Exploring advanced control in high-entropy coatings by tailoring gas phase process during deposition

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High-entropy materials (HEMs), represent a groundbreaking class of multi-principal element materials that enable the exploration of diverse and variable properties within a single multielement system. Generating HEA thin-film by means of plasma-based technologies provide unique opportunities for scalability by tailoring microstructure, morphology, and functional properties by understanding the plasma environment.

In this work we report on the dynamics of laser produced high-entropy plasma are investigated by angle resolved electrical and the space and time resolved optical emission spectroscopy. The results showed a complex dynamic of a multi element plasma with selective acceleration and angular separation angular splitting of the plasma based on the nature of the ions and their kinetic energy. The nature of the expansion environment (Ar, O_2, N_2) of the high entropy plasma shows acceleration up to keV in O_2 and N_2, while the inert atmospheres confine the dynamics in the 50-800eV kinetic range. The time resolved electrical investigation showed a modulation of the electron temperature at high pressure, signaling potential gas phase chemical reaction, while optical emission spectroscopy revealed different electron excitation temperatures for each of the composing element of the plasma which can indicate differential oxidation or nitridation processes.

Complementary thin films were fabricated using pulsed laser deposition under various atmospheres (up to 100 Pa), substrate temperatures (500 °C), and variable fluences. Morphological and structural investigations were completed using several surface analysis techniques such as AFM, SEM, XRD, XPS and far infrared spectroscopy. It is shown that by controlling ion dynamics during the growth process the thin films parameters can be systematically tuned to achieve a diverse range of microstructures, from amorphous and nanocrystalline to mixed-phase morphologies. Plasma characterization provided further insight into fundamental of laser-high entropy matter interaction, linking the resulting properties of the thin films with the fundamental aspect of property of the plasma such as electron temperature, plasma potential or Debye length. This work highlights the potential of high-entropy alloy and oxide thin films for advanced applications, including microwave absorption, where their tunable structural and optical characteristics play a crucial role.

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