Dense Hard TiB_x Films Grown by Magnetron Sputtering without Substrate Heating Using W-Ion Irradiation

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Abstract. Transition metal diborides (TMB_2) are characterized by high hardness, wear resistance, good thermal and electrical conductivity, as well as chemical stability at elevated temperatures. Combination of these properties makes them suitable for various thin film applications motivated by minimizing energy and material waste (e.g., wear protective coatings on cutting tools or low-friction films for machine components). Therefore, it is reasonable to optimize the deposition process of the functional coatings to make it more energy efficient. Large potential for lowering the energy consumption has been shown by employing high-mass metal ion irradiation from targets operated in high-power impulse magnetron sputtering (HiPIMS) mode. As demonstrated for TM nitrides, irradiation by high-mass ions can replace the thermally induced adatom mobility, which significantly reduces the external heating necessary to grow dense crystalline films [1, 2, 3]. In this work, we test this method for TiB_x, which is a model system for TM-based diborides. We show that while binary TiB_x films deposited by DCMS with no external heating develop porosity over a wide range of B/Ti ratios, ternary $(Ti_{1-y}W_y)B_x$ films grown by hybrid W_2B_5-HiPIMS/Ti-TiB_2-DCMS co-sputtering with substrate bias synchronized to W-ion rich fluxes, are dense (without porosity), irrespective of x. The elimination of porosity leads to a significant increase in hardness from ~20 GPa for TiB_x to ~40 GPa for $(Ti_{1-y}W_y)B_x$. The estimated reduction of the consumed process energy due to lowering of the substrate heating is almost 86%. These results show that utilizing heavy ion irradiation is an energy-efficient way for low-temperature growth of hard diboride films.

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