A System for measuring Temperature dependent Surface Photovoltage

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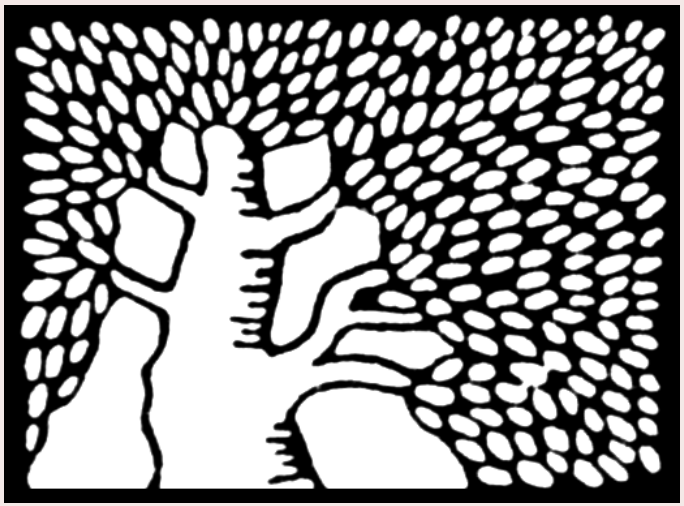
Outline

Some Background

About my M.Sc. project...

- Research carried out in 13/14 at The Weizmann Institute of Science
- Project had two parts: P(VDF) & SPV(T)
- Only part two will be presented



Motivation

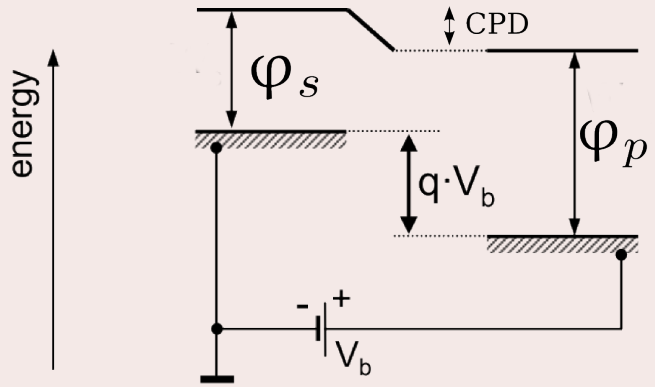
The goal of this project is to...

- verify results from a 'new' experimental set up against established systems
- expand the capabilities of the 'new' set up
- ultimately measure temperature dependent SPV

Physical Causes of CPD & SPV

The Kelvin Probe

$$
\begin{aligned}
\text{CPD} &\equiv \varphi_{\text{Probe}} - \varphi_{\text{Sample}} \\
C(t) &= \frac{\epsilon\epsilon_0 A}{d(t)} \\
I(t) &= \frac{dQ}{dt} = (\text{CPD} + V_b)\frac{dC}{dV} \\
I(\Delta V) &= -\epsilon\epsilon_0 A(\text{CPD} + V_b)\, f(\omega t)
\end{aligned}
$$



