Tuning ZrON thin film colors through pulsed oxygen and nitrogen gases in reactive sputtering

B. Nano-engineered coatings and thin films: from design to applications

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Abstract

DC reactive sputtering was implemented to successfully deposit zirconium oxynitride thin films from a zirconium metallic target, argon as plasma gas and nitrogen and oxygen as reactive gases. Both reactive gases were simultaneously and independently pulsed with a rectangular signal during the film deposition by means of the reactive gas pulsing process (RGPP). A constant pulsing period was used for O_2 and N_2 with a delay time of a few seconds between each reactive gas starting injection. O_2 and N_2 duty cycles (α_{O2} and α_{N2}, respectively) were systematically changed from 0 to 100% of the pulsing period. From real time measurements of the Zr target potential and total sputtering pressure, it was shown that some operating conditions can be reached to alternate the reactive sputtering process between elemental, nitrided and oxidized sputtering modes.

Playing with O_2 and N_2 duty cycles leads to a substantial increase of the deposition rate and adjustable film compositions compared to a conventional injection of the reactive gases (*i.e.,* constant flows) with rates approaching that of the pure Zr metal. These reactive gases duty cycles also allow extending the working range of deposition conditions suitable to modify the optical properties of ZrON films from absorbent (colors in the bulk) to interferential. Analyses of Zr target potential and total sputtering pressure during reactive gas pulsing show that the process needs to be periodically changed between 3 modes: elemental, nitrided and oxidized to get high deposition rates.

Last but not least, a two-dimensional qualitative diagram based on O_2 and N_2 duty cycles as the two key parameters was proposed. Occurrence of different reactive sputtering regimes was clearly identified, with transitions involving periodic alternations between two or three process modes. These results demonstrate that independent pulsed injection of O_2 and N_2 using the RGPP technique is an effective approach for controlling the reactive sputtering process and for producing an extended range of ZrON thin films with changeable properties, especially optical reflectivity in the visible range and film colors in the L*a*b* space related to their chemical composition.