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HIGH-TEMPERATURE NANO-IMPACT TESTING 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 (i.e. high strain rate, temperature, or impact).

In this work, we present our first results using a newly developed Alemnis piezo actuated nanoindenter device which utilizes dynamic indentation testing at frequencies approaching 10 kHz. A sinusoidal displacement amplitude input is provided, while a stage heater allows for sample temperatures exceeding 500 °C. Thermal drift can be minimized through high frequency, and therefore low contact time, impacts. We investigated a thin (4.65 µm) physical vapor deposited chromium nitride (CrN) ceramic coating, which had been deposited onto plasma nitrided tool steel.

Forces of approximately 400 mN were applied sinusoidally at 500 Hz using a 5 µm diameter diamond flat-punch at room temperature, 200°C, 300°C, 400°C and 500°C. It was found that increasing the number of impacts led to plastic deformation and fatiguing of the hard ceramic coating. At 300°C a transition to increased material flow and consequently larger crater size, and crack initiation and propagation in the ceramic, was observed. These ceramic deformation results are understood using high-resolution scanning electron microscopy (HR-SEM), elastic simulations, and large scale batch processing of force-deformation data which are generated during high-frequency measurement and collected at a sampling rate of 50 kHz. The results are further put into context by understanding recently measured small-scale high-temperature fracture toughness and yield strength properties of thin CrN films.

The presented results are the first for in situ high-temperature nano-impact testing, and will be useful for hard coatings industries involving high service temperatures and high impact strain rates, such as for forging processes.

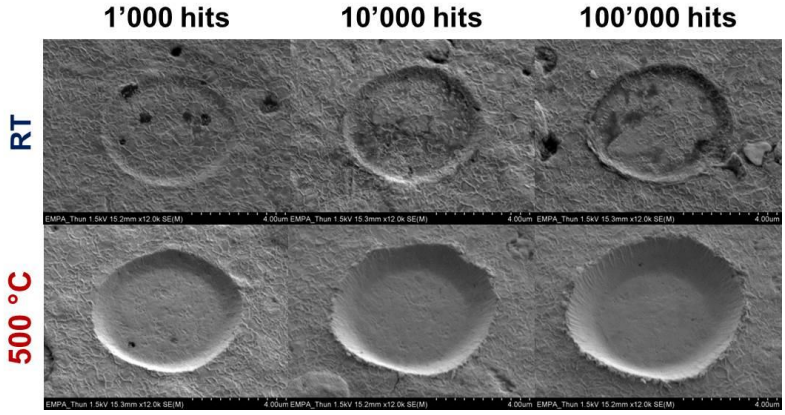

Figure 1 – HR-SEM residual imprints from high-temperature nano-impact tests using a diamond flat punch onto CrN coated nitrided tooling steel.