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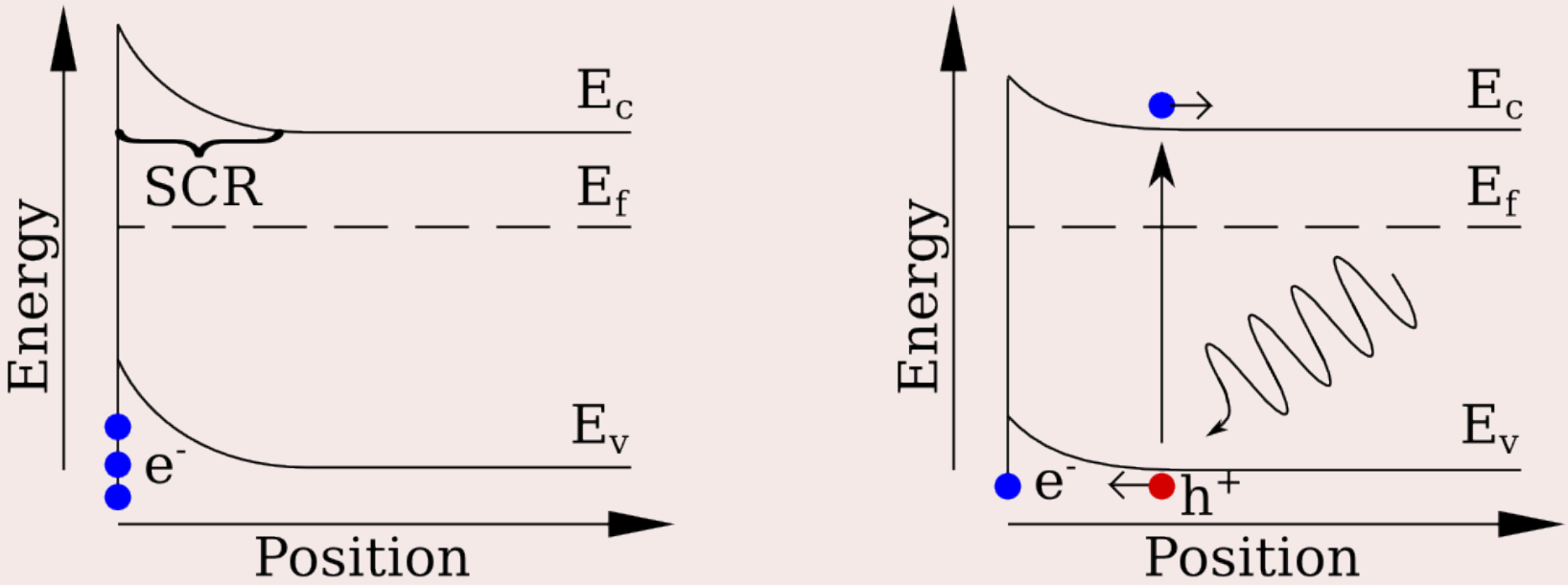
Physical Causes of CPD & SPV

