Bridge martensite phase transformation through microbands for superior dynamic mechanical properties in a metastable high-entropy alloy

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Introduction

As a new class of metallic materials, high-entropy alloys (HEAs) consisting of five or more elements equally or near-equally of equal or non-equal atomic content have changed the strategy of alloy design ([1],[2]). most of mechanical properties of HEAs are measured under quasi-static tests conditions. Studies in of HEAs under high strain rate conditions regime are limited. Furthermore, the well-known Cantor alloy (CoCrFeMnNi) or Al-doped FeNiCoCr HEAs [3], as the two of few HEAs that have been studied under dynamic test, did not show exceptional dynamic yield strength. Therefore, the design and fabrication of HEAs with high strength under high strain rate conditions can help to expand the applications.

Methods

The cylinder specimens were fabricated through arc-melting method, which was followed by hot rolling at 1250 °C with reduction in thickness (RIT) of ~30%. The aging treatment proceeded at 600°C for 24 h. Cylindrical specimens were prepared by Electrical discharge machining (EDM) for dynamic and quasi-static compression testing, respectively. Stopper rings with different dimension were used to control plastic strain.

Mechanical properties

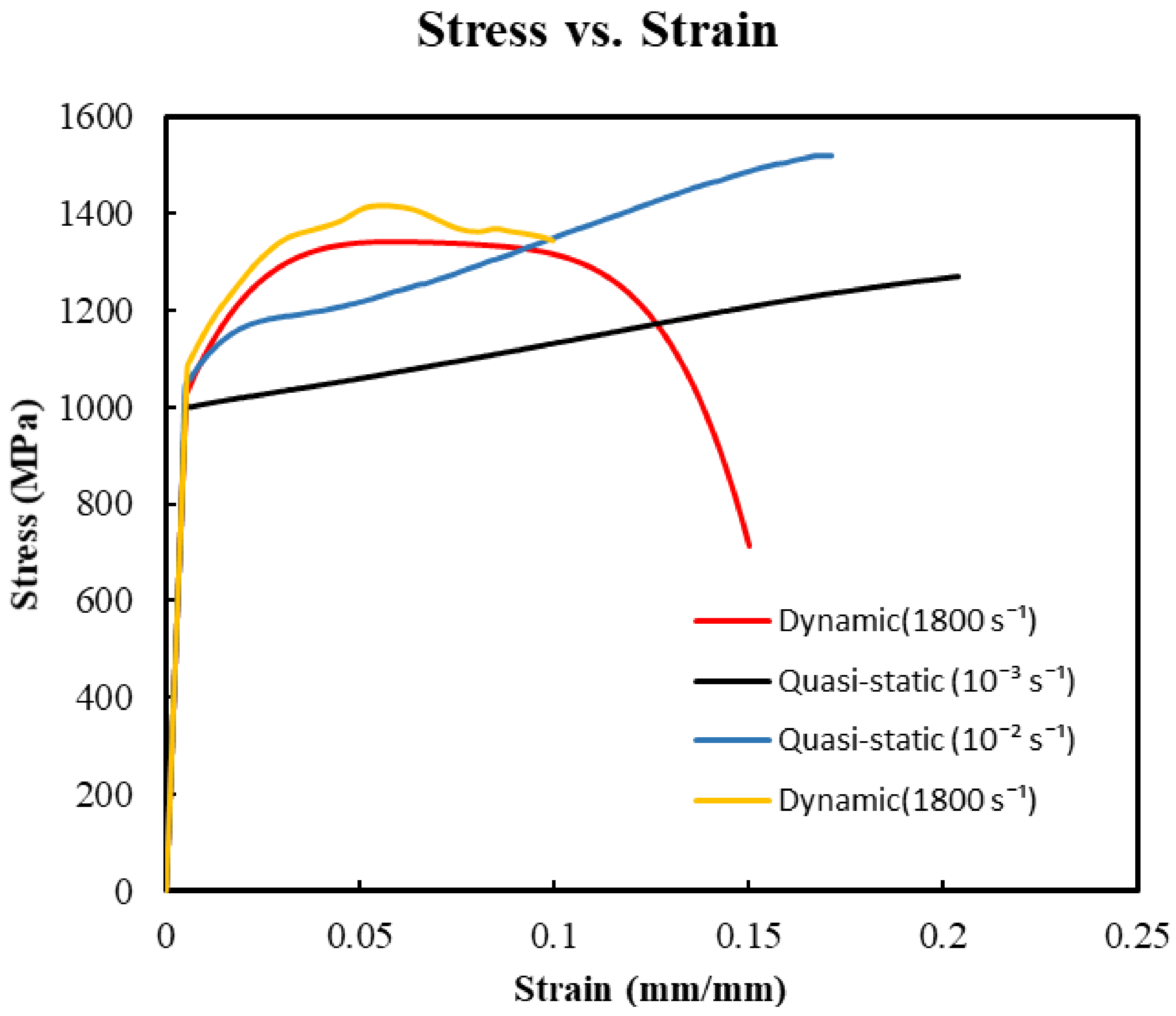

Fig.1 Stress strain curve of high-entropy alloy subjected to quasi-static and dynamic compression

Slip band

Corresponding SADE does not show appearance of mechanical twinning and BCT martensite, suggesting only the formation of slip bands. Thus, we here depicted slip band as first deformation substructures to form with ongoing plastic deformation.

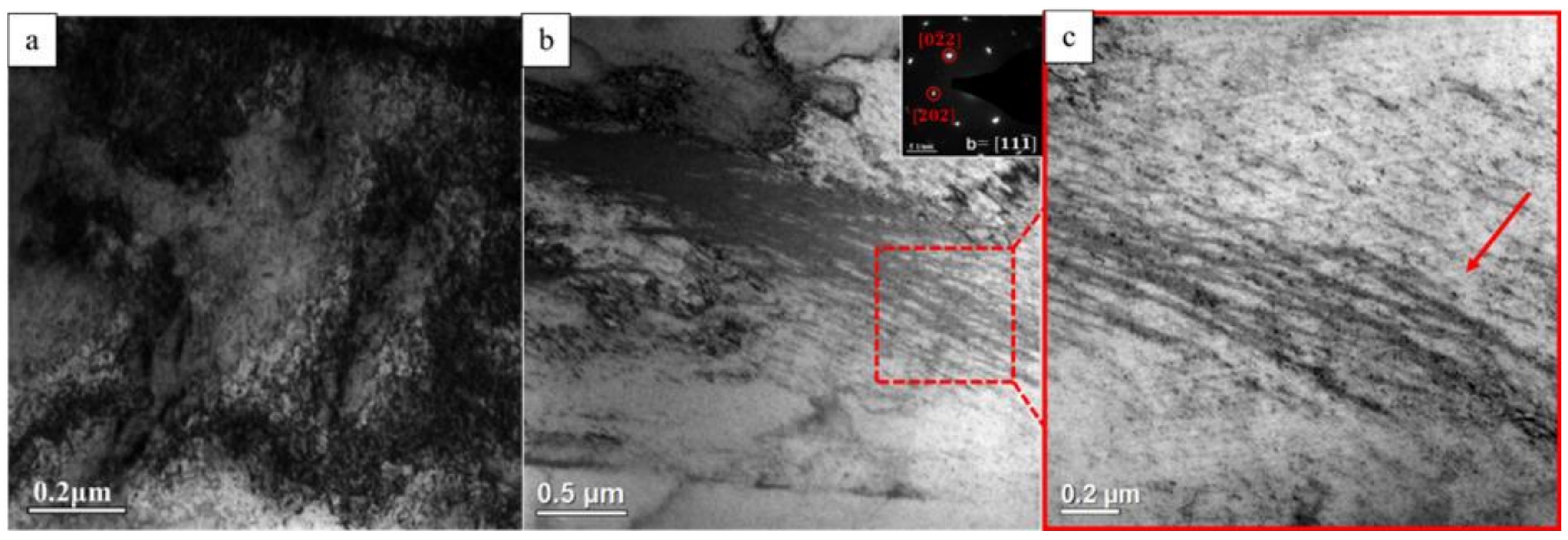

Fig.2 (a) TEM micrographs of HEA after dynamic test with strain of 0.04. (b)(c) Magnified TEM image of slip band and its corresponding SAED pattern.

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Microband strengthening

Microbands can provide high strain hardening rate at dynamic deformation impact test via impeding dislocation gliding.

