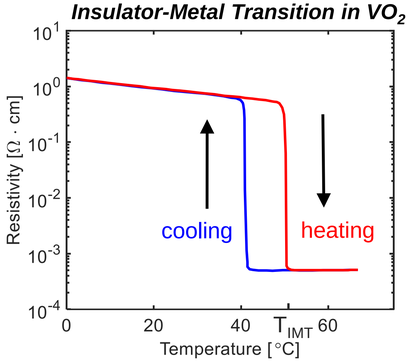
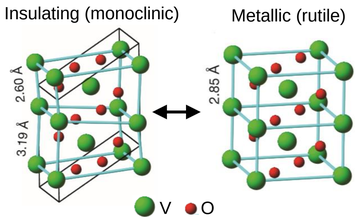
Insulator-Metal Transitions (IMTs)

- Insulator-metal transition (IMT) materials exhibit an abrupt change in resistance by orders of magnitude, attractive for nanoelectronics
- Triggered by Joule heating in devices and accompanied by changes in lattice, optical, and thermal properties

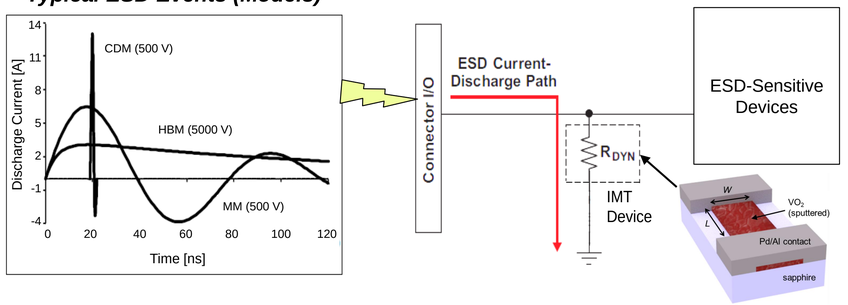
Insulator-Metal Transition in VO_2





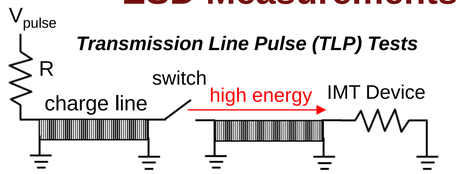
Application: Electrostatic Discharge (ESD) Protection

Typical ESD Events (Models)



- ALL chips require ESD protection clamps that rapidly short to divert large currents away from sensitive circuits, then return to insulating once ESD is over
- IMTs could form bidirectional ESD clamps that could save chip area
- Can IMT devices withstand the high energies of an ESD event?

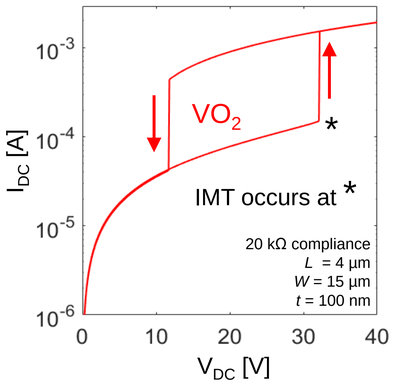
ESD Measurements of IMT Devices



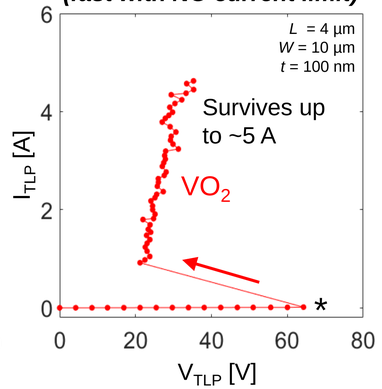
Transmission Line Pulse (TLP) Tests

- Increasingly high energy pulses (100 ns width) for evaluating ESD reliability

Classic DC Testing (slow with current limit)



ESD Testing (fast with NO current limit)



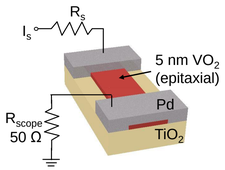
- VO_2 and NbO_2 devices have a high maximum current carrying capability in their metallic state (pushed to failure)
- Performance and IMT trigger voltage engineered via geometry

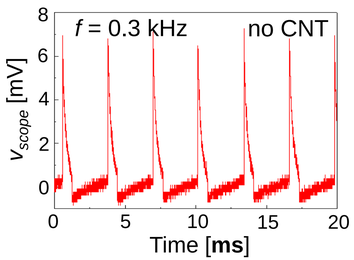
S.M. Bohaichuk, *et al.*, *IEEE Electron Dev. Lett.*, **41**, 292-295 (2019).

Application: Neuron-Like Oscillators

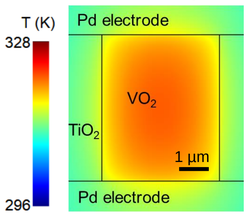
- Brain-inspired computing needs compact sources of neuron-like spiking, and IMT devices can output self-sustained oscillations between insulating and metallic
- How can their size, frequency, and power efficiency be improved?

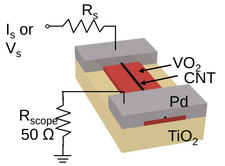
Integration of Carbon Nanotubes (CNTs) in VO_2 Oscillators

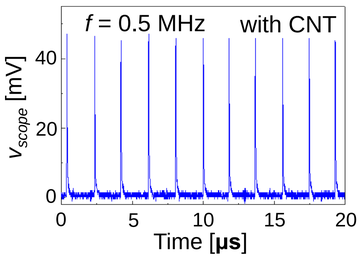




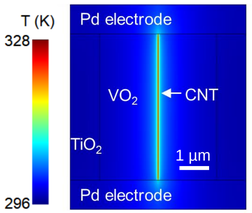
Simulated Surface Temperature



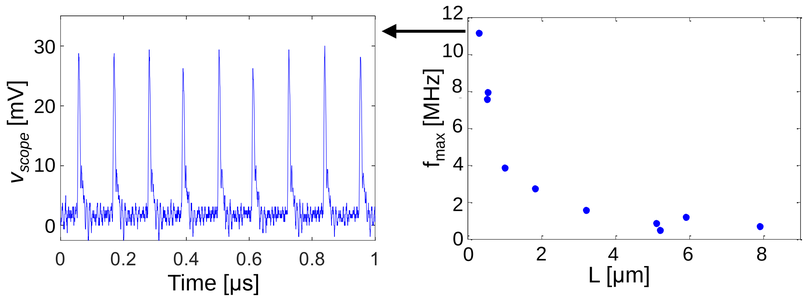




Simulated Surface Temperature



Scalability of VO_2 + CNT Devices



- A ~1 nm diameter CNT heater on VO_2 localizes heating and the IMT, resulting in 1000X higher frequency spiking
- By shrinking device length, can obtain frequency >10 MHz

S.M. Bohaichuk, *et al.*, *Nano Letters*, **19**, 6751-6755 (2019).

Acknowledgements

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Summary

- IMT devices are viable for ESD protection with a fast, temporary metallic transition and high current capacity
- Thermally engineering IMT devices (e.g. adding a CNT heater) results in fast spiking for use in brain-inspired computing

Future Work

- Optimization for ESD reliability and low off-state current
- Coupling of IMT oscillators for performing computation

S. Bohaichuk

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