Study of Insulator-Metal transition of VO_2 thin films with ultrafast optical pulses

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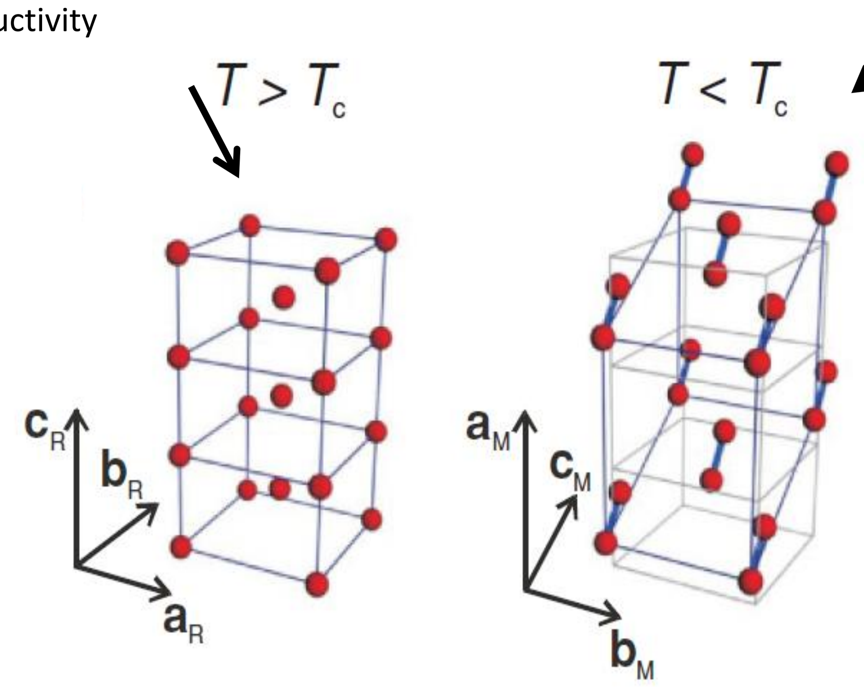
Abstract

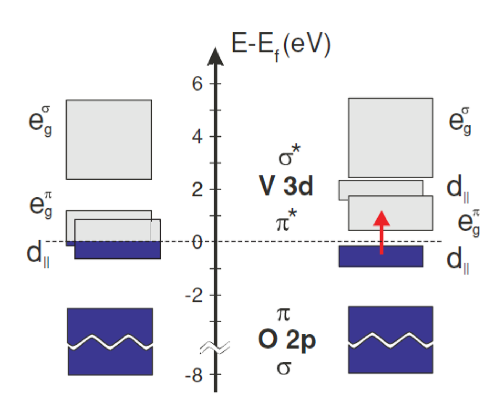
VO_2 has been a popular material to study in the past few decades as it has a reversible insulator-metal transition (IMT) when heated past 340K or stimulated with an ultrafast optical pulse. The resistance and optical properties change by several orders of magnitude, making it an attractive candidate for low loss plasmonic devices, ultrafast switches, or smart windows. We study the dynamics of the transition of VO_2 thin films on different substrates with femtosecond pulses in a pump-probe experiment in order to better understand the mechanisms behind the transition. We have measured the IMT at several different temperatures to investigate any change in the dynamics of the transition. We also study the Raman spectroscopy of VO_2 thin films heated through the transition. The effects of the different substrates on the transition of the VO_2 thin film will be discussed.

Insulator-Metal Transition

High temperature rutile phase: Large increase in conductivity

Low temperature monoclinic phase





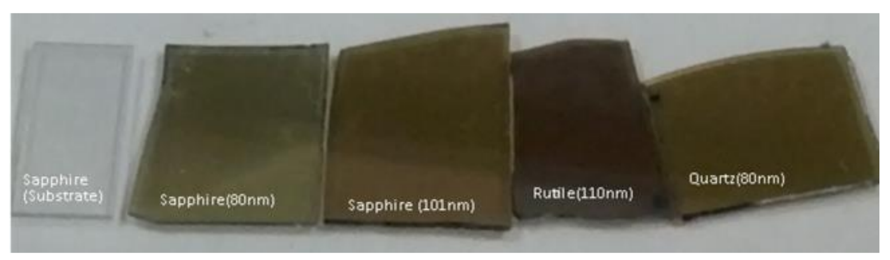
Electronic band structure change narrows band gap.

