ICSMA19 Metz, France, June 26 - July 1, 2022
International Conference on Strength of Materials

Mesoscopic-Scale Complexity of Plastic Flow in a $Al_{0.3}$CoCrFeNi High-Entropy Alloy

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The concept of a smooth and homogeneous plastic flow of solids is nowadays constantly challenged by various observations of the self-organization of crystal defects on mesoscopic scales pertaining, e.g., to acoustic emission or the evolution of the local strain field. Such investigations would be of particular interest for High-Entropy Alloys (HEAs) characterized by extremely complex microstructures. However, the complexity of their plastic deformation has been only studied in relation to the macroscopic plastic instability, or jerky flow. In the present work, the complexity of the macroscopically smooth plastic flow of a $Al_{0.3}$CoCrFeNi high-entropy alloy was studied for a range of mesoscopic scales with the aid of various material responses to deformation, including the acoustic emission, the local strain-rate, and force variations. A similitude was found between the geometry of shear during smooth and jerky flow. Furthermore, the recorded responses were processed using complementary approaches comprised of statistical, spectral, refined composite multiscale entropy, and fractal analyses. This comprehensive approach revealed transitions between distinct dynamical regimes, which may be assimilated with noises of different colors, in particular the blue noise, which is rarely observed in complex systems. The evolution of the measured quantities also exhibited various kinds of "reddened" behavior, including avalanche-like dynamics of the dislocations. Such findings provide significant new insights into the micro/macro transition in the deformation behavior of HEAs.

Keywords: complexity of plastic flow, acoustic emission, digital image correlation, statistical analysis, entropy-based analysis, fractal analysis.