Band bending & SPV: dark vs. light

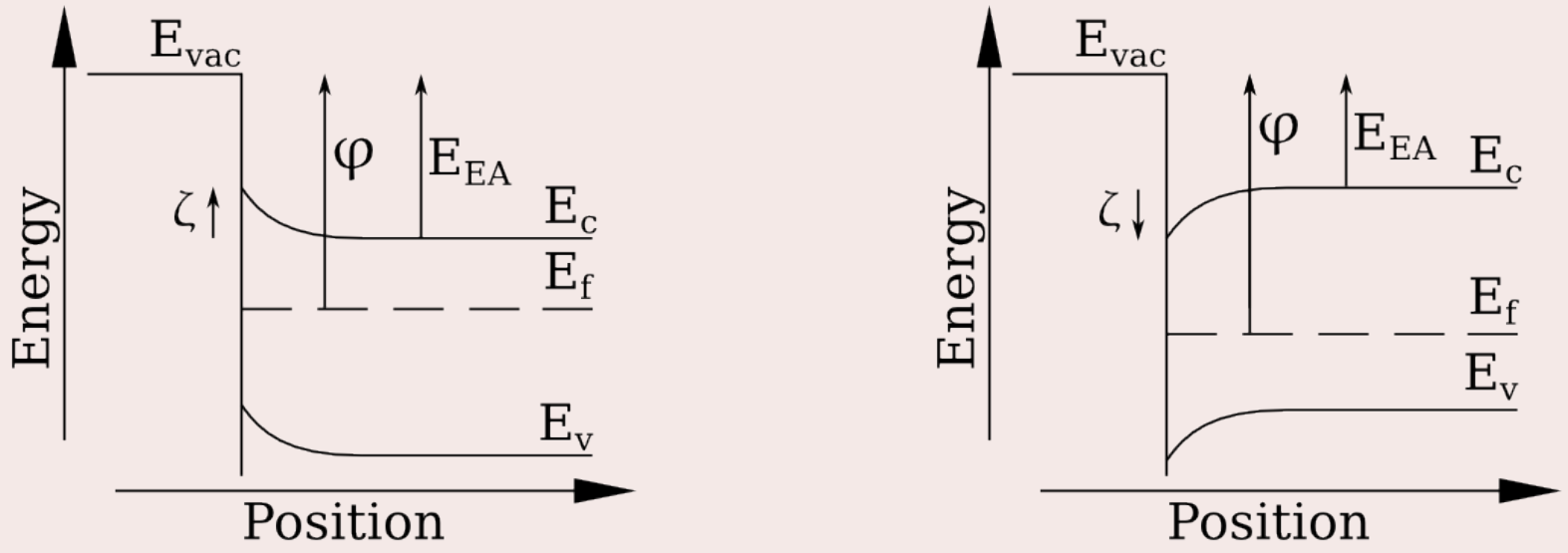
$$SPV \equiv CPD_{light} - CPD_{dark}$$



Physical Causes of CPD & SPV

Band bending & SPV: n-type vs. p-type

$$SPV \equiv \varphi_{s,dark} - \varphi_{s,light}$$

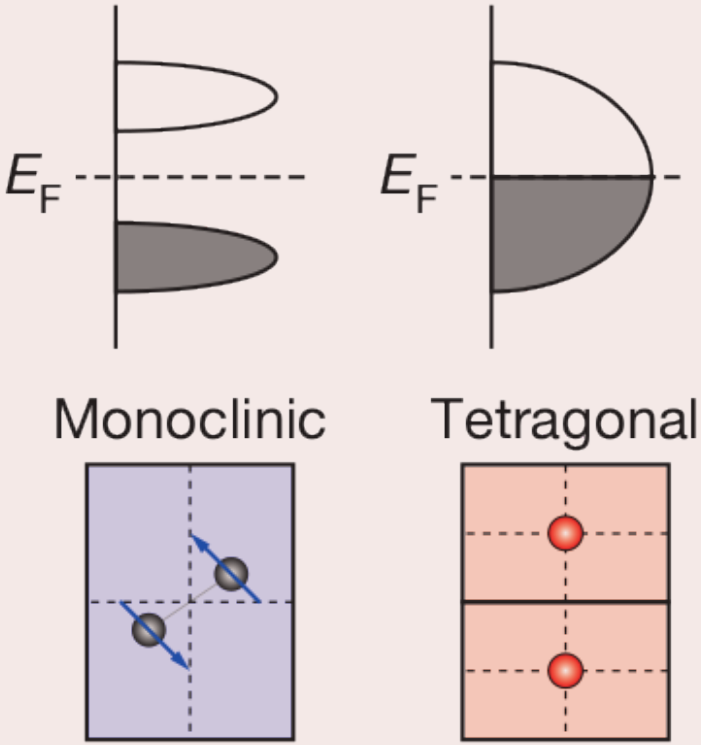


$SPV_{n\text{-}Type} > 0$ $SPV_{p\text{-}Type} < 0$

Choosing a Model System

Metal Insulator Transition in VO_2

- metal at $T > T_{MI}$
- semiconductor at $T < T_{MI}$
- insulator at $T \ll T_{MI}$
- Influences of W-doping:
  - $T_{MI} \approx 270\,\mathrm{K}$ [2]
  - $\varphi \approx 5.15\,\mathrm{eV}$ [3]



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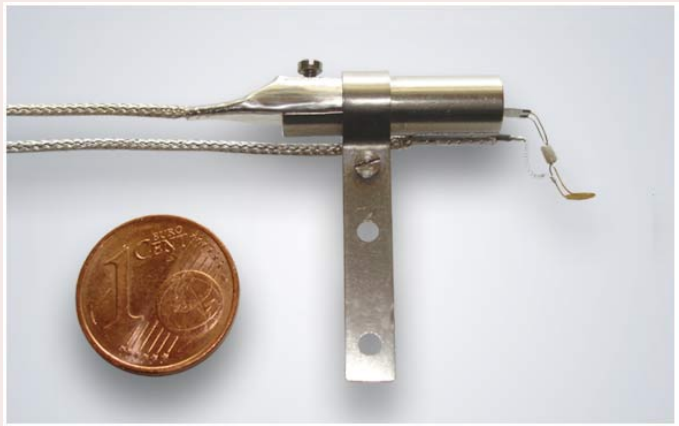
Established KP Systems

Ambient & Glovebox KPs

- Besocke KP head & controller
- Humidity controlled ambient
- Glovebox (< 5ppm O_2 & H_2O)
- Xenon lamp & VariAC ($\sim$80 W)
- Illumination is source of heat!