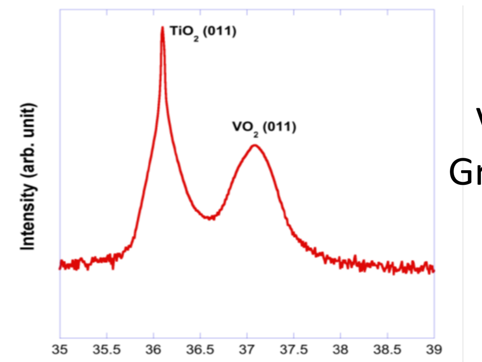
[1] a. Pashkin, C. Kübler, H. Ehrke, R. Lopez, a. Halabica, R.F. Haglund, R. Huber, and a. Leitenstorfer, Physical Review B **83**, 195120 (2011).

Samples

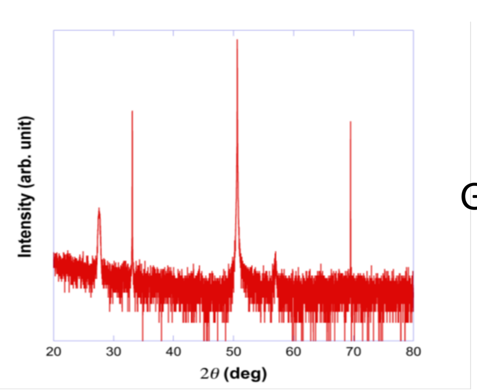
Thin films of VO_2 grown by sputtering

Three different substrates: quartz (SiO_2), sapphire (Al_2O_3), Rutile (TiO_2)

