Effect of Temperature and Device Size on the Switching Voltage of LCO Devices

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Abstract

Insulator-to-metal transition (IMT) materials have boundless possibilities for application because of their simple ability to switch from an insulating to metal state by changing a device's temperature or size. Lanthanum cobaltite (LCO) is an IMT material of particular interest because of its high switching speed, low transition temperature, high thermal stability, and large resistivity change. Here, we characterized the variation in switching threshold voltage of the lattice-matched MBE-grown LCO thin film devices with temperature and size. Threshold voltage was determined by performing a voltage sweep across the devices while measuring the resultant current.

Introduction

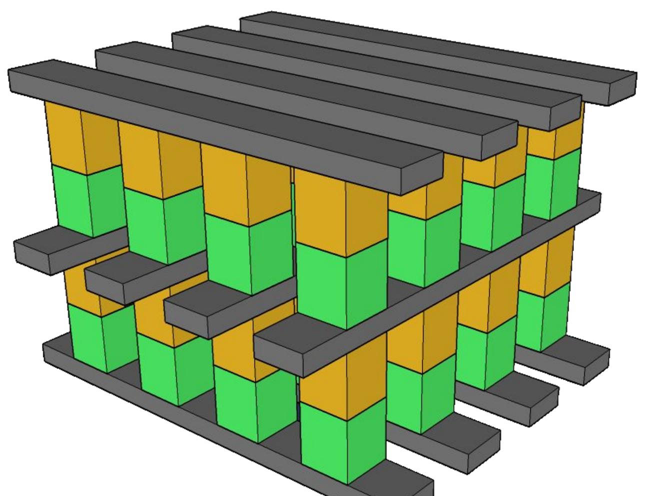

Fig 2. 3D Cross-Point Memory [4]

LCO belongs to a family of transition metal oxides where IMT properties are common. LCO is the most promising material because of its significantly larger change in resistivity per change change in kelvin and a switching temperature practical for use in electronics. When LCO increases in temperature from 200K to 400K there is a change in electron configuration and electron spin state from low to high [1,2]. This change to the molecules electron structure changes the materials ligand structure and also lowers the band gap [3]. With the band gap lowered, electrons are move easily able to move from the valence band to the conduction band and the materials resistivity is lowered.

Device Fabrication

LCO Devices were made by first depositing a thin film of LCO on lattice matched LaAlO3 substrate using MBE. The individual LCO devices were patterned and then etched using reactive ion etching. The palladium contact electrodes and pads were then patterned using electron beam lithography, deposited via evaporation, and patterned using photolithography.

