X-ray nano-diffraction and indentation studies in Zr-based bulk metallic glasses

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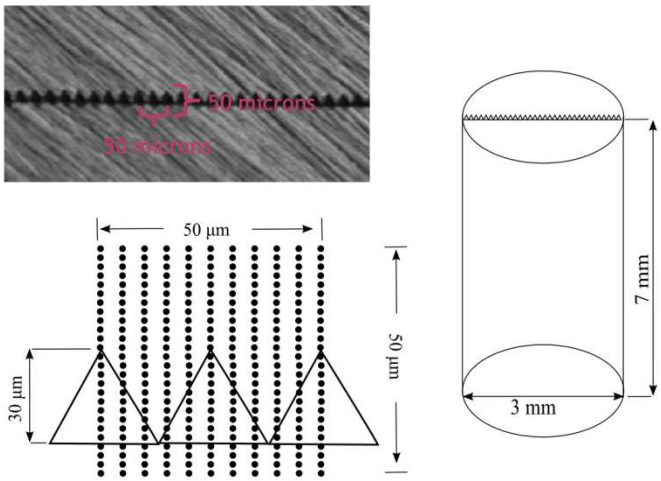
Zr-based bulk metallic glasses are novel materials in the field of engineering materials that exhibit extremely interesting mechanical (high strength, ductility and toughness) and chemical (corrosion and wear resistance, biocompatibility). They are currently used like tiny mechanical devices, golf clubs, hard tissue prosthesis and dental prosthesis. Unfortunately, their applications are restricted due to the brittle behaviour and size/shape limitations. While surface measurements such as EBSD or AFM can help us to understand surface, mechanical properties (like deformation) are volumetric issues and as such have to be confronted with the structural changes inside the material. For this reason, we connected two methods – indentation and X-ray diffraction. Indentation testing is a simple method that offers us from experimental readings (load versus displacement curve) the value of elastic modulus and hardness. Using X-ray diffraction we observe the structural changes induced by indentation [1]. The correlation of mechanical and structural properties helps to tackle composition-structure-property relationships and so to optimize mechanical properties of bulk metallic glasses for particular applications.

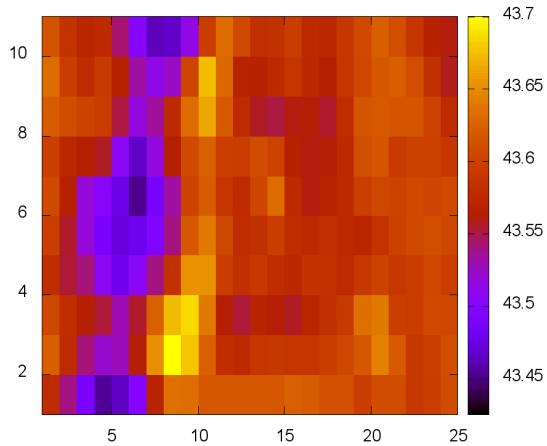
Information on structural changes of indented amorphous sample $Zr_{53}Cu_{18.7}Ni_{12}Al_{16.3}$ were obtained at the P06 beamline using nano-meter sized beam, 600 x 600 nm. We made spatial matrix scans of indents and their surroundings and we monitored the position changes of the first diffuse maximum. These changes are correlated with mechanical properties of samples and indicate strain fields introduced into the sample during indentation. Obtained results show us that investigation of structural properties of materials using X-ray diffraction is sensitive also on the morphology of sample and so is directly connected with its mechanical properties.

Indented sample $Zr_{53}Cu_{18.7}Ni_{12}Al_{16.3}$ bulk metallic glass. Indentation was done at Slovak Academy of Science.



Sample has a shape of cylinder. On the top of cylinder is line of indents. One indent has width of 30 micrometers. Matrix scan covers an area of 50 x 50 micrometers. Dashed lines depict supposed position of spatial matrix scan.

$Zr_{53}Cu_{18.7}Ni_{12}Al_{16.3}$ bulk metallic glass measured at energy 15 keV in reflection mode.



Spatially resolved scan of indent and its surrounding. The colour encodes the peak position of the first diffuse maximum.

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References:
[1] A. C. Fischer-Cripps, Nanoindentation, Springer (2011).