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# High-temperature small-scale fracture mechanics and plasticity of a hardcoating system

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# HIGH-TEMPERATURE SMALL-SCALE FRACTURE MECHANICS AND PLASTICITY OF A HARD-COATING SYSTEM

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Forging and cutting tools for high-temperature applications are often protected using hard nanostructured ceramic coatings. While a moderate amount of knowledge exists for material properties at room temperatures, significantly less is known about the system constituents at the elevated temperatures generated during service. For rational engineering design of such systems, it is therefore important to have methodologies for testing these materials to understand their properties under such conditions. Additionally, small-scale mechanical testing is of inherent importance for thin-films systems and materials subject to surface modification or treatment as for plasma nitrided steels.

In this work, we present results on both the hard ceramic coating and the nitrided steel substrate using in situ micro-mechanical measurements at temperatures to 500 °C. The fracture and plastic yield behavior of FIB milled micro-pillars of plasma-nitrided tool steel was first investigated using in situ compression experiments. It was found that the yield strength of nitrided steel is particularly sensitive to temperatures within the service range. Elevated temperature led to significant softening of the nitrided steel and transition from slip-based to more ductile plastic flow. A 70% reduction in yield stress was observed when transitioning from room-temperature to 500 °C, which was then recovered upon cooling back to RT indicating a mechanistic activation at high temperature.

The fracture toughness behavior of a hard CrN coating was then investigated using various micro-geometries and notching parameters. Toughness measurements at high temperatures highlighted the profound effect of the notching ion during small-scale fracture measurements. It was found that gallium ion implantation led to significant toughening of CrN, based on gallium dosage experiments and alternative notching using both xenon and helium sources. The effect of different notching ions was additionally understood through Monte Carlo simulations of energetic ion interactions in a dense ceramic matrix.

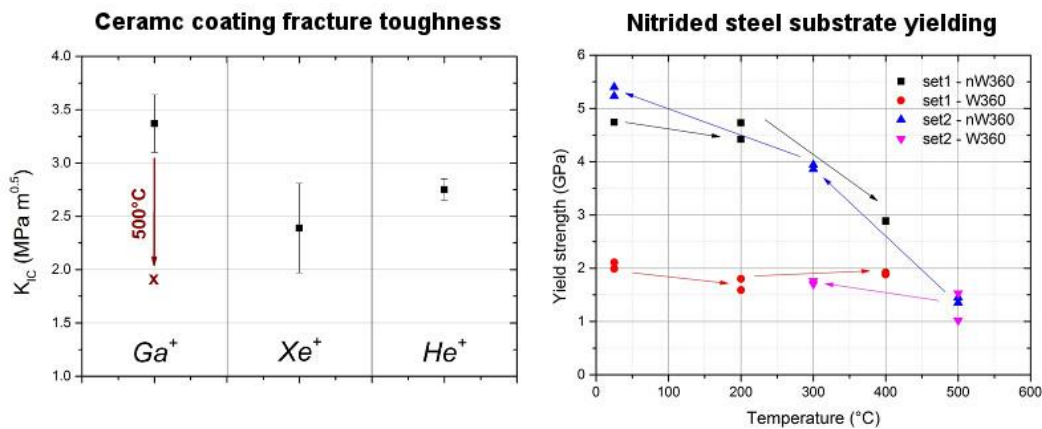


Figure 1 – Small-scale mechanical properties of constituent hard-coated system materials.