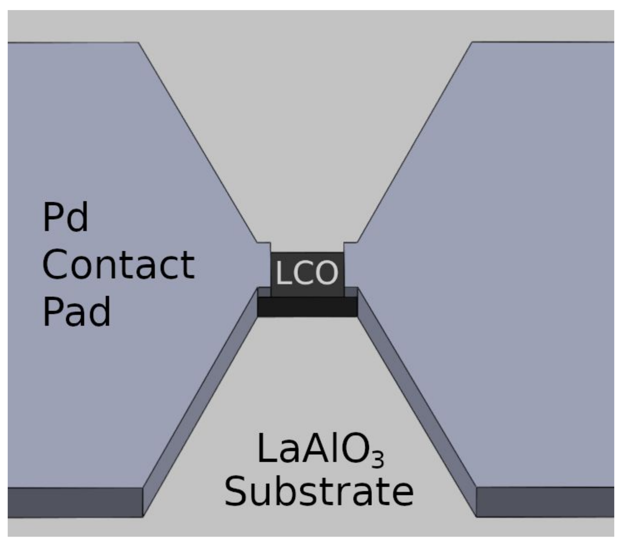

Fig 3. Render of LCO Device

Methods

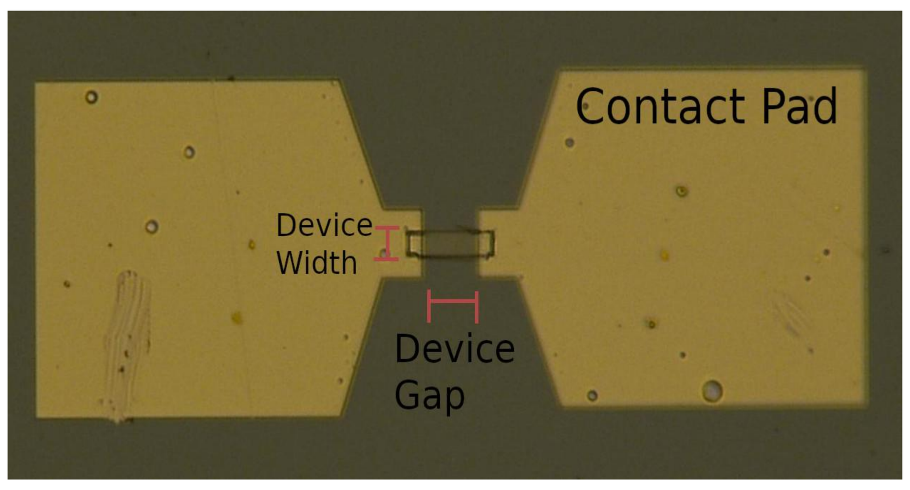

Fig 4.A. Image of LCO Device

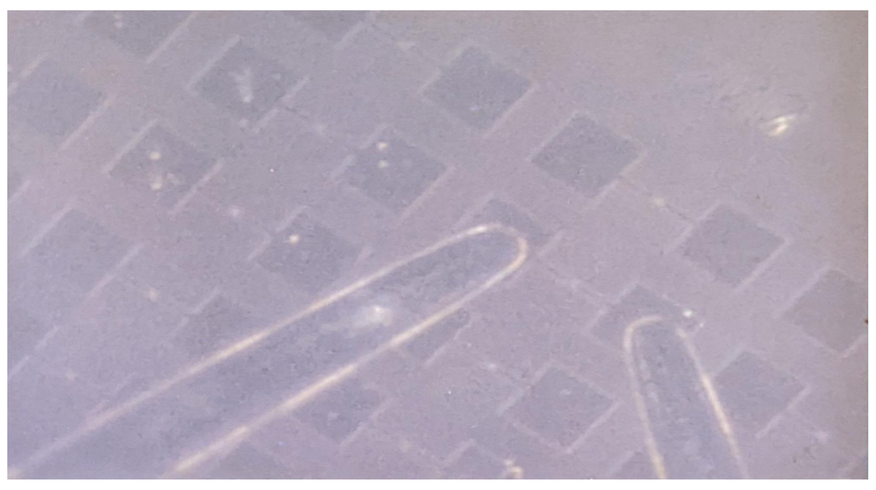

Fig 4.B LCO Device with probes on contact pads

Each device had a voltage swept across it using a LakeShore cryogenic probe station and Keysight B1500A while measuring the resultant current. For devices with a gap of less than 2µm the voltage range was -10V to 10V with a compliance of 1mA and larger devices used a voltage range of -15V to 15V and compliance of 3mA. Both voltage ranges used a step size of 100mV. The devices were measured in 25K increments from room temperature to 475K. The probe station also allowed us to heat the substrate and maintaining a vacuum to minimize temperature fluctuations.

