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ACCESSING THE PHASE TRANSFORMATION AND DEFORMATION BEHAVIOR OF METASTABLE STAINLESS STEELS THROUGH CYCLIC NANOINDENTATION

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Austenitic metastable stainless steels are a materials group distinguished by their excellent mechanical properties, offering high potential for further improvement by thermo-mechanical treatments. Under deformation, these steels undergo a complex deformation and phase transformation. Their mechanical properties at macroscale, such as strength, ductility or fatigue behavior, have been largely investigated, yet they are not always predictable, as they highly depend on the microstructural characteristics of the material. In order to achieve a better understanding at the microstructural level, this work aims at the investigation of the deformation mechanisms in metastable stainless steels at sub-grain level and the interaction between grains. Therefore, monotonic and cyclic nanoindentation tests were performed in order to increase the cumulative deformation in a controlled way with the number of cycles. The emerging deformation mechanisms under the indents and on the surface, as well as the resulting morphology and mechanical and magnetic properties of the different phases, were characterized through different advanced microscopy techniques.

It was found that, even after a high number of nanoindentation cycles, a loading-unloading hysteresis is present, indicating a reversible plastic behavior (which is believed to be due to formation of unstable dislocations at maximum load). The apparent hardness of the material drops with increasing cycles due to the high plasticity of austenitic stainless steels. Gradual phase transformation was triggered and the load–displacement curves exhibited features, such as pop-ins and changes in the slope and hysteresis size, probably related to the propagation of the induced martensite to the neighboring grains and the resulting stress relaxation. This behavior was found to be highly dependent on the crystalline orientation of the respective indented austenite grains. Nucleation of martensite at shear band intersections was detected by TEM investigation of a horizontal lamella, as well as by MFM, while a FIB tomography revealed the shape and location of the nucleated martensitic zones.