80 nm-resolved *in situ* X-ray nanodiffraction reveals multiaxial stress-strain transfer at the indenter-thin film interface

M. Meindlhumer[1*], M. Alfreider M. Burghammer[2], A. A. Medjahed[2], M.Zitek[3], R. Daniel[3], D. Steinmüller-Nethl[5], J. Todt[1] and J. Keckes[1]

[1]*Department of Materials Science, Montanuniversität Leoben, Franz Josef Straße 18, 8700 Leoben, Austria*

[2]*ESRF, The European Synchrotron, 71 Avenue des Martyrs, CS40220, 38043 Grenoble Cedex 9, France*

[3]*Chair of Functional Materials and Materials Systems, Department of Materials Science, Montanuniversität Leoben, Franz Josef Straße 18, 8700 Leoben, Austria*

[4]CarbonCompetence GmbH, Weisstraße 9, 6112 Wattens

**michael.meindlhumer@unileoben.ac.at*

Contact between materials occurs through microscale asperities, where stress evolves under highly localized, multiaxial deformation. Despite the significant importance to numerous scientific fields, to date, direct experimental quantification of these stress fields across the materials in contact remains elusive. In this contribution, we combine *in situ* scanning synchrotron X-ray nanodiffraction using a scanning resolution of 80×80 nm^2 with a custom-built indentation setup developed for the ID13 beamline at the ESRF to resolve the nanoscale stress fields developing at the contact between a diamond indenter and both single-layer ZrN and multilayered ZrN–ZrCu thin films (Fig. 1a). For this purpose, a single crystalline diamond wedge indenter tip was coated with a nanocrystalline diamond thin film using chemical vapor deposition. During the experiment, both films were loaded stepwise to a peak load of 2.0 N and 37500 2D diffractograms were recorded before loading, at each step and after the experiment. X-ray scattering and scanning electron microscopy, micromechanical testing, analytical and elastic-plastic finite element modeling corroborate the nanoscale stress maps obtained for both sides of the tip-surface contact region. The two samples exhibited markedly different elasto-plastic behavior during loading; depending on their stiffness resulting in substantially different indentation depths and imprint geometries. A maximum compressive stress of approximately −8 GPa was measured perpendicular to the contact direction (Fig. 1b). The individual interfaces in the ZrN-ZrCu along the projected load paths diffuse stresses in both the tip and the multilayer, thereby controlling the overall mechanical response at the asperity (Fig. 1b). Finally, this new kind of indentation experiment allows for the first time to directly assess the multi-axial stress distributions across the contact area for both tip and tested volume. The thereby gathered results give unprecedented insights into the deformation of both indenter and tested (thin film) material.

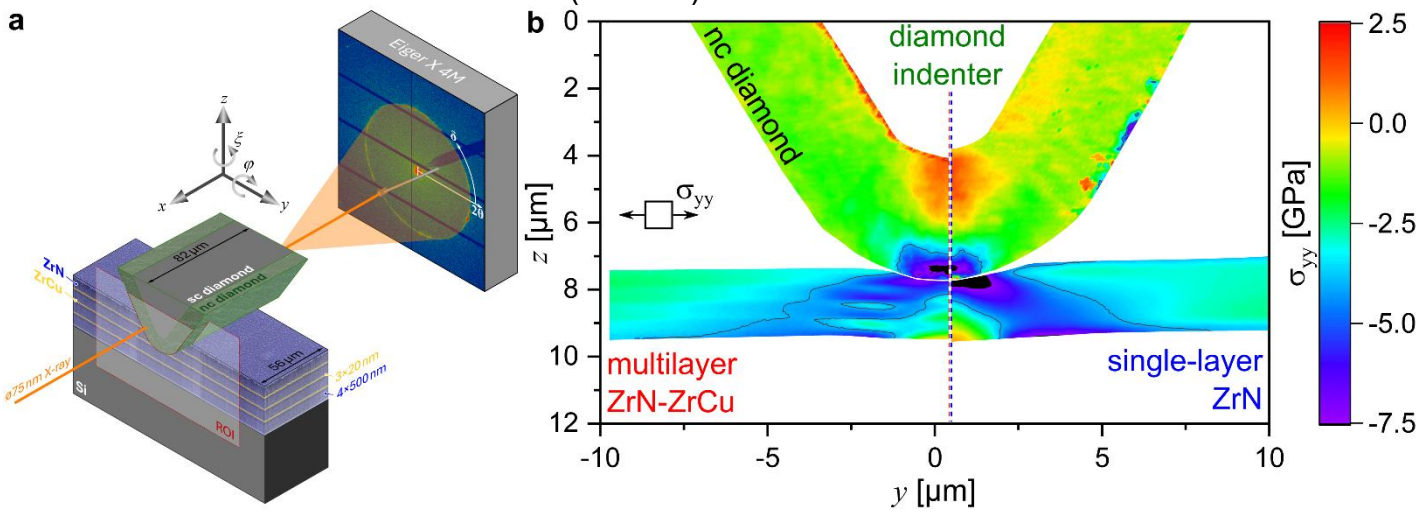


Figure 1. *In (a), a schematic of the in situ experiment is shown, while in (b) the horizontal (in-plane) stress component σ_{yy} of the diamond indenter tip in contact with multilayer ZrN-ZrCu and the single-layer ZrN is presented.*