Characteristics of the peak current evolution in reactive multi-pulse HiPIMS of vanadium in Ar/O_2

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Vanadium dioxide (VO_2) is a material showing a thermochromic transition, also called metal-insulator transition (MIT) at about 68°C. The latter is related to a transition from tetragonal to monoclinic structure. Because of the significant change in optical and electrical properties, VO_2 is expected to be used in smart windows and switching devices. Reactive sputtering is widely used to grow VO_2 thin films. It is, however, difficult to form single-phase VO_2 films because of the large number of V-O stoichiometries available, leading to an exceptionally small process window. Thus, precise process control of, for example, the oxygen partial pressure and/or the discharge conditions is required [1]. As an approach for reactive mode control, we focused on a peak current (I_{pk}) regulation technique in reactive High-Power Impulse Magnetron Sputtering (R-HiPIMS) [2]. Based on the relationship between the HiPIMS peak current and oxygen partial pressure, this technique enables reactive mode control simply by monitoring the pulse current waveform without any external monitoring devices and/or the use of gas flow control. In the present work, arcing was also addressed using very short HiPIMS pulses. Another advantage of this approach was that a sequence of such short pulses, i.e., multi-pulse HiPIMS (m-HiPIMS), enhances both the ionization fraction and deposition rate [3]. In m-HiPIMS mode, we, furthermore, found characteristic variations of I_{pk} as a function of O_2 gas flow, exhibiting a local maximum, while continuously increasing or decreasing I_{pk} trends were observed in the conventional single pulse HiPIMS scheme. Film growth experiments using m-HiPIMS revealed that films grown at a lower O_2 flow than the flow at the local maximum exhibited a highly crystallized V_2O_3 phase, while the V_2O_5 phase was obtained for films grown at higher O_2 flow. On the other hand, film growth at the O_2 flow corresponding to the local I_{pk} maximum resulted in the VO_2 phase. The cause of this local maximum of I_{pk} was further studied using mass spectrometry and correlated to the vanadium target surface chemistry.

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