Ultrafast Laser Plasma Engineering of Functional Metal Oxide Thin Films

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Functional metal oxide materials such as titanium and vanadium dioxide thin films have been received significant attention during the last 3 decade, owing to their numerous applications. For instance, titanium dioxides (TiO_2) are frequently used for electro-optical devices, self-cleaning and/or antifogging surface coatings, microelectronics, solar cells, photocatalyst, gas sensors, and lithium ion batteries [1]; while vanadium dioxide (VO_2(M))thin films being utilised to design ultrafast optical switches, thermochromic smart windows, and modulation of near-to mid-infrared wavelengths [2].

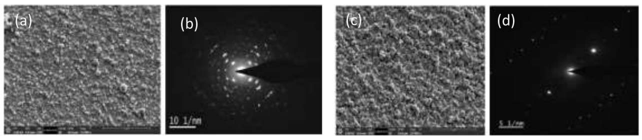

Figure 1: SEM images and SAED diffraction patterns of the TiO_2 (a),(b) and VO_2 (c),(d)

However, there are significant challenges associated with fabricating pure crystalline metal oxide thin films employing conventional techniques such as plasma-enhanced chemical vapour deposition, chemical vapour deposition and radiofrequency sputtering, nanosecond (ns)-PLD, because these metal oxides have various multiphase states [3]. Consequently, most of these methods require a postannealing processing to convert amorphous metal oxide thin films into crystalline, use of expensive and highly corrosive precursors, which are major disadvantages. Moreover, numerous studies of metal oxide thin films had been reported using the ns-PLD ablation technique and characteristics of as deposited films. In contrast, the ablation mechanism of the femtosecond (fs)-PLD method is quite different from ns-PLD, with enormous potential for producing metal oxide thin films without introducing any thermal heating effect onto the target surface. Therefore, it is appealing to investigate into the fs-PLD fabrication of the metal oxide thin films such as TiO_2 (anatase and rutile) and VO_2 (M) to better fathom their surface morphology, optical and electrical properties. Here, we report on the high rate synthesis of anatase/rutile mixed-phase and rutile TiO_2 nanoparticulate thin films on silica substrates and thick and good quality polycrystalline VO_2 thin films on sapphire substrates using the fs-PLD technique. The effect of the substrate temperature on their surface morphology, structure, composition, optical and electrical properties of these thin films were thoroughly investigated by using scanning electron microscopy (SEM), transmission electron microscopy (TEM), X-ray diffraction (XRD), Raman spectroscopy, Ultraviolet–visible-near infrared (UV- Vis-NIR) spectroscopy, and Hall Effect measurements.

References

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