doi:10.1017/S1431927619013710
Microsc. Microanal. 25 (Suppl 2), 2019

Understanding Microstructural Properties of Al_xCrCoFeNiCu High Entropy Alloy by Advanced Scanning Transmission Electron Microscopy

Ping Lu, Andrew Kustas, Nicolas Argibay, Michael Chandross and Shaun Whetten

Sandia National Laboratories, Albuquerque, NM, USA.

High Entropy Alloys (HEAs) such as Al_xCrCoFeNiCu, typically consist of five or more alloying constituents in equal or nearly-equal concentrations and are a class of materials with extraordinary mechanical properties [1, 2]. The structural and chemical characterization down to the atomic-scale plays a critical role in understanding the process-structure-property relationships. The presence of many alloying elements with similar atomic number, however, makes the structural characterization a challenge. Here we describe several efforts utilizing advanced scanning transmission electron microscopy (STEM) techniques to quantify the microstructure of Al_xCrCoFeNiCu HEAs processed by casting and laser-based rapid solidification methods. Particularly, STEM imaging with high-angle annular dark-field (HAADF) detectors and atomic-scale elemental mapping using energy-dispersive X-ray spectroscopy (EDS) [3] are used to study phase decomposition of the alloys and nanostructured dendrites formed near the phase boundaries.

Fig. 1a shows a low magnification STEM HAADF image of a cast Al_xCrCoFeNiCu HEA. The compositional segregation can be seen in the STEM EDS map in Fig.1b, constructed by utilizing the two EDS components shown in Fig.1c, that were obtained by principal component analysis (PCA) of the EDS spectrum imaging dataset. The analysis shows compositional segregation taking place on the micron-scale, with formation of a minor, highly Cu-rich phase within the Cu-deficient matrix. In addition, the transitional regions at the phase boundaries exhibit nanostructured dendrites. Fig.2a shows the STEM HAADF image, showing the dendrite structure on a scale of ~ 10 nm. Selected area electron diffraction (SAED) from the region (Fig.2b) indicates the region has an ordered f.c.c. lattice. The compositional segregation within the dendrite is revealed by STEM EDS mapping in Fig.2c, indicating the coexistence of the Cu-rich, and Cu-deficient phases which have compositions like those in Fig.1c. High-resolution STEM imaging and analysis (Fig.2d) indicate the ordered f.c.c. lattice has a LI_2 structure. The dendrite structures are found to be highly responsive to the changes of processing conditions [4].

References:

[1] S. Ranganathan, Current Sci. **85** (2003), p. 1404.
[2] J. W. Yeh et al., Adv. Eng. Mater. **6** (2004), p. 299.
[3] P. Lu et al., Sci. Rep. **4** (2014), p. 3945.
[4] Sandia National Laboratories is a multi-mission laboratory managed and operated by National Technology and Engineering Solutions of Sandia LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

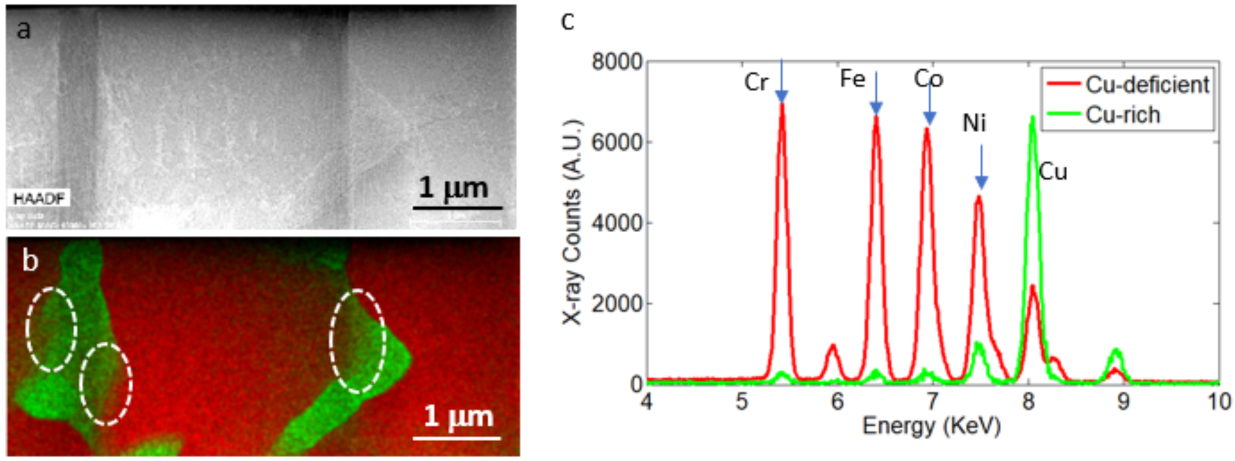

Figure 1. (a) STEM HAADF image of a cast $Al_xCrCoFeNiCu$ HEA; (b) EDS maps formed using two EDS components derived from a PCA analysis; and (c) EDS spectra of the two components with different compositions. The dash areas in (b) indicate the transitional regions with nano-scale dendrite structure, further analyzed in Fig.2.

