Effect of surface treatment on the microstructure and mechanical properties of a high entropy alloy

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High entropy alloys (HEAs) with at least 4 principle elemental components demonstrate superior mechanical properties partly due to their high mixing entropy. However, these alloys usually present low yield strength at room temperature, which limits their applications. Significant efforts have been made to increase the yield strength of HEAs via manipulating their microstructures. In this research, we applied the rotationally accelerated shoot peening (RASP) surface treatment technique to introduce gradient structures (GSs) to an FeCrCoNiMn HEA. It was found that the yield strength of the alloy was apparently improved without sacrificing much of its ductility. We investigated the microstructure and deformation mechanisms using various microscopic characterisation techniques and built the relationships among the microstructure, deformation mechanisms and mechanical properties.

The coarse-grained (CG) FeCrCoNiMn HEA was prepared by arc-melting and drop-casting followed by cold rolling and subsequent heat-treatment which gave the grain sizes of 5~15 m. GS was then developed on CG sample using the RASP technique with various processing parameters. Vicker hardness testing and tensile testing were conducted to check the gradient thickness and mechanical properties. Samples for electron back scattered diffraction (EBSD) mapping in the scanning electron microscope were polished by silicon carbide papers and 60 nm suspended silica. Samples for transmission Kikuchi diffraction (TKD) mapping and transmission electron microscopy (TEM) investigation were prepared by twin-jet electropolishing, FIB milling and Ion milling. The structural characterisation revealed microstructural evolution and deformation mechanisms from the surface to the centre of the HEA samples.

GS impacts significantly on the mechanical properties, as demonstrated in Fig. 1(a), in which the yield strength was almost double and the ductility was reduced. Fig. 1(b) shows the hardness of CG sample and the hardness distribution of a sample with GS, indicating that the centre of RASP-processed samples was also deformed. Fig. 2(a) presents an EBSD map from the surface to a depth of 250 m, revealing the gradient distribution of microstructures. Fig. 2(b) and Fig. 2(c) present a TKD map at the top layer and a TEM image at a depth of ~ 20 m, respectively, indicating clearly the different structural features at different locations of the GS sample. The relationships among the GS, deformation behaviours at different parts of the GS, and the improved yield strength will be discussed and a proposal on how to further improve the mechanical properties (e.g., improving strengths without sacrificing the ductility) using different processing parameter will be given.

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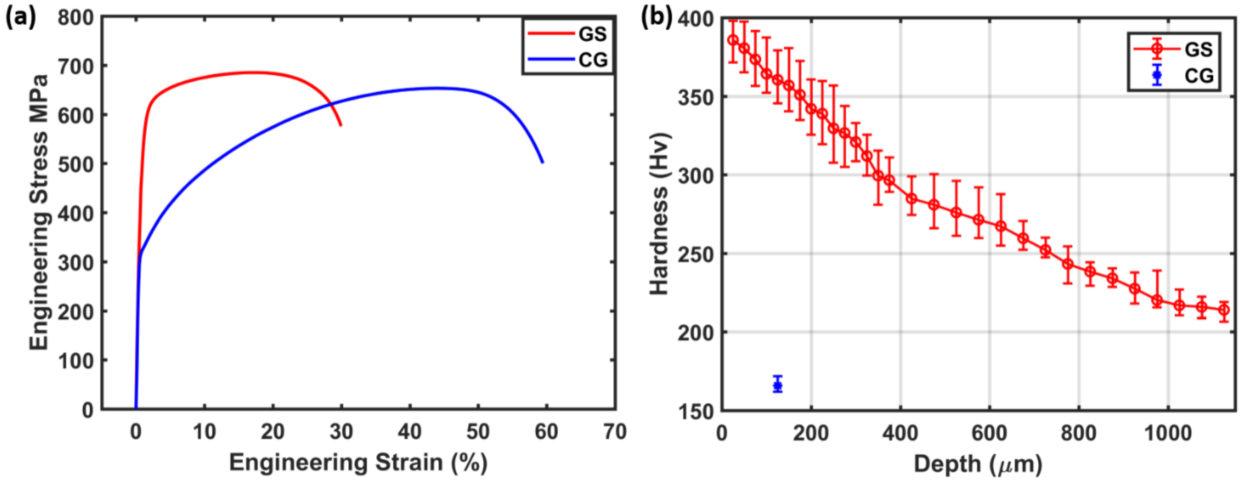

Fig.1: (a) Engineering Stress - Strain curves and (b) Hardness of a CG sample and of a sample with GS.

