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On the energetic deposition of TiAlSiN thin films by reactive modulated pulsed power magnetron sputtering discharges: A global plasma model and experiments

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A global plasma model has been developed to describe the TiAlSiN thin film deposition by reactive modulated pulsed power magnetron sputtering (MPPMS) discharges in Ar/N_2 mixture gas, based on the particle balance and the energy balance in the ionization region, and considering the formation and loss of compound at the target surface. The modeling results show that, as increasing the N_2 partial pressure from 0 to 40 % at constant working pressure of 0.3 Pa, the maximal electron density in the ionization region increases from 2×10^{19} m^{-3} to 3×10^{19} m^{-3} after inletting the N_2, and decreases to 2.5×10^{19} m^{-3} with further increasing the N_2 partial pressure, the electron temperature during strongly ionized period increases from 5 eV to 7 eV, the effective power transfer coefficient increases from 0.05-0.06 to 0.08; as increasing the working pressure from 0.1 to 0.7 Pa at constant N_2 partial pressure of 30 %, the maximal electron density increases from 1.3×10^{19} m^{-3} to 2.6×10^{19} m^{-3}, the electron temperature decreases from 13 eV to 5 eV, the effective power transfer coefficient decreases from 0.1-0.12 to 0.04-0.09. Using the modeled plasma parameters to evaluate the kinetic energy of arriving ions and the substrate temperature, the variations of processing parameters which decrease both values lead to a weakened diffusion ability of adatom and a reduced input energy to the substrate, corresponding to the experimental observation of surface roughness increase, the microstructure transition from dense amorphous structure to columnar structure, and the reduction of phase separation. The increase of electron temperature shifts the discharge balance of Ti species from Ti^+ to Ti^{2+}, results in a higher return fraction of Ti species as well as a higher Al/Ti ratio of the deposited TiAlSiN thin films. The characteristics of reactive MPPMS discharges are explained based on the modeling as well as its correlation with the experimentally observed composition and microstructure transition of deposited thin films.

Keywords
MPPMS
HiPIMS
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