SCIENCE OF ENTROPY-STABILIZED ULTRA-HIGH TEMPERATURE THIN FILMS: SYNTHESIS, VALIDATION, AND PROPERTIES

Jon-Paul Maria, North Carolina State University
jpmaria@ncsu.edu
Trent Borman, North Caorlina State University
Donald Brenner, North Carolina State University
Elizabeth Oplia, University of Virginia
Patrick Hopkins, University of Virginia
Tina Rost, University of Virginia
Ken Vecchio, University of California San Diego
Tyler Harrington, University of Californial San Diego
Cormac Toher, Duke University
Stefano Curtarolo, Duke University

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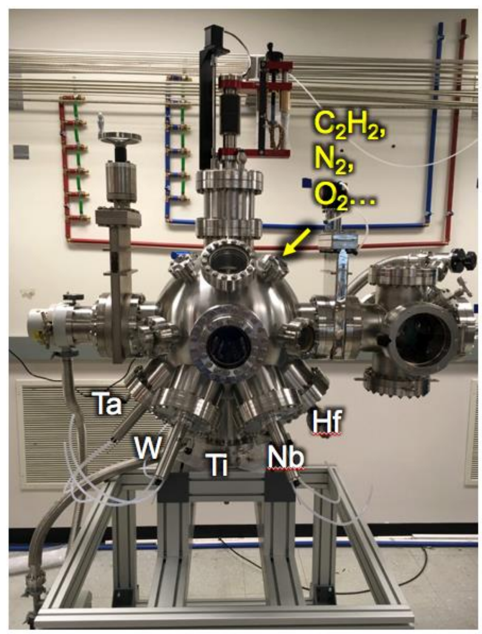
The authors report on using multi-cathode magnetron sputtering to fabricate 5-component refractory carbides that are stabilized by configurational entropy to form a robust and high-temperature class of high temperature materials. Magnetron sputtering is an appealing fabrication method as one can prepare layers with high density and the compositional flexibility afforded by five independent metallic sources. Thin layers that comprise mixed carbides of the following elements: W, Mo, Ti, Hf, Zr, Ta, V, and Nb, will be discussed. In all cases sputtering is performed reactively in a gas atmosphere including Ar as the inert sputter gas and propane as the carbon source. Sputter depositions can be conducted between room temperature and 800 °C. The relationship between sputtering parameters including power, pressure, rate, gas mixture, and film properties including density, thermal conductivity, lattice constant, and phase evolution will be discussed.

In general, we find a substantial composition spread for five-component carbides that exist in the single-phase state and adopt a rocksalt structure. The single-phase state can be produced by sputtering over a broad temperature range. It is interesting to note that several of the available compositions include W and Mo as principle components, as the carbides of these cations do not stabilize in the rocksalt phase until very high temperatures. We speculate that the kinetic energy (and thus effective temperature) associated with adatoms in a sputtering plasma contribute to the entropic free energy term and allow a pathway to quench in a high temperature structure due to the extremely rapid cooling rate upon condensation from the plasma.



We will demonstrate how the thin film process can be used to facilitate property evaluations. While the films are thin (typically several microns total thickness) they provide an embodiment with very smooth surfaces, a uniform and fine microstructure, and tunable composition. As such, they facilitate creation of engineered interfaces with stepped compositions, sample sets that feature systematic composition variation, and evaluation of thermal properties using laser based approaches. Finally, we will compare our phase stability observations with predictions from high throughput computations approaches.

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