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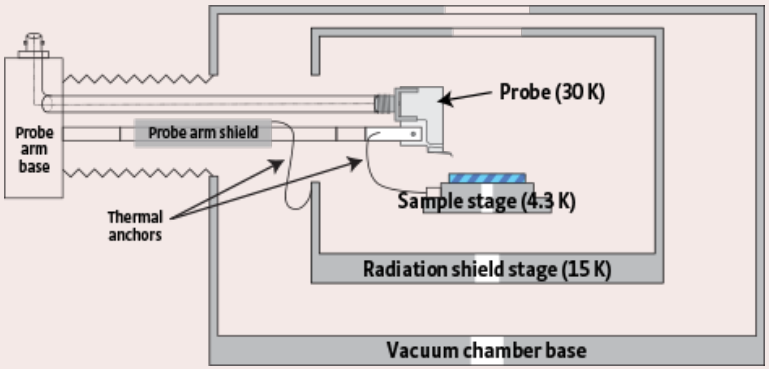
Cryogenic System with a KP

Lakeshore with Mc Allister & LED



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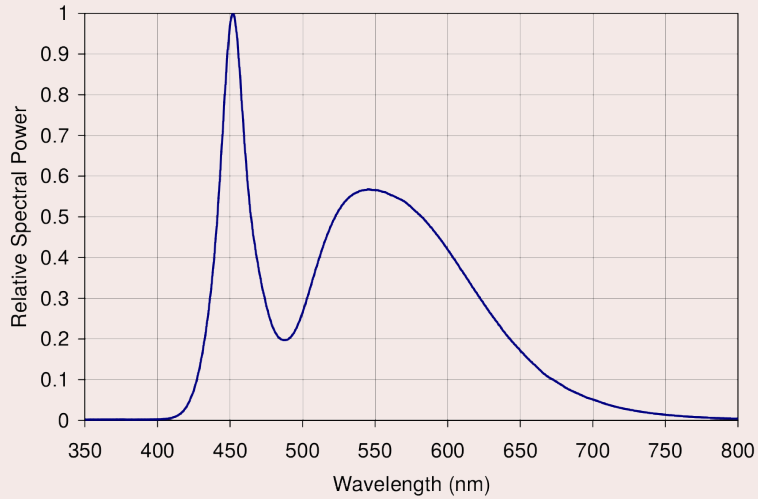

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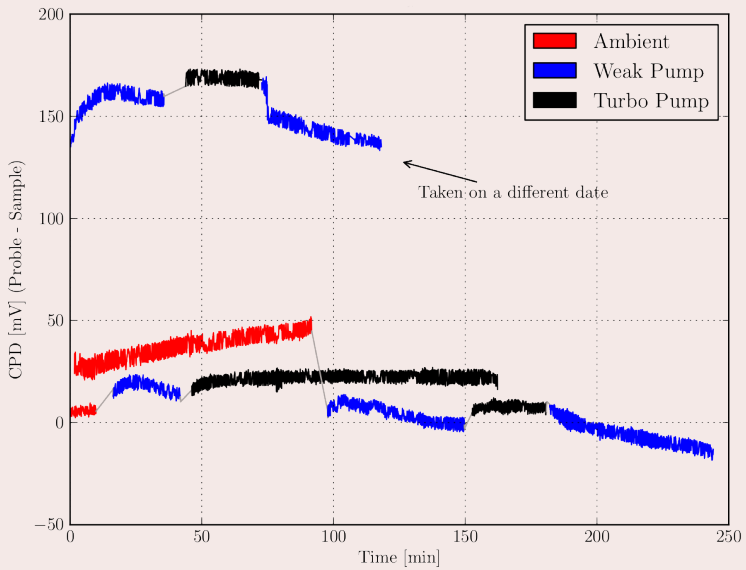
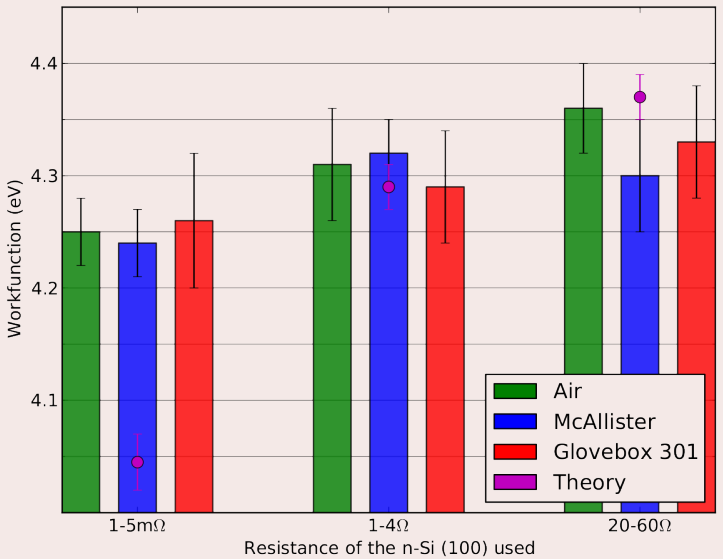
Checking against Established Systems

