TOWARDS NANOINDENTATION AT APPLICATION-RELEVANT TEMPERATURES - A STUDY ON CMSX-4 ALLOY AND AMDRY-386 BOND COAT

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With nickel-based superalloys reaching their fundamental limit in high-temperature applications, new alloys are required with improved mechanical properties. Small-scale mechanical testing – particularly nanoindentation – is of great benefit to alloy development, allowing hardness and modulus to be measured on small volumes of newly-developed materials.

We show that it is now possible to carry out such tests in vacuum up to 1000˚C, paving the way for candidate alloys and coatings to be tested at operation-relevant conditions. In this work, a <001> oriented single-crystal CMSX4 sample and a 200 µm Amdry-386 bond coat were tested using a modified MicroMaterials NanoTest indenter. 1 µm indents were placed at 50 µm spacings from the bulk into the coating, allowing local mechanical properties to be determined.

The data show a room-temperature hardness of CMSX4 of 4 GPa and modulus of 110 GPa, close to that found in the literature. The Amdry-386 at this temperature has a hardness and modulus of 4 GPa and 95 GPa, respectively. The CMSX4 shows a hardness peak at 400˚C and 5.5 GPa, after which the hardness rapidly decreases to around 2 GPa at the highest temperatures. The bond coat matches this behaviour closely.

At both room and elevated temperatures, almost 100% of the indents show a thermal drift of <0.3 nm/s, corresponding to a depth uncertainty of <5%. This unparalleled drift performance allows future investigations of creep behaviour that were not possible until now.