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VO_2 Films Prepared by Atomic Layer Deposition and RF Magnetron Sputtering

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Among the vanadium oxides, VO_2 has been made considerable research efforts due to its remarkable metal-insulator transition (MIT) or semiconductor-metal transition (SMT) behavior, a dramatic reversible change in its electrical and optical properties occurring across the phase transition at 321K [1, 2]. Electrically, the resistivity of VO_2 can be changed as large as four or five orders of magnitude; Optically, VO_2 thin films are also infrared transmission with the insulating phase and highly reflective in the metallic state. All these properties result from a transformation in crystallographic structure, which transitions from a low temperature monoclinic form to a high temperature tetragonal phase. In addition VO_2 is also a thermochromic material which can be employed in smart windows. Therefore, VO_2 has potential to be used in nonvolatile resistive memories, switches in microelectronics and optical sensors.

VO_2 films have been prepared using many techniques, including Reactive Bias Target Ion Beam Deposition (RBTIBD), magnetron sputtering, metal organic chemical deposition (MO-CVD), pulsed laser deposition (PLD) and sol-gel spin coating. Recently, atomic layer deposition (ALD) has been extensively investigated for the deposition of thin films of semiconductors, metals, alloys and oxides. This technique exhibits greatest potential for deposition of accurately controlled thickness and composition of thin films and producing uniformity and exceptional conformality of complex nanostructures. In this work, a novel metal-organic ALD precursor, Tetrakis[ethylmethylamino] vanadium $\{V(NEtMe)_4\}$ [TEMAV], was employed as vanadium precursor source to develop an ALD process for the synthesis of VO_2 films. For comparison of film properties, such as morphology, microstructure and electrical properties, VO_2 films were also fabricated by combining RF magnetron sputtering of Vanadium thin film and poster annealing under mixture of N_2 and O_2 at low pressure.

VO_2 thin films were grown on Si using the Savannah 100 ALD system from Cambridge Nanotech. TEMAV and H_2O were employed as vanadium precursor and oxidizing agent. Generally 20 sccm N_2 was used as a carrier gas for the precursors. The growth temperature was set at 150°C. VO_2 thin film were also deposited by magnetron sputtering of a vanadium metal target (2 inch in diameter, 99.9% purity) on Si substrate. The base pressure of magnetron sputtering was less than 10^{-6} Torr, while sputtering deposition was conducted under Ar with a pressure of 3 mtorr. The growth temperature of Vanadium on Si substrate was controlled at 450°C to obtain high crystallinity and uniformity. However, VO_2 thin films obtained by ALD process are mostly in V_2O_5 phase. In addition, the ALD deposited thin films are amorphous since the growth temperature is lower than the crystalizing temperature. Therefore, the post thermal heat treatment has to be used to produce polycrystalline VO_2 structure in inert gas. The as-grown thin films were annealed with N_2 plus O_2 with different ration in the furnace. Vanadium thin films deposited by magnetron sputtering were annealed under N_2 plus different amount O_2 to obtain VO_2 at temperature range from 450 to 600°C for 6 hours. From XRD and FE-SEM measurements we conclude that the amorphous phase of as-grown ALD thin films was changed into polycrystalline after 450°C annealing and magnetron sputtered vanadium thin film were oxidized in to VO_2 phase as shown in Figure 1 and 2. It is noted that vanadium oxides were considerably dependent on the O_2 concentration and oxidized atmosphere pressure for both as-grown thin films by ALD and magnetron sputtering process. In addition, Electrical and optical properties of VO2 thin films grown by the ALD and magnetron sputtering are also discussed.

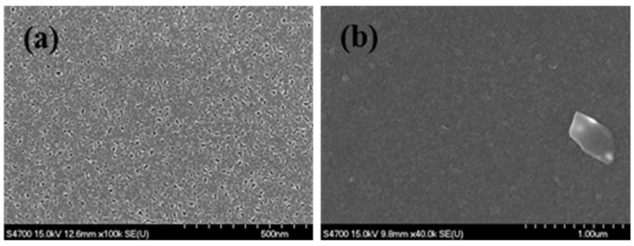

Figure 1. FE-SEM micrograph of recrystallized polycrystalline (a) thin ALD VO_2 film furnace annealed at 450 ºC and (b) thin magnetron sputtering film anealed at 450°C.

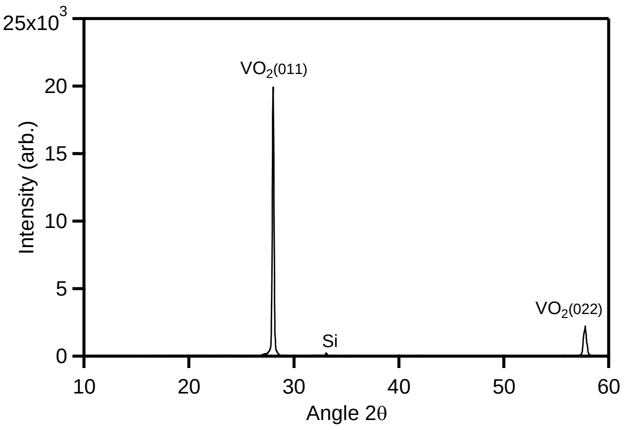

Figure 2. XRD pattern of VO_2 thin films obtained by annealing of magnetron sputtered vanadium films at 600°C under mixture of N_2 and O_2.

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