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Controlled reactive HiPIMS – effective technique for low-temperature deposition of functional oxide films

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Reactive high-power impulse magnetron sputtering (HiPIMS) with a feedback pulsed O_2 flow control and to-substrate O_2 injection into a high-density plasma in front of the sputtered metal (Hf or V) target was used for high-rate deposition (up to 230 nm/min) of densified, highly optically transparent, stoichiometric HfO_2 films onto floating substrates at the substrate temperatures T_s below 140 °C, and for low-temperature (T_s = 300 °C) deposition of VO_2 films with a pronounced semiconductor-to-metal transition onto conventional soda-lime glass substrates without any substrate bias voltage and without any interlayer. The HfO_2 depositions were performed using a strongly unbalanced magnetron with a planar Hf target of 100 mm diameter in argon-oxygen gas mixtures at the argon pressure of 2 Pa. The deposition-averaged target power density was close to 30 Wcm^{-2} at a fixed repetition frequency of 500 Hz. The voltage pulse duration ranged from 50 μs to 200 μs (duty cycle from 2.5% to 10%). The target-to-substrate distance was 100 mm. The HfO_2 films were nanocrystalline with a dominant monoclinic phase. They exhibited a hardness of 18 GPa, a refractive index of 2.12 and an extinction coefficient of $5x10^{-4}$ at the wavelength of 550 nm. The high deposition rates of the films are explained using a simplified formula and model calculations. The VO_2 depositions were performed using an unbalanced magnetron with a planar V target of 50.8 mm diameter in argon-oxygen gas mixtures at the argon pressure of 1 Pa. The deposition-averaged target power density was close to 13 Wcm^{-2} at a fixed duty cycle of 1% with a peak target power density up to 5 $kWcm^{-2}$ during voltage pulses ranged from 40 μs to 100 μs. A high modulation of the transmittance at 2500 nm (between 51% and 8% at the film thickness of 88 nm) and the electrical resistivity (changed 350 times) at the transition temperature T_{tr} = 56-57 °C was achieved for the VO_2 films synthesized using 50 μs voltage pulses when the crystallization of the thermochromic phase was supported by the high-energy (up to 50 eV relative to ground potential) ions.

Keywords
Controlled reactive HiPIMS
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