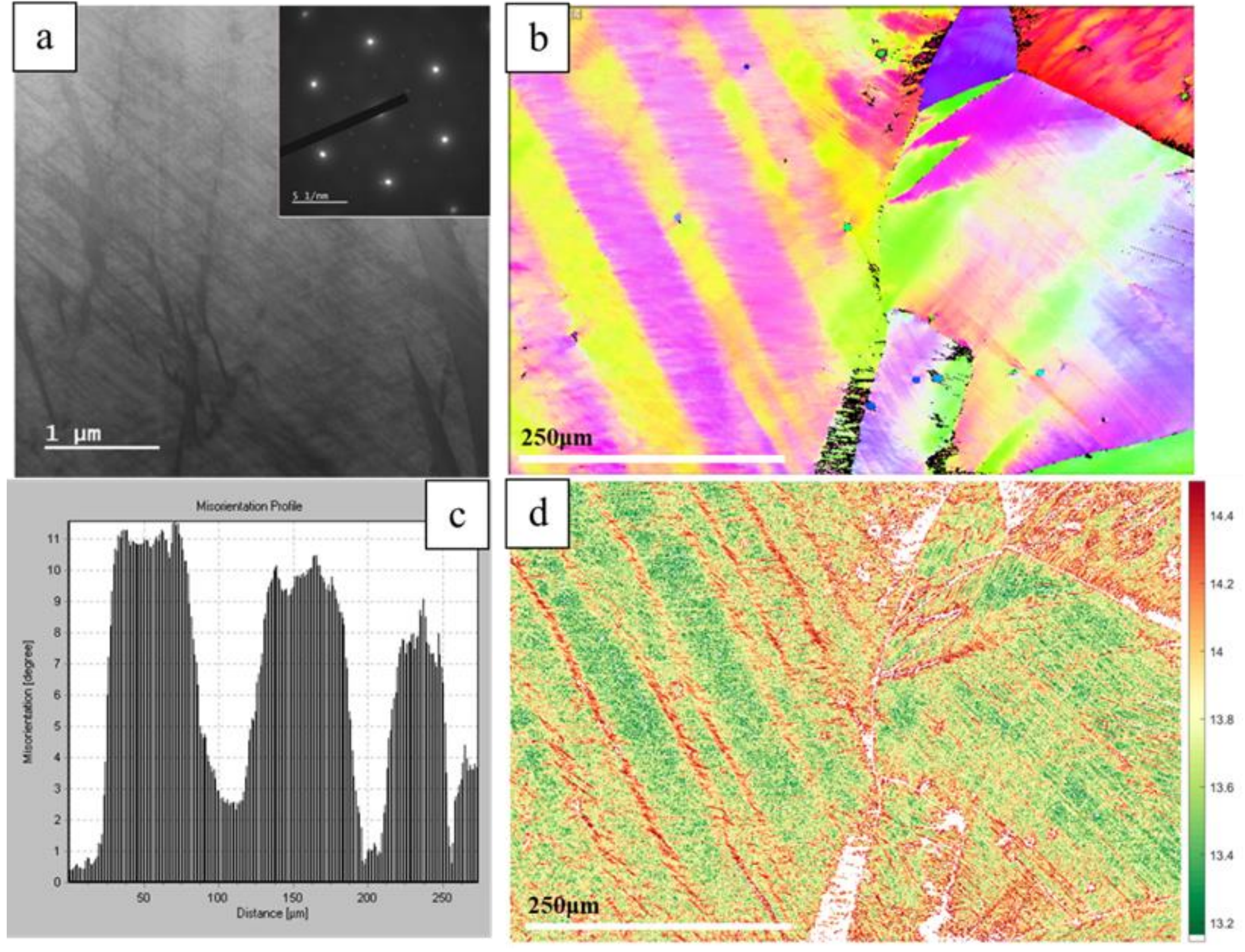

Fig.3 TEM micrograph and EBSD IPF micrograph of specimen subjected to dynamic testing. (b) EBSD IPF micrograph of HEA after dynamic test, showing the existence of large microbands; (c) Misorientation profile corresponding to domains comprised of microband shown in (b). (d) Calculated GND density (m^{-2}) distribution map corresponding to (b), indicating that higher GND density locates along the boundaries of microbands.

