Annealing induced modulation of joule heating based metal-insulator transition point of VO_2 nanobeams for smart nanodevice applications

S. Rathi[1], Jinhyung Park[1], Inyeal Lee[1], Min Jin Kim[2], Jeong Min Baik[2], Kyung Soo Yi[3] and Gil-Ho Kim[1]

[1]*Department of Electronic and Electrical Engineering and Sungkyunkwan Advanced Institute of Nanotechnology (SAINT), Sungkyunkwan University, Suwon 440-746, Korea*
[2]*School of Mechanical and Advanced Materials Engineering, Ulsan National Institute of Science and Technology (UNIST), Ulsan 689-805, Korea*
[3]*Department of Physics, Pusan National University, Busan 609-735, Republic of Korea*

Of all correlated transition metal oxides, vanadium dioxide (VO_2), transition temperature (T_{IMT}), at which transition from insulator to metal phase (IMT) occurs, is closest to room-temperature (67 ^oC), which makes this material interesting for potential technological applications including sensors and memristors.[1]
Joule heating based transition is one of the simple and common method to induce IMT in VO_2 nanobeams (NBs).[2] However, the voltage at which Insulator to Metal Transition (V_{IMT}) occurs is susceptible to processing and fabricating conditions, though its accurate determination and control is at the heart of devices like sensors and switches based on VO_2.

In this work, the effect of annealing conditions on VO_2 NBs having average width of 300 nm, have been studied through voltage and temperature induced hysteretic plots, Fig.1. Our analysis shows that annealing conditions have a profound impact on the V_{IMT} values through a simultaneous variation in both NBs conductivity and T_{IMT} values. The results obtained were also confirmed by a mathematical model. These variations in V_{IMT} and T_{IMT} are possibly due to oxygen deficiency induced monoclinic lattice defect and doping behavior of oxygen vacancies in the resulting nonstoichiometric VO_2 NBs. These finding can be very useful for device engineers who can not only control V_{IMT} point, albeit at the cost of minor trade-off (variation in conductivity and T_{IMT} point), but can also scale down voltage supply for prospective low-voltage sensors applications.

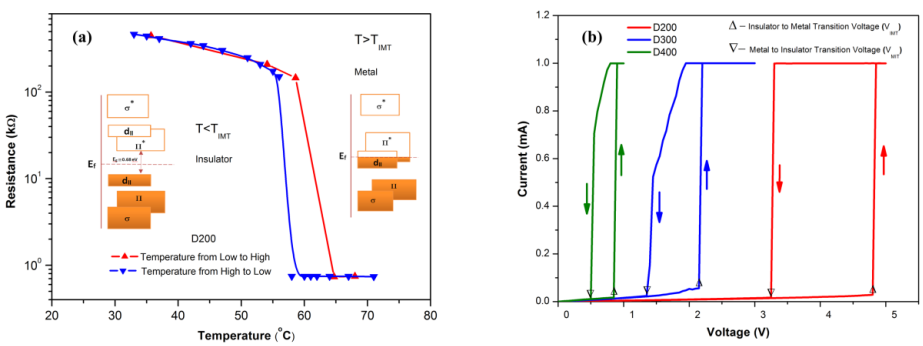

Fig. 1. (a) Temperature hysteretic plot of VO_2 NB, annealed at 200 ^oC, 1 minute in Argon ambient. [inset showing energy band diagrams in insulating and metallic phase], **(b)** Variation in V_{IMT} point of VO_2 nanobeams following Rapid Thermal Annealing (RTA) at 200 ^oC (D200), 300 ^oC (D300), 400 ^oC (D400) in Argon ambient for 1 minute, with compliance set at 1.0 mA to avoid thermal breakdown.

[1] Z. Yang, C. Ko, and S. Ramanathan, Annu. *Rev. Mater. Res.* **41**, 337 (2011).
[2] J. W. Byon, *et al. Jour. Phy. Chem. C.* **116**, 226 (2012).