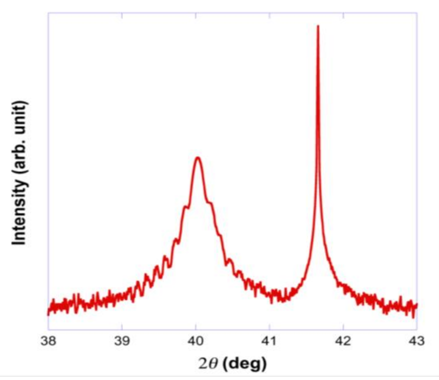




VO_2 on Rutile
Grain size ~10nm

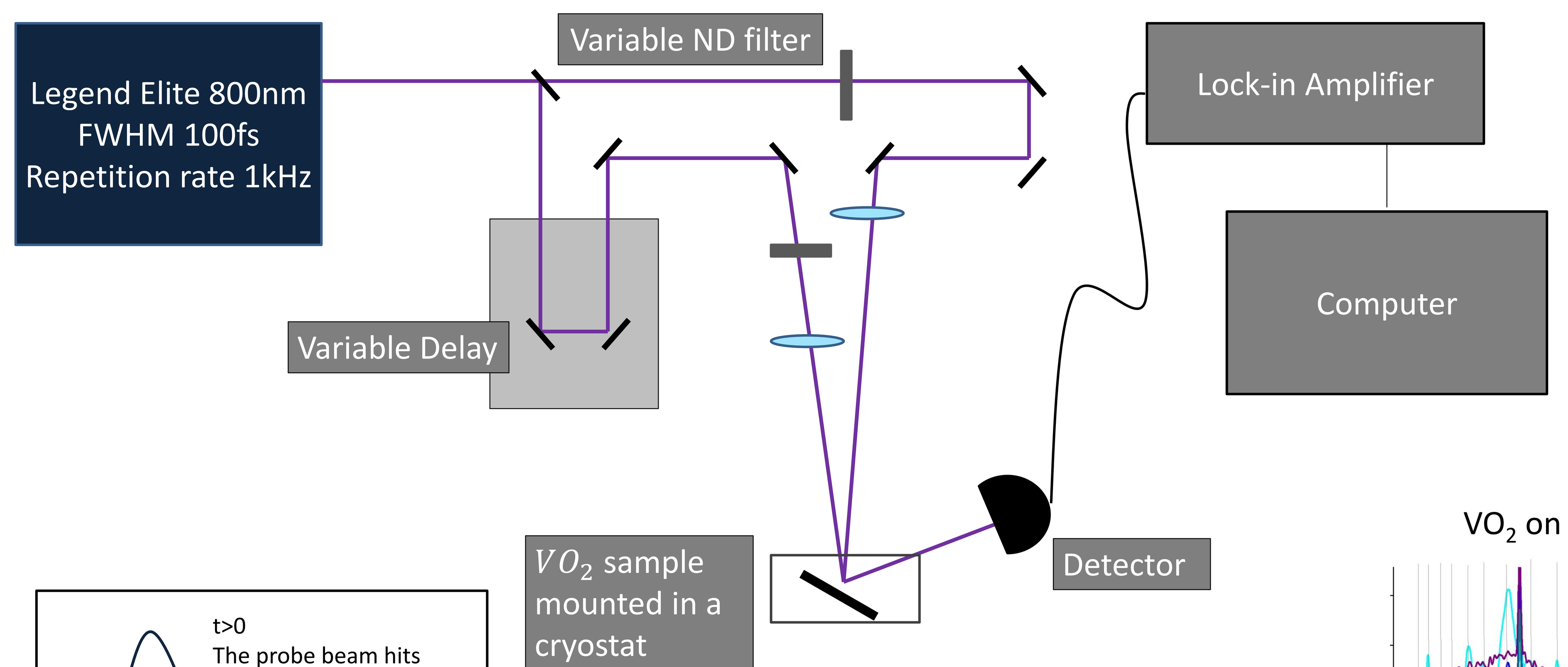


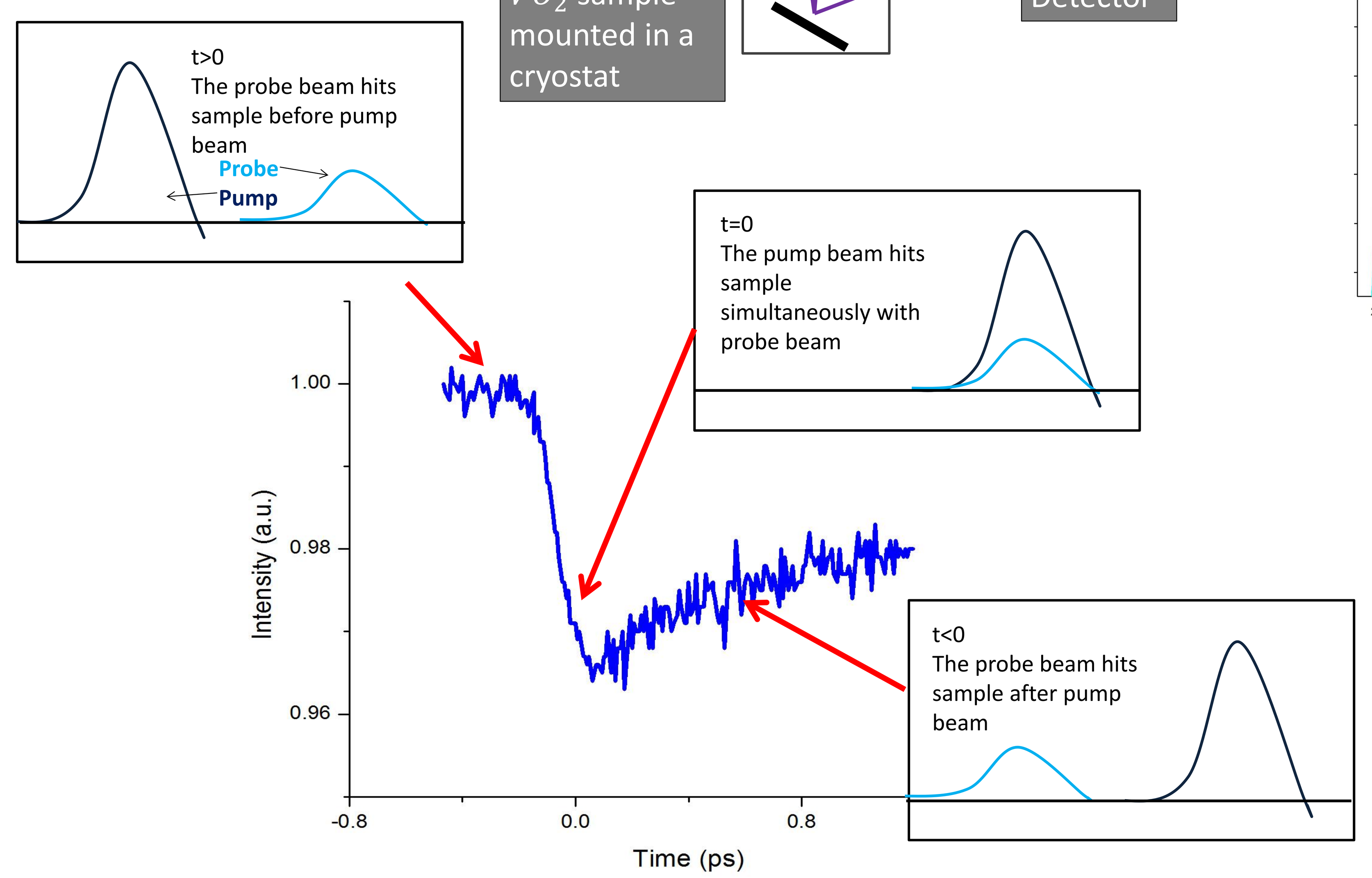
VO_2 on Quartz:
Grain Size ~70nm

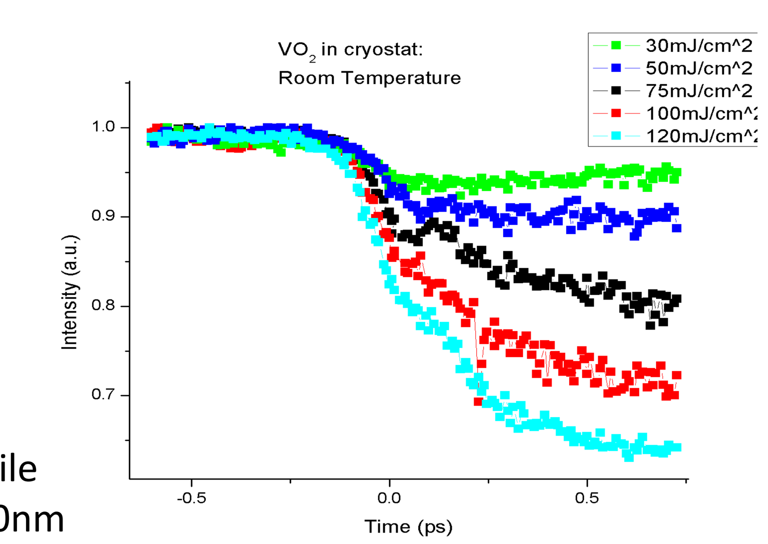


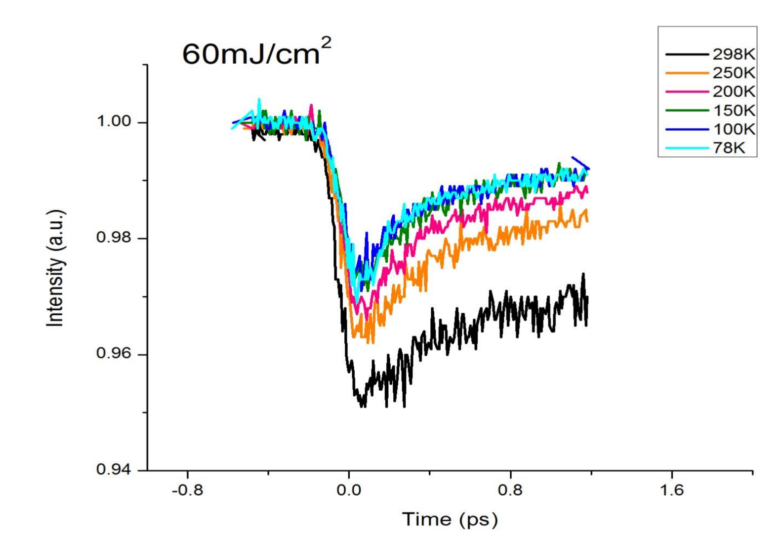
VO_2 on Sapphire
Grain Size ~20nm

Ultrafast Measurement



