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Thermal stability of structure and properties of ternary Zr-Ta-O films with low and high tantalum content

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Development of novel multicomponent ceramic oxide systems is the promising way how to extend application potential of binary oxides. Zirconia is one of the most studied oxide ceramic materials because of its excellent chemical inertness and good mechanical, electrical, optical and thermal properties. Tantalum pentoxide used as thin-film material exhibits interesting electrical and optical properties. The limit for an application of these oxides is the stability of their structure and properties at elevated temperatures. The present study focuses on investigation of the thermal stability of the structure and properties of ternary Zr-Ta-O films with a low and high tantalum content. For this purpose, Zr-Ta-O film with 5 at. % of Ta ($Zr_{25}Ta_5O_{70}$), Zr-Ta-O film with 25 at.% of Ta ($Zr_5Ta_{25}O_{70}$) and binary ZrO_2 and Ta_2O_5 films were prepared by reactive high-power impulse magnetron sputtering of a single Zr-Ta target (with a varying Ta fraction in the target erosion area) in argon-oxygen gas mixtures using a pulsed reactive gas flow control. The thermal stability of the structure, microstructure, mechanical and optical properties of the films was investigated in air in the temperature range of 700°C – 1300°C. It was found that the ternary Zr-Ta-O films investigated exhibit an enhanced thermal stability of the as-deposited structure and enhanced properties than the corresponding binary oxides. The $Zr_{25}Ta_5O_{70}$ film is a single-phase material with the nanocrystalline solid solution structure corresponding to $TaZr_{2.75}O_8$. This solid solution is stable up to a maximum temperature investigated (1300°C) and the film retains a high hardness of 19 GPa even after the annealing to 1000°C in air. The $Zr_5Ta_{25}O_{70}$ film exhibits an amorphous structure in the as-deposited state with its thermal stability up to 800°C. At higher temperatures a crystallization of the film occurs. The thermal stability of mechanical and optical properties will be presented as well.

Keywords
Zr-Ta-O
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