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Thermally activated processes in materials probed by nanoindentation - challenges, solutions, and insights

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THERMALLY ACTIVATED PROCESSES IN MATERIALS PROBED BY NANOINDENTATION - CHALLENGES, SOLUTIONS, & INSIGHTS

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Nanoindentation experiments are widely used for assessing the local mechanical properties of materials. In recent years some new exciting developments were established for also analyzing thermally activated processes during deformation using indentation based techniques, namely nanoindentation strain rate jump and nanoindentation long term creep tests. For these different methods, control of the indenter tip movement as well as determination of the correct contact conditions are hugely important to assure reliable data. In fact, long term nanoindentation tests are prone to be strongly influenced by thermal drift, starting at room temperature but even more intensified for elevated temperatures.

This talk will first focus on experimental issues and challenges, but also solutions during advanced nanoindentation testing to overcome thermal drift influences, as demonstrated for fused silica and ultra-fine grained (ufg) Au. Special focus will be on high temperature testing, different testing methodologies will be described, and it will be demonstrated how distinct indentation time and indentation depths related errors influence the basic results.

In the second part different results on single crystal (sx) and ufg Cr but also on the intermetallic phase $Mg_{17}Al_{12}$ are presented. For $Mg_{17}Al_{12}$, it was observed that the deformation behavior, especially in terms of thermally activated processes, is significantly changing over temperature. While at room temperature up to 125°C deformation is dominated by jerky flow and a slight negative strain-rate sensitivity due to dislocation pinning and the Portevin - Le Chatelier effect, overcoming 150°C the material behaves remarkably different. In this regime the indentation data show significant ductile deformation behavior with large pile-up formation and a pronounced strain rate sensitivity in the superplastic regime, where the deformation is sustained by dislocation glide and climb. Sx and ufg Cr also show significant changes in deformation behavior with temperature. At ambient conditions, both microstructures show an enhanced strain-rate sensitivity due to the large thermally activated component in the flow stress. Overcoming the materials specific temperature T_c (~150°C for Cr) the behavior changes. For sx Cr the apparent strain-rate sensitivity diminishes completely, while for the ufg state the strain-rate sensitivity increases due to the increased importance of dislocation – grain boundary interactions paired with a change in the dominating deformation mechanism.

References:

- [1] K. Durst, V. Maier: *Dynamic nanoindentation testing for studying thermally activated processes from single to nanocrystalline metals*; Current Opinion in Solid State and Materials Science (2015), doi: 10.1016/j.cossms.2015.02.001.
- [2] V. Maier, A. Hohenwarter, R. Pippan, D. Kiener: *Thermally Activated Deformation Processes in Body-Centered Cr – How Microstructure Influences Strain-Rate Sensitivity*; Scripta Materialia (2015) accepted.