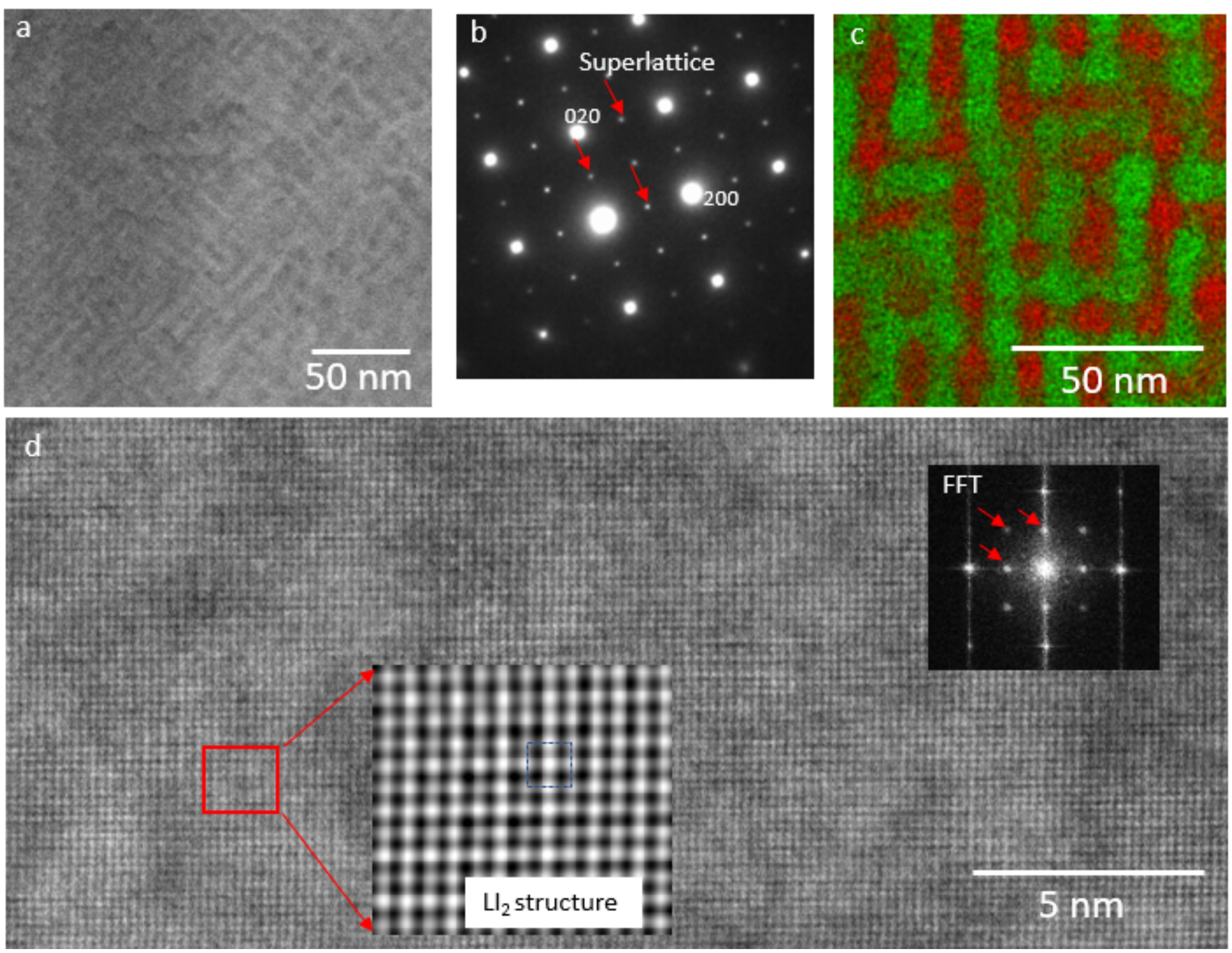

Figure 2. (a) STEM HAADF image, (b) SAED pattern and (c) EDS maps showing the nano-scaled dendrite strucuture found in the transitional regions. (d) High-resultion STEM image and analsysis, showing the dendrite region has a LI_2 structure.

https://doi.org/10.1017/S1431927619013710 Published online by Cambridge University Press