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High-rate reactive high power impulse magnetron sputtering of multifunctional Ta-O-N films

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High power impulse magnetron sputtering of a planar tantalum target (diameter of 100 mm) in various argon-oxygen-nitrogen gas mixtures was investigated at a fixed average target power density of 50 Wcm^{-2} in a period. A strongly unbalanced magnetron was driven by a pulsed dc power supply (HMP 2/1, Huettinger Elektronik) operating at the repetition frequency of 500 Hz and the average target power density of up to 2.4 $kWcm^{-2}$ in a pulse with a fixed 50 μs duration. The nitrogen fractions in the reactive gas flow were in the range from 0 to 100% at the argon partial pressure of 1.5 Pa and the total pressure of the argon-oxygen-nitrogen gas mixture around 2 Pa. The Si (100) and glass substrates were at a floating potential, and the substrate temperature was less than 250°C. The target-to-substrate distance was 100 mm. An effective reactive gas flow control made it possible to produce high-quality Ta-O-N films of various elemental compositions with high deposition rates (97 to 190 nm/min). Their compositions (in at. %) were varied from $Ta_{27}O_{72}$ with a low content (less than 1%) of hydrogen to $Ta_{38}O_4N_{55}$ with 3% of hydrogen. The former films were nanocrystalline with high optical transparency (extinction coefficient less than 10^{-4} at 550 nm), refractive index of 2.12, band gap of 4.0 eV, very low electrical conductivity (resistivity of $7.7x10^9$ Ωcm) and hardness of 7 GPa. The latter films exhibited a more pronounced crystallinity, they were opaque with relatively high electrical conductivity (resistivity of $4.2x10^{-2}$ Ωcm) and hardness of 19 GPa. The $Ta_{27}O_{40}N_{31}$ films with 2% content of hydrogen, produced at the 50% nitrogen fraction in the reactive gas flow with the highest deposition rate of 190 nm/min achieved, were nanocrystalline with the band gap of 2.4 eV, electrical resistivity of $5.5x10^6$ Ωcm and hardness of 8 GPa. Such films seem to be suitable candidates for visible-light responsive photocatalysts. Details of the deposition process and measured properties of the films will be presented.

Keywords
HiPIMS
High-rate deposition
Ta-O-N films