References

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Support Information

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Results

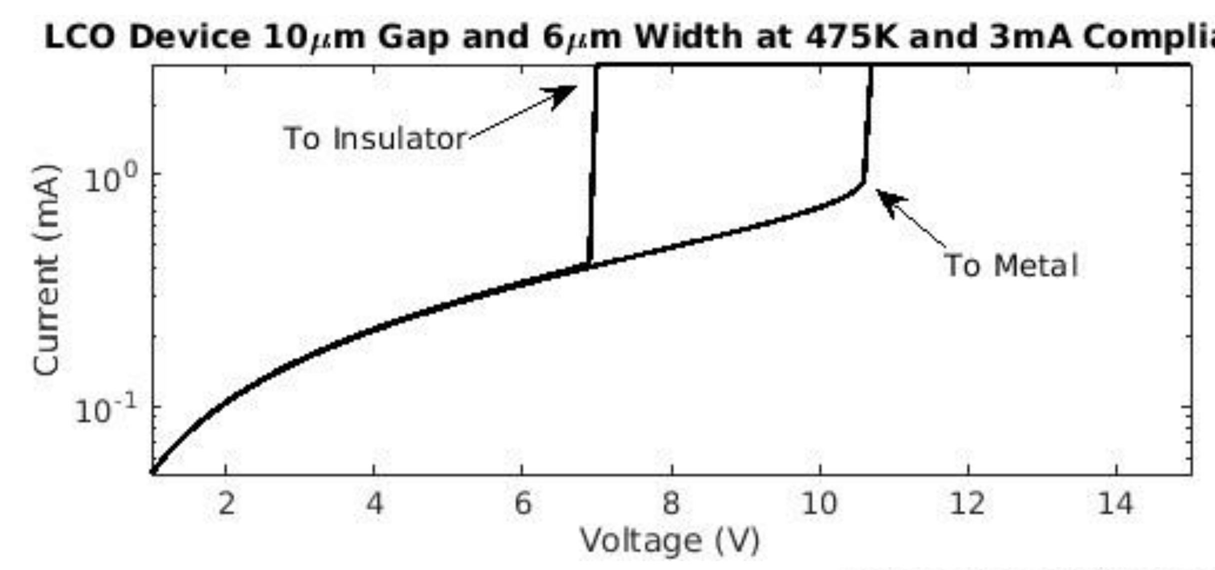

Fig 1.A. Typical device transition with the Y axis plotted in the log scale.

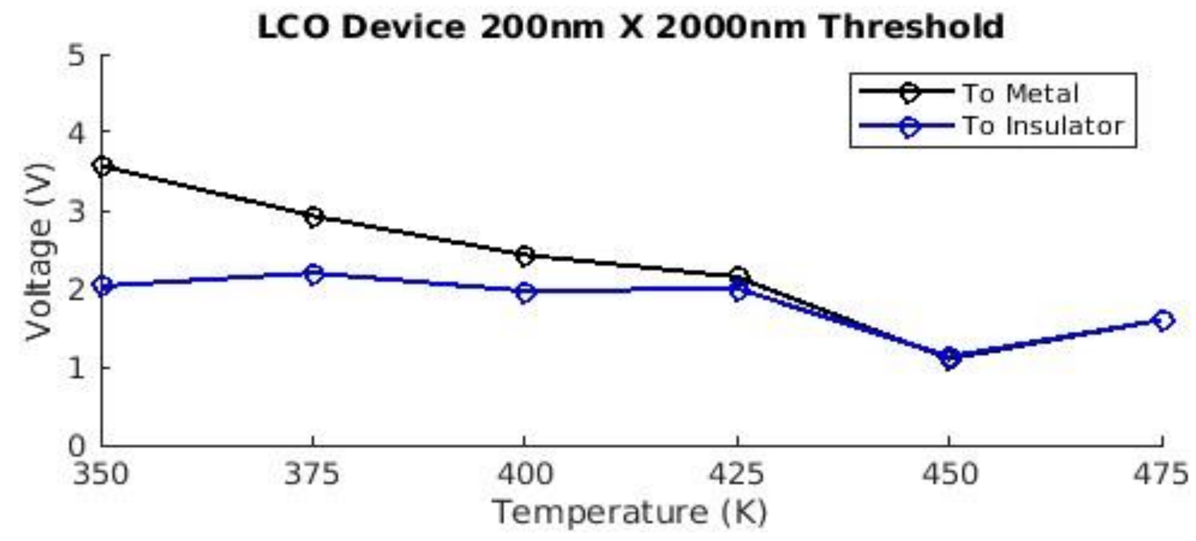

Fig 1.B. One LCO device variation in threshold voltage plotted as temperature is changed in 25K increments.

