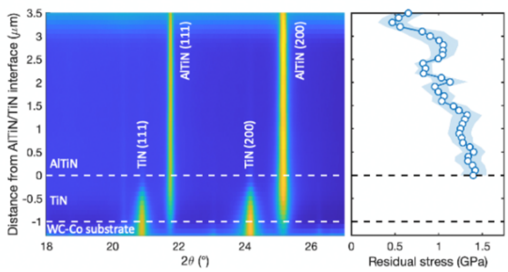

Figure 2. Example of phase composition and residual stress as a function of position in an AlTiN coating.

Read more at: *https://www.maxiv.lu.se/news/metal-industry-giant-conducts-experiments-at-max-iv/*

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