Martensite strengthening

As strain continued continues to rise, more microbands will be formed across grains, thereby retaining consistently high strain hardening rate which served to induce the γ to α' martensitic transformation. Appearance of BCT martensite was confirmed by TEM and the corresponding FFT pattern,

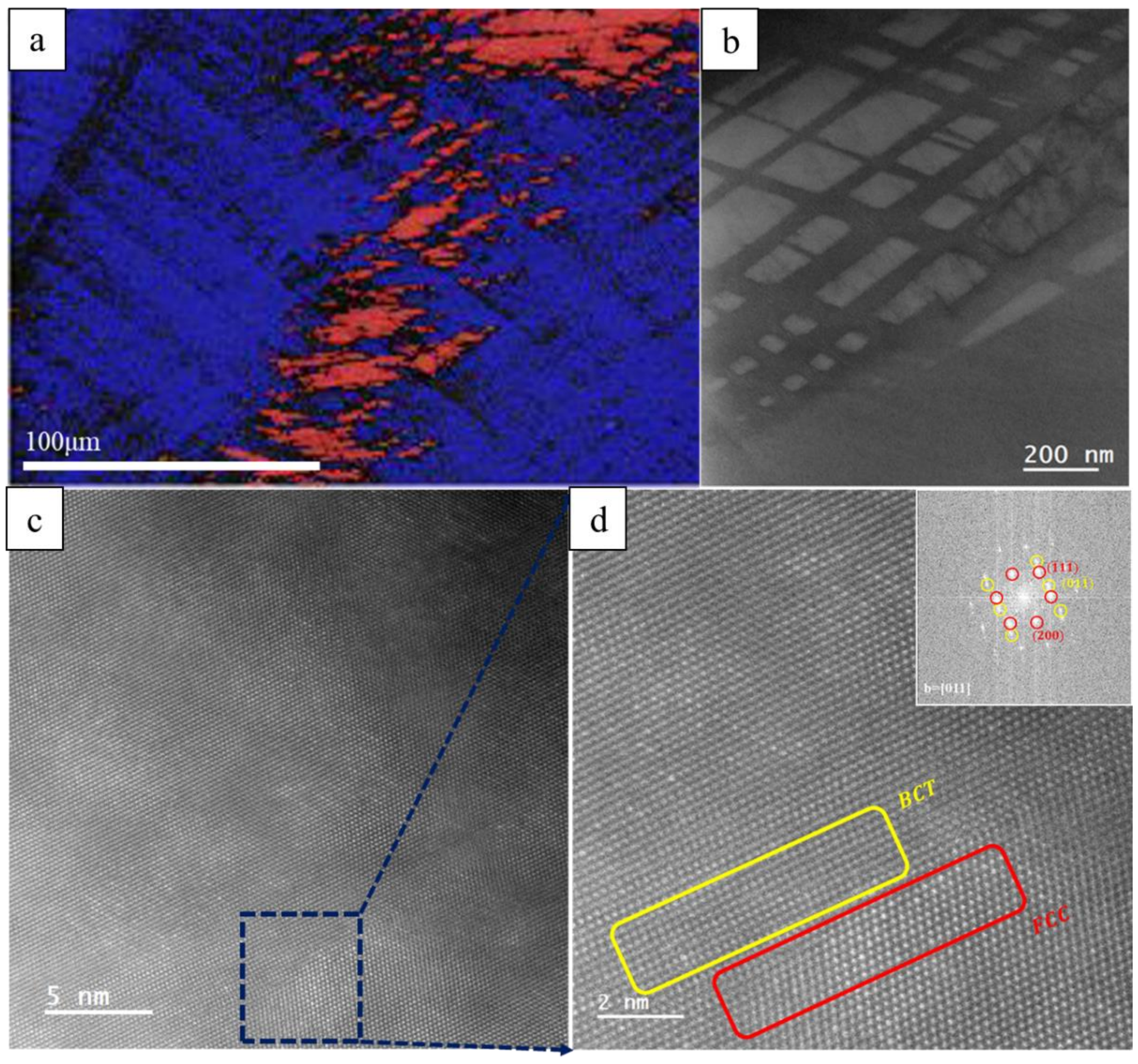

Fig.4 TEM micrograph and its corresponding FFT pattern of 15% strained specimen

Summary

With increasing deformation velocity, operation of strain localization triggered the onset of heterogeneous structures such as HDDWs and slip bands, which served important roles in work-hardening. As strain increases, microbands originated from HDDWs splits and propagates across grain cells, subsequently dividing coarse grains into smaller area and impeding movement of dislocations. Multiple strengthening effects contributed to the stress induced martensitic transformation.

Reference

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