TiO_2 Metal-oxide Nanostructured-based Thin Films for Hydrogen Gas Sensing/catalytic application

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1 Introduction

In recent years, the significance of research focused on metal oxide semiconductor TiO_2 related to clean and green energy production, storage, transmission, and utilization has substantially increased. In the realm of clean energy, the development of affordable, stable, and energy-efficient hydrogen gas sensors are one of the key challenges. While sensors for higher hydrogen concentrations exist, detecting low levels of hydrogen in various environments remains necessary for fuel-cell setups and syngas applications.

In our project, we are concentrating on nanomaterials or metal-oxide nanoparticles, especially in the form of thin films, via the use of advanced Physical vapor deposition techniques (PVD). Nanostructured thin films are interesting because they enhance reactivity due to a large surface area-to-volume ratio. For our target application – hydrogen gas sensing – this enables the detection of smaller concentrations of hydrogen. We also expect the response time to be shortened. [1-4]

Our innovative approach addresses a modified DC/RF magnetron sputtering technique, which utilizes helium, argon and oxygen as processing gases. The goal is to enlarge the surface area and so enhance the reactivity of the material. The advantage of our approach is the compatibility of the selected process with thin film technologies used for producing electronics. Magnetron sputtering is also a clean production method, as it does not require harmful chemicals.

2 Methodology

The magnetron sputtering depositions were carried out using a circular titanium target in the presence of argon(71%) helium(19%) and oxygen(9%) at 725 mPa total working pressure. Magnetron was operated in DC regime at a power of 100 W; all depositions were performed at room temperature. Silicon substrates were used as substrates. Subsequently, the samples were annealed in a furnace in ambient air at 400 °C.

3 Result

Synthesized films were analyzed by means of X-ray diffraction (XRD) and scanning electron microscopy (SEM). Figure 1(a) shows the cross-sectional SEM micrographs of TiO_2 films deposited in an argon and oxygen mixture, while Figure 1(b) shows the cross-sectional of TiO_2 films deposited in helium, argon and oxygen mixture. The impact of introducing helium into the system is clearly visible; it becomes more nanostructured or porous, whereas, without

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helium, it is less porous. In Figure 2, XRD analysis successfully confirmed the presence of two crystalline phases, rutile and anatase, validating the composition of TiO_2.

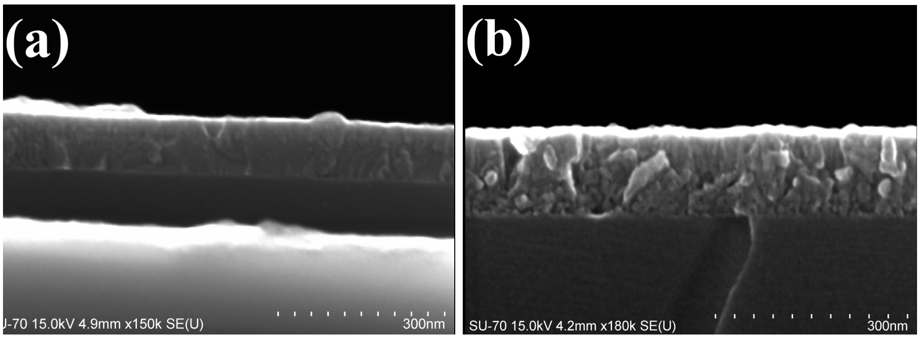

Figure 1: SEM micrographs of the deposited
(a) TiO_2 films in Ar and O_2 (b) TiO_2 films in Ar, He and O_2

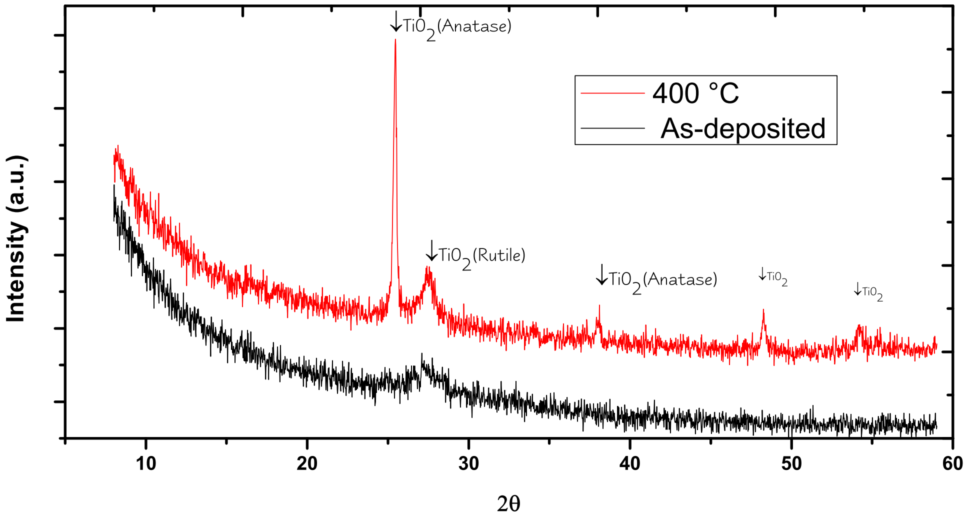

Figure 2: XRD patterns of TiO_2 films as-deposited and annealed temperatures.

4 Outlook

Our primary objective is to utilize thin films with enhanced surface area as conductometric hydrogen sensors. For this, we will synthesize films with most apparent nanostructuring on specialized substrates which enable measuring the sensing response.

References

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