

Electrical Conduction Mechanisms in Metal–Insulator–Metal (MIM) Structure with TiO_xN_y Thin Films Deposited with Different O/N Ratios

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In this work, the current–voltage characteristics of titanium oxynitride thin films were measured and the charge carrier transport mechanisms established as a function of film composition. The films were deposited by magnetron sputtering, where the oxygen/nitrogen ratio was varied via a pulsing technique to enable the achievement of desired concentrations. Thus, the obtained films showed metallic titanium nitride (TiN) or semiconductor titanium dioxide (TiO_2) character and were used to fabricate metal–insulator–metal structures. An ohmic conduction mechanism was identified in the films with higher nitrogen incorporation or presenting TiN-rich phase. Decrease in the nitrogen content resulted in films with TiO_2 -rich phase. In this case, Poole–Frenkel and space-charge-limited current conduction mechanisms were observed. The dielectric constants were calculated from the high-frequency capacitance–voltage dependences, with a reduction from 10 to 3 being observed due to the stoichiometric changes and probable incorporation of defects into the film structure. Finally, the film composition and structural characteristics of the films were revealed by Rutherford backscattering and x-ray diffraction techniques, respectively.

Key words: Charge carrier transport, titanium oxynitride (TiO_xN_y) thin film, gas pulsing technique, MIM structures

INTRODUCTION

Identification and understanding of the conduction mechanism in thin films are crucial when they are used as gates in metal–oxide–semiconductor field-effect transistors (MOSFETs), photoactive coatings in solar cells, and resistive switching materials in MIM capacitors. TiO_xN_y is a promising material for such applications since it exhibits significant photocatalytic behavior and a dielectric constant greater than that of silicon dioxide (3.9) depending on its stoichiometry.^{1–3}

Many factors can influence the charge transport mechanism of such films, but the most important is of course the crystalline structure, its type and density, the defect type and its distribution, as well as the electrode nature and operating temperature. Therefore, study of this topic appears to be a complex task, and careful interpretation of I – V curves should reveal the inherent electrical properties of the film.^{4,5}

It is worth noting that one or more mechanisms may be found in the same structure, depending on the range of measurements used.^{6,7} The latter phenomenon results from the type of charge centers revealing different traps allocated near the conduction or valence bands. The resulting properties

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