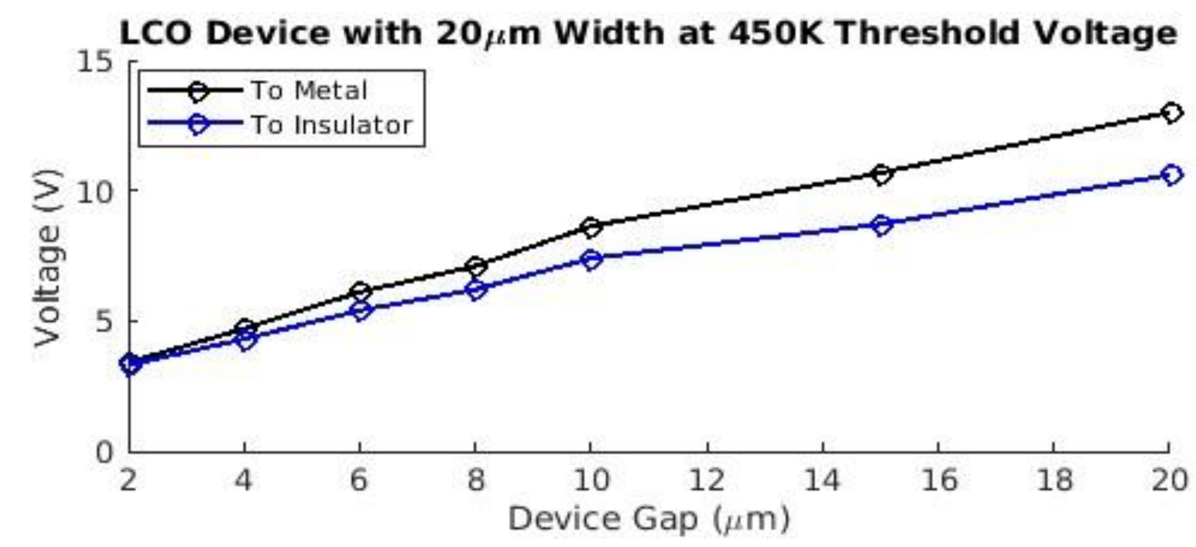

Fig 1.C. Threshold voltage of LCO devices with 20µm widths plotted as device gap is increased from 2µm to 20µm.

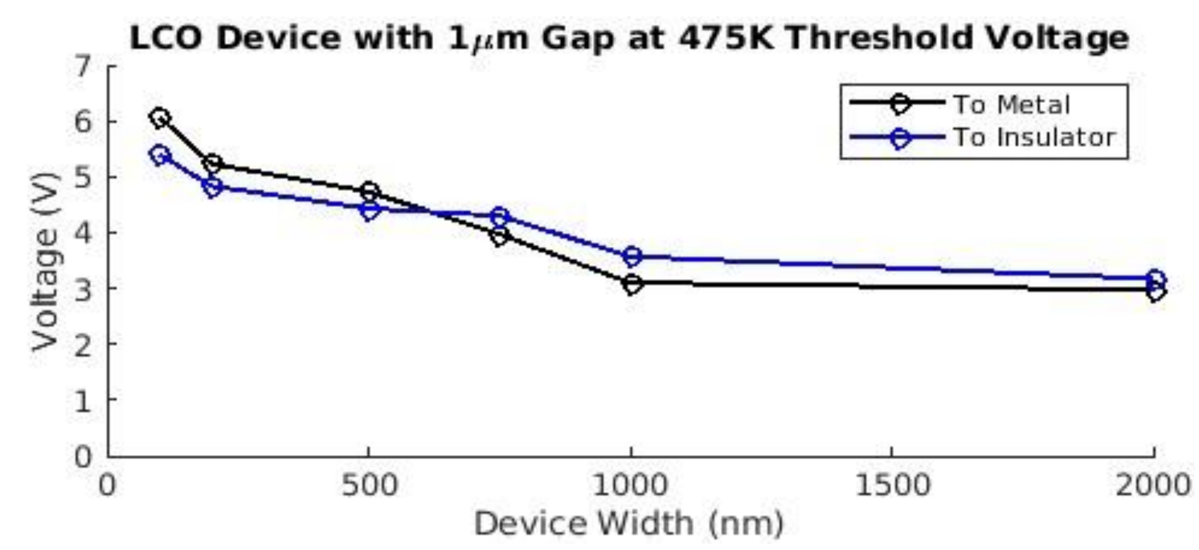

Fig 1.D. Threshold voltage of LCO devices with 1µm gap plotted as device width is increased from 100 nm to 2000 nm.

Conclusion

Changing an LCO device's gap or width allows for easy engineering of characteristics to meet the requirements of many applications. LCO Devices have also been shown to predictably transition across a wide temperature range.

- -Threshold voltage trends down as device gap is lowered and as device width or temperature is raised.
- -Device hysteresis diminished as threshold voltage lowered
- -The range for threshold voltage was from 1.1V to 14.8V.
- -The smaller a device was the lower its starting and last measurable threshold voltage would be.

The next important steps to make LCO devices ready for broad implementation is to determine switching speed, perform device durability testing, and amperage ratings. Building simulations will also help to deepen the understanding of these devices.

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