Preparation of VO_2 ultra-thin films on the hexagonal Boron Nitride and their thicknesses dependence of electrical properties

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Keywords: VO_2, h-BN, ultra-thin film

Vanadium dioxide (VO_2) thin film with a metal-insulator transition (MIT) near room temperature is one of the promising candidates for novel oxide electronic devices such as field effect transistors, sensor etc, and reducing their film thickness is an important breakthrough in the fabrication of high-performance devices. It is well known that the interfacial strain with substrate such as Al_2O_3, TiO_2, plays important role to modulate, often degrade physical properties of films, especially MIT temperature (T_{MIT}). The two-dimensional hexagonal boron nitride (hBN) is one of interesting candidates as a substrate to realize excellent physical properties of films taking advantage of weak van der Waals interaction at their surface. We previous reported bulk like metal-insulator transition in VO_2 film with film thickness of 40 nm [1]. Here, we report their thickness dependence down to 10 nm scale with keeping bulk-like T_{MIT}.

VO_2 thin film were grown on hBN by ArF pulse laser deposition with varying film thickness from 50nm down to 12nm, and their metal-insulator transition behaviour was investigated by Raman spectroscopy and electrical transport measurements. Figure 1 shows the dependence of resistance on temperature for 15 nm VO_2 thin film, which show metal-insulator transition at 66.3℃ similar to bulk T_{MI} with resistance change of over 2 orders of magnitude. Figure 2 shows cross-sectional TEM image of well crystallized VO_2 film with clear lattice fringes, indicating coexistence of monoclinic M_2 phase grow along [201] direction (Fig.2a) and monoclinic B phase grow along [001] direction on hBN (001) plane (Fig.2b). Figure 3 shows the dependence of resistance change ($\rho_{Insulator}/\rho_{Metal}$) during phase transition on film thickness and the inset shows dependence of T_{MI}, in which indicated that VO_2 films keep resistance change ratio and T_{MI} down to 15nm whereas it is reported that metal-insulator transition properties degraded on Al_2O_3 (0001) substrate in the film that thickness is thinner than 100nm [2]. The result suggests that the electrical properties of VO_2 grown on hBN are free from the constrain of substrate owing to weak van der Waals interaction at their surface. Our findings will supply effective reference for the development of oxide thin film devices.

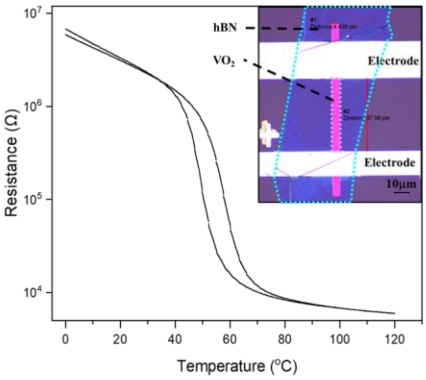

Fig.1 Resistance-temperature curve of VO_2 thin film with 15 nm thickness. The inset shows optical microscope image of VO_2 thin film on hBN with Pt electrodes.

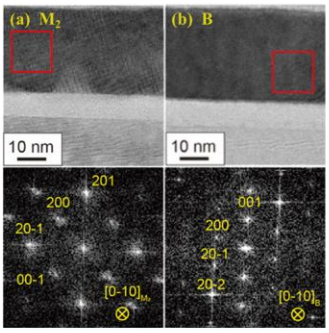

Fig.2 Cross-sectional STEM images of VO_2 film, (a) monoclinic M_2 phase, (b) monoclinic B phase.

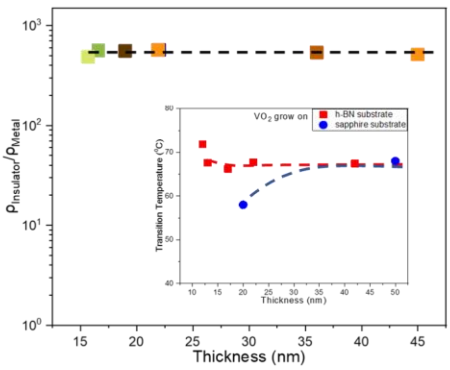

Fig 3. The dependence of resistance change ($\rho_{Insulator}/\rho_{Metal}$) during phase transition on film thickness, and the inset shows dependence of T_{MI}.

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[2] H. T. Zhang et al, Nat Comm. 6 (2015) 8475