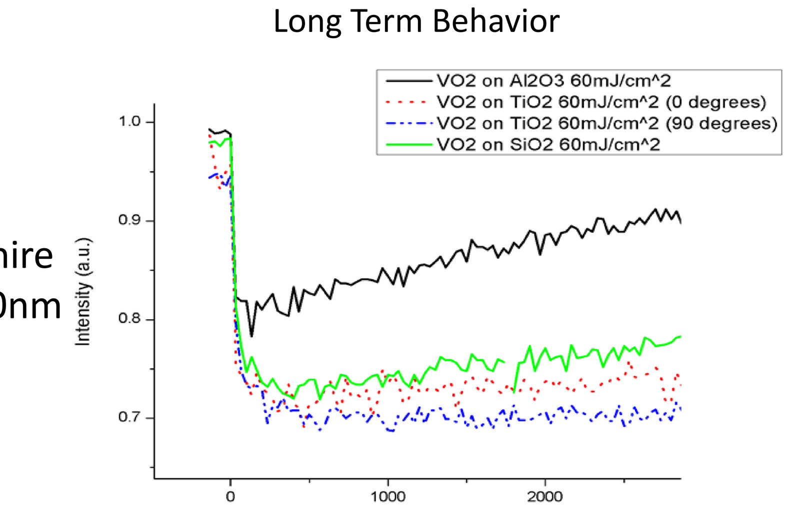




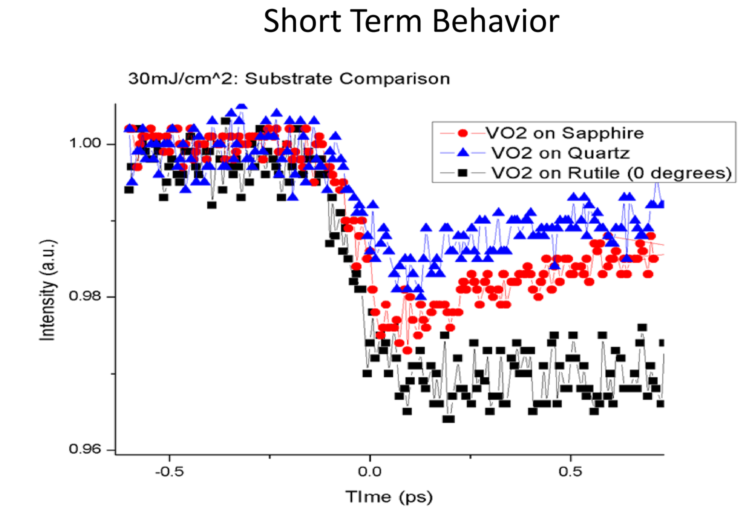


Substrate Effects

Long Term Behavior

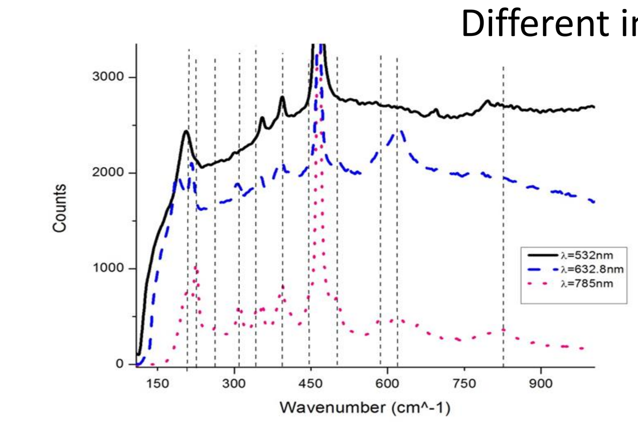


Short Term Behavior

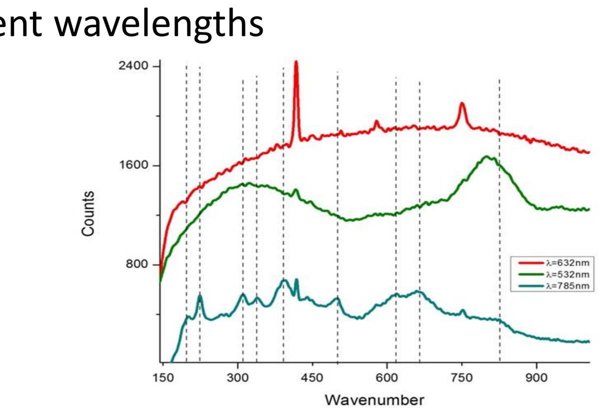


Raman Spectroscopy of VO_2

Different incident wavelengths



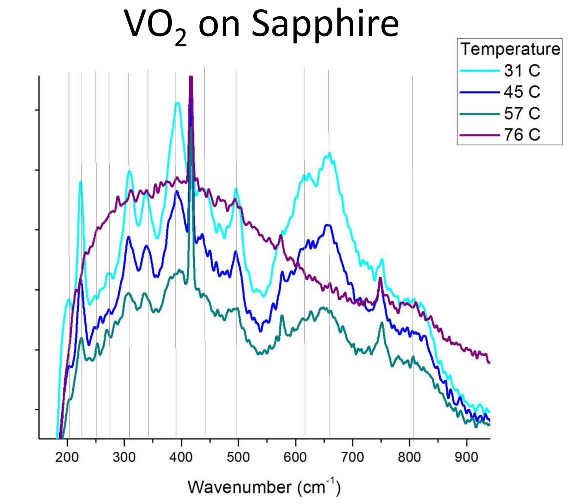
