Developing Titainum Alloys with Higher Strength and Improved Ductility

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Titanium alloys are high strength, lightweight materials that are becoming increasingly important in the aerospace sector where they are a much better match for the composite fuselage than aluminium alloys. Light weighting can be achieved by increasing the strength of alloys but, in titanium, increased strength often comes with decreased ductility. This LATEST2 project, a collaboration with TIMET, aims to understand the fundamental strengthening mechanisms in titanium alloys and to help develop new compositions that have higher strengths without sacrificing ductility.

Conventionally studies of deformation mechanisms have relied on ex-situ observations of the microstructure and texture via optical or electron microscopy and x-ray diffraction. However, these only show the effects of deformation, leaving much of the active mechanisms to be divined. In-situ studies using digital image correlation (DIC) are more appropriate to track slip activity during deformation. To achieve a spatial sub-grain resolution, gold features in the nanometer scale (Figure 1, top left) are applied on the sample surface. The advantage of having small gold particles on the surface of the material is the fact that they enable, for the first time, strain mapping with sub-micron spatial resolution. The downside of the technique is the tremendous effort to record images using electron microscopes. Patterns obtained using spray paint or etching marks on grain boundaries can be imaged on optical microscopes and are therefore much easier to use, but do not give sub-grain resolution and many of the questions posed by alloy development require sub-grain resolution answers.

Figure 1 shows schematically how the high resolution strain mapping approach works. The top left image is an electron backscattered image of gold droplets on a polished titanium specimen. The strain map shows 0% strain for the macroscopically unloaded state. The microstructure map from electron backscattered diffraction measurements (EBSD) of this alpha titanium alloy shows equiaxed grains. The colours correspond to the crystal orientation, with blue and green tones representing crystals with the prismatic planes orientated towards the loading direction. Images of the gold droplets were acquired step-wise during compression. In accordance with the deformation of the underlying metal grain, the droplets will move on the imaged surface. The DIC software DaVis converts these relative movements into displacement vectors which can be differentiated to give strain. Areas without strain stay dark blue, while areas of high strain appear in bright blue, up to yellow-red for higher strains. As the strain increases slip lines 1-10μm apart become apparent. Finally, at 8.7% strain, a big area of strain localisation is present, which was identified as a deformation twin from the EBSD map after the test. The ex-situ EBSD microstructure maps represent the microstructural evolution from a bigger area: they are not appropriate to represent the slip activity but show therefore the deformation induced twin lamellas. The twins appear red as the basal plane points towards the loading.

It is thought that the interaction between slip localization and deformation twinning is key to obtaining strong alloys with good ductility and with high resolution strain mapping we can study the mechanism as it happens and understand how it is affected by alloy compositions.

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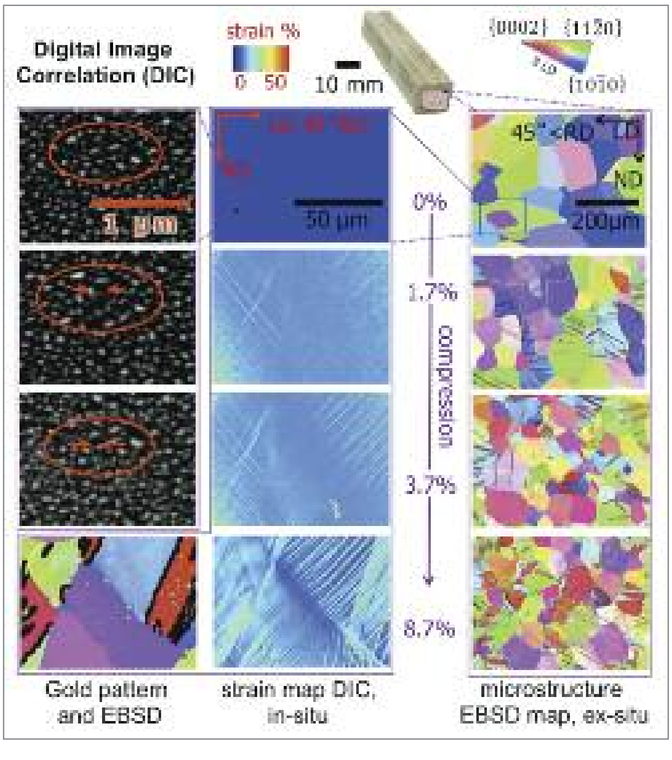

Fig. 1 Starting with a nano-scaled gold pattern (left), used for digital image correlation to evaluate strain localisation (middle) with increasing compressive deformation, which relates to microstructure (right)) development during uniaxial compression.