Optical anisotropy of pristine and reduced V2O5(010)

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The vanadium-oxygen system consists of four single valence phases as well as a range of mixed valance phases. Many of the phases exhibit a semiconductor-to-metal transition linked to the strongly correlated nature of the vanadium 3d electrons. VO2 sees application in electronics and uncooled bolometers due to its semiconductor-to-metal transition close to room temperature and V2O5 is intensively researched for gas sensing and supercapacitor technologies. V2O3 has received interested as a strongly electron correlated semi-metal with p-type conductivity and increased visible optical transparency due to electron correlation shifting the screened plasma energy [1,2]. The reduction of single valance phases is complex resulting in the coexistence of multiple phases that can be close in stoichiometry but exhibit drastically different electronic and optical properties. This is a challenge but can also be utilized in resistive switching, for example [3].

In this work, the optical anisotropy of pristine and reduced single crystalline (010) orientated V2O5 is presented. Reflectance anisotropy spectroscopy (RAS) measures the difference in reflection along two orthogonal surface directions and provides a non-destructive probe that can be employed in real-time to monitor changes in thin films. Pristine orthorhombic (010) orientated V2O5 exhibits strong reflectance anisotropy with significant features beyond the optical bandgap of 2.5eV. The spectra is well described by the resolved optical constants extracted by ellipsometry. Vacuum annealing has been performed at four different temperatures and X-ray Diffraction and RAS have been conducted after each anneal. Depending on the anneal temperature, different phases are introduced into the V2O5 crystal including V4O9, V6O13 and VO2. Spectral features of each of these phases are identified. V6O13 is understood in terms of the axially resolved optical constants from the literature, while isotropic VO2 modifies the total reflection once it undergoes it’s semiconductor-to-metal phase transition at 340 K. This understanding of the optical response of the ideal single crystal facilitates applying RAS to monitor the growth and changes of V2O5 thin films in-real time.

1. Ainabayev, A, et al. "High-performance p-type V2O3 films by spray pyrolysis for transparent conducting oxide applications." *Scientific Reports* 14.1 (2024): 1928.
2. Hu, L., et al. "Exploring high-performance p-type transparent conducting oxides based on electron correlation in V2O3 thin films." *Physical Review Applied* 12.4 (2019): 044035.
3. Walls, B, et al. "VOx Phase Mixture of Reduced Single Crystalline V2O5: VO2 Resistive Switching." *Materials* 15.21 (2022): 7652.