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Synergy of experiment and model for reactive HiPIMS: effect of discharge parameters on WO_x composition and deposition rate

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Abstract

Reactive high-power impulse magnetron sputtering of tungsten oxide films using metallic tungsten target (72 mm in diameter) in argon-oxygen atmosphere (total pressure of 0.75 Pa) was carried out. The effect of various discharge parameters on the deposition rate and film oxygen concentration was investigated. Moreover, a model combining a reactive high-power impulse magnetron sputtering model and a discharge plasma model for the ionization region was successfully used for deeper insight into the effect of particular discharge parameters such as voltage pulse length (from 100 –800 μs), oxygen partial pressure (from 0.25–0.50 Pa) or the value of pulse-averaged target power density (from 2.5–500 W cm^{-2}). The results of the presented model, most notably trends in the target- and substrate oxide fraction, composition of particle fluxes onto the substrate, degree of W atom ionization or degree of O_2 molecule dissociation are discussed and put into context with experimentally measured quantities.

Keywords: reactive HiPIMS model, deposition rate, tungsten oxide

(Some figures may appear in colour only in the online journal)

1. Introduction

In the field of thin-film research and development, reactive high-power impulse magnetron sputtering (r-HiPIMS) has become the centre of attention in recent years. This is thanks to the ability of this technique to produce densified, high-quality defect-free oxide, nitride and oxynitride coatings [1–6]. The maximization of the deposition rate during r-HiPIMS has also been studied intensively and many approaches allow one to produce thin films at high deposition rates without sacrificing film quality [7, 8]. Much attention is also devoted to the investigation of processes connected with the presence of reactive gas (RG, typically oxygen and/or nitrogen) in the gas mixture and its interaction with the target and substrate surface. There are a few theoretical models describing the complex behaviour of r-HiPIMS plasma discharge that have been developed. In order to be applicable to high-power impulse magnetron sputtering (HiPIMS) discharge conditions, the models of conventional reactive sputtering (e.g. [9–14]) were extended to account (especially) for the ionization and return of sputtered metal atoms onto the target [15–19] and the dissociation of RG in the discharge plasma [15, 16, 19]. Some of those models simulated mainly the composition of the reactive surfaces and the balance of RG in the discharge chamber and the hysteresis effect [17, 20], while another focused on the simulation of the

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