VO_2 film on Quartz



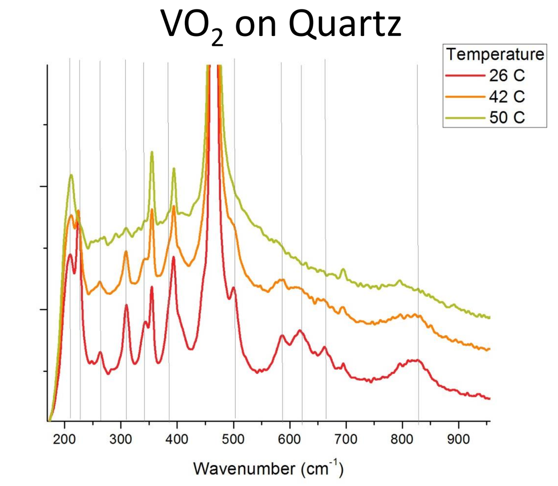
VO_2 film on Sapphire

Raman Spectra through IMT

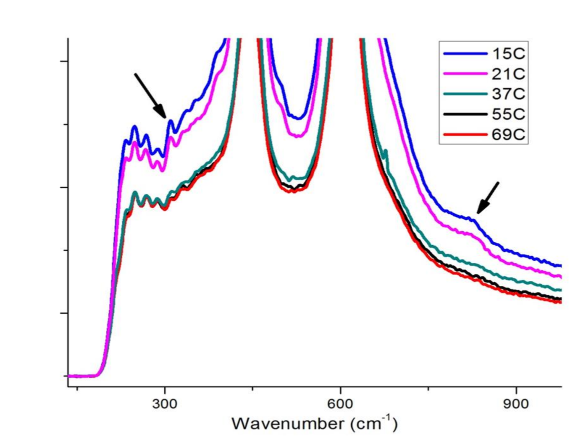
VO_2 on Sapphire



VO_2 on Quartz

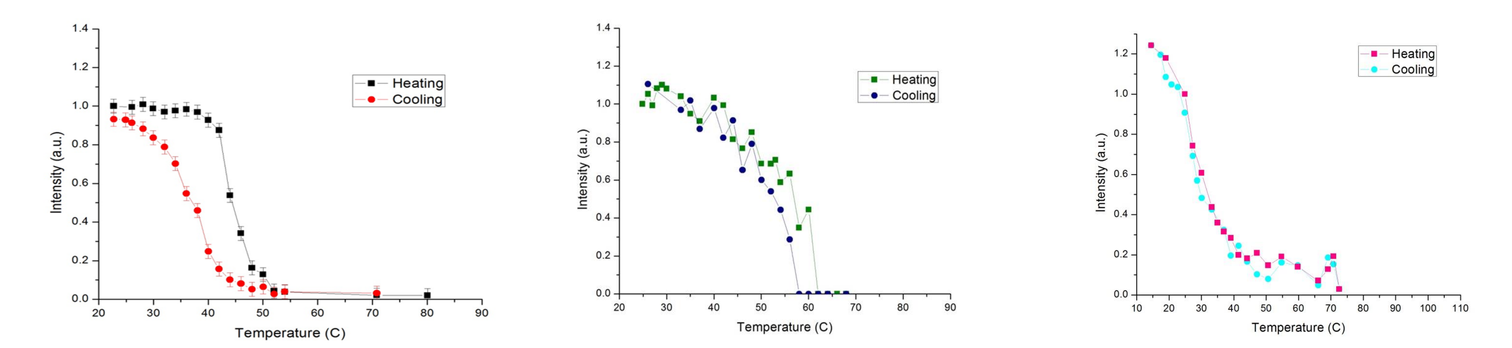


VO_2 on Rutile

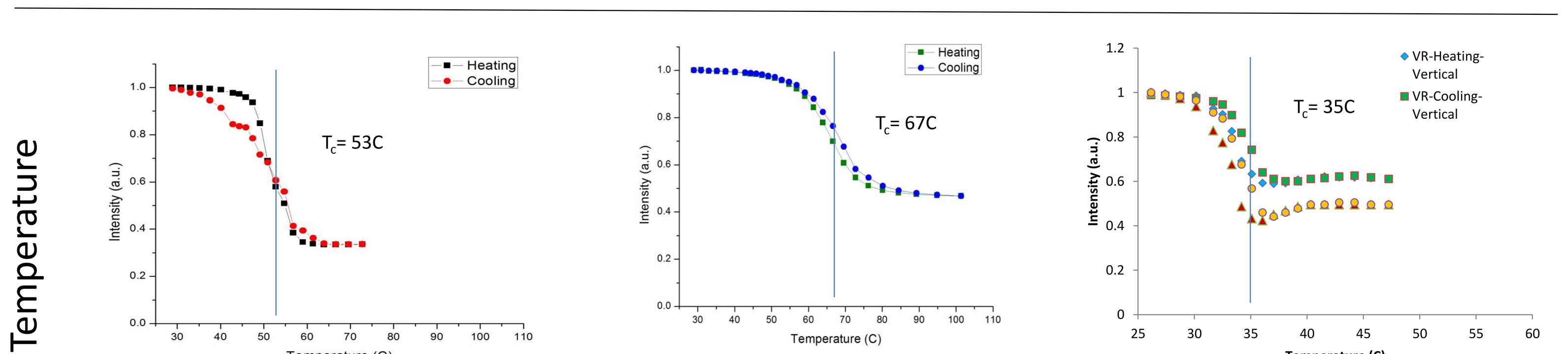


Raman Peak amplitude and cw Optical Reflection Measurements

Raman Peaks vs. Temperature



CW Reflectivity vs. Temperature



VO_2 on Quartz | VO_2 on Sapphire | VO_2 on Rutile

Conclusion

We have compared the different behavior of films grown at different substrates. By looking at the response from the time dependent measurement , the change in amplitude of the Raman spectrum, and the change in intensity of reflectivity associated with IMT, we find a strong dependence on differences in microstructure. In future studies, we will study further how the ultrafast response and recovery differs for films with different strain and microstructure.

Acknowledgements

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