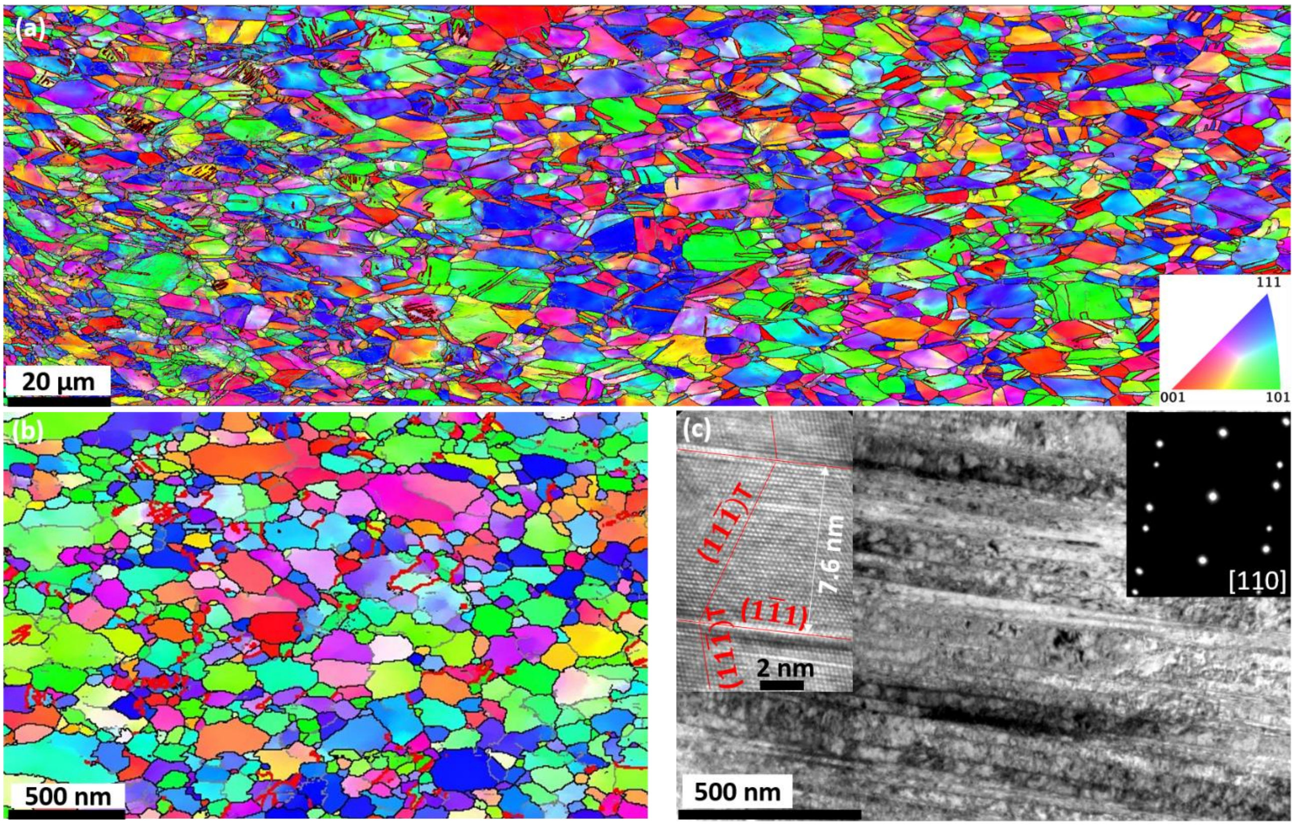

Fig.2: (a) An EBSD map from the surface to a depth of 250 μm, (b) a TKD map at the top surface area, and (c) a TEM image taken from an area ~ 20 μm from the surface, showing a high density of twins. Insets on the upper left and right corner of (c) are a high-resolution TEM image and an electron diffraction pattern, respectively, evidencing the existing of twinned structures.