Novel Quantum Materials for Low Power Electronics

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Global energy consumption is increasing rapidly due to the proliferation of electronic devices, causing sustainability concerns, thereby requiring the use of new semiconductor materials. The quantum material Vanadium Dioxide (VO2) is a prime candidate, as it undergoes a sharp insulator-to-metal phase transition (IMT) near room temperature (67ºC) and can act as a switch. The IMT can be optimized by electron doping using tungsten (W 6+). Currently, there are few models for determining the properties of this alloy material, given its complex electronic properties. Further, characterization of materials containing low dopant concentrations is challenging. In this study, linear models were developed based on experimental data collected from literature review to define the relationships between composition (dopant atom-percent concentration, ionic radius) and IMT properties (transition temperature, threshold voltage, activation energy). The linear models demonstrate that transition temperature and threshold voltage reduce as W concentration increases (~21K/at. % and ~19.6V/at. % respectively). These models were compared with impurity conduction theory and were found to agree at doping concentrations <1.8 at. %. Threshold voltage for IMT displays a similar trend as IMT temperature, suggesting that their mechanisms are related. Rutherford Backscattering Spectroscopy (RBS) was simulated using SimNRA and was determined to be a powerful method for characterizing the concentration of tungsten doped VO2 thin films. The models predict that power consumption per device could reduce as much as 76%. The results from this study have established a quantitative relationship between impurity doping, transition temperature, and threshold voltage reduction to design low power electronics.