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Editorial: Advances in the fundamental understanding and prospects for practical applications of high-entropy materials

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Editorial on the Research Topic
Advances in the Fundamental Understanding and Prospects for Practical Applications of High-entropy Materials

The present Research Topic features innovative experimental and computational techniques to address key aspects of high-entropy materials research and development. We are grateful for the opportunity to serve as Guest Editors for this timely Research Topic, and we thank the contributors to this topic who have reported impactful and interesting results, worthy of the Frontiers in Materials journal.

Local atomic order is of great interest to the high-entropy materials community. The contribution by Greenhalgh et al. includes a newly developed way of visualizing and identifying ordering in atomic data sets using their proposed Fractional Cumulative Radial Distribution Function (FCRDF). The authors validate the FCRDF using synthetic data, then apply it to experimental data, including an atom probe tomography study of the multiphase $Al_{1.3}CoCrCuFeNi$ alloy. Their technique captures elemental aggregation at the nanoscale in this complex alloy and gives a new path for identifying atomic ordering at the nearest neighbor level.

The high-entropy materials design paradigm of using multiple elements in near-equimolar ratios pushes researchers explore vast regions of compositional phase space, creating a great need to develop high-throughput synthesis and experimental validation techniques. The review article by Sreeramagiri et al. evaluates high-throughput and combinatorial synthesis using additive manufacturing (AM). Particularly promising is directed energy deposition (DED) based AM because it allows compositional variations suitable for demanding tasks, such as functionally graded component manufacturing as well as surface cladding. The authors predict that the full benefits of DED for high-entropy materials synthesis will not be realized until data-informed techniques are implemented to optimize the processing parameters. They cite examples of how DED process parameters greatly affect the material properties, independent of composition, and give a path forward for experimental high-throughput materials exploration.

Given the importance of microstructures on the properties of high-entropy materials, it is appropriate that the present Research Topic includes in depth studies on this topic. Jorgensen et al. use *in-situ* small angle neutron scattering (SANS) and scanning transmission electron microscopy (STEM) to investigate microstructure evolution at high temperatures. The $Al_{1.3}CoCrCuFeNi$ alloy, which is the same composition studied at the nearest-neighbor atomic level by Greenhalgh et al., is shown to undergo a microstructure evolution between room temperature and 800 °C involving the precipitation/dissolution of ordered Fe-Cr and Al-Ni nanoplatelet phases. Having both the Jorgensen and Greenhalgh papers in the present Research Topic highlights the importance of both short and long-range ordering in high-entropy materials.

There is a great potential to tune the properties of high-entropy materials by adjusting the ratios of the multiple elements in high concentrations (in contrast to conventional materials with a single base element plus low-concentration additives). Lee et al. tuned the stoichiometric Mn composition to systematically explore the magnetic properties of $(CoCrFeNi)_{1-x}Mn_x$ high-entropy alloys. They show that small increases in Mn-content give rise to large reductions in magnetization, and they propose a mechanism whereby the Mn atoms flip the moments of neighboring atoms. Their work demonstrates the tailoring of ferrimagnetic transition temperatures, coercivity fields, and saturation magnetization, which is of great scientific and practical significance.

While high-entropy materials warrant studies based upon fundamental scientific questions, the potential for practical applications certainly plays a major role in the continued interest and funding for this field. The contribution by Peng et al. examines high-entropy alloys with potential tool steel applications, where high-temperature tribological behavior is one of the major life-determining factors. The $Al_{0.3}Cr_{0.5}Fe_{1.5}Mn_{0.5}Ni$ high-entropy alloy with additions of titanium and carbon demonstrated exceptional oxidation resistance and a lower friction coefficient than M2 steel. They find that a dense glazed layer on the alloy surface serves as a lubricant to decrease the friction coefficient and protect the surface from oxidation. Their work strengthens the case that high-entropy materials have the potential for high-temperature applications.

Developing high-entropy materials for practical applications requires finding both the right compositions and the right processing conditions. Various thermal and mechanical techniques may be involved in processing. The contribution by Chen et al. explores the use of a vibratory technique to relieve and stabilize residual stress, which is crucial for high-precision machine tools. They use synchrotron X-ray and neutron diffraction to map residual stress on the surface, in the bulk, and on average throughout a load frame made from gray iron. The results indicate that the vibratory stress relief technique, rather than the annealing process, can effectively reduce the stress on the surface of the gray iron and stabilize the stress on the surface or inside the bulk. This work on gray iron paves the way for similar studies on high-entropy alloys.

As Guest Editors, we are delighted that the present contributions address both practical applications and fundamental scientific issues. High-entropy materials research is a thriving field, and the present Research Topic gives a small sample of the exciting work being done in this area. We are confident the present contributions will help advance this important

Author contributions

LJS drafted the initial version, and all authors have reviewed and commented on the editorial.

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