Behaviour at Room Temperature



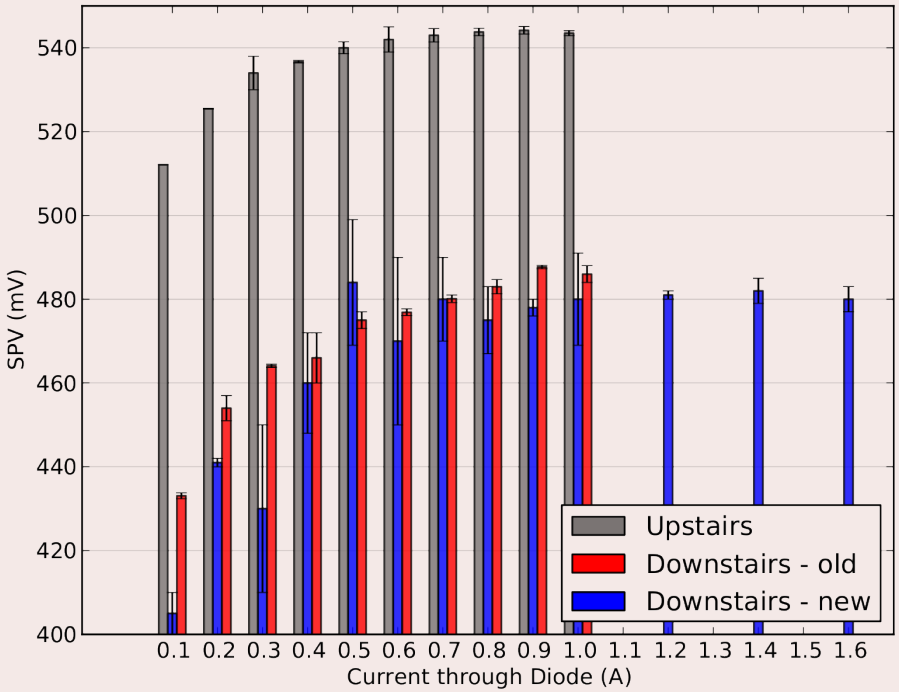


'Jumps' probably due to movement of probe head
Excellent agreement between systems

Checking against Established Systems

Behaviour at lower temperatures and SPV

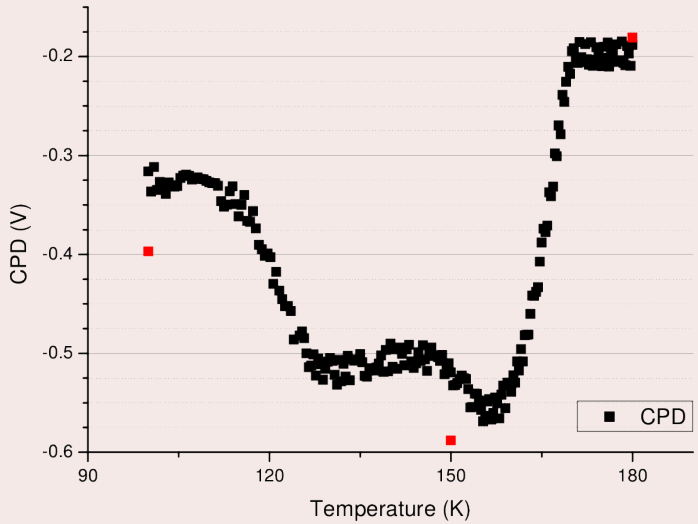
- φ_{Alumina} at 300 K: (4.00 ± 0.12) eV
- φ_{Alumina} at 250 K: (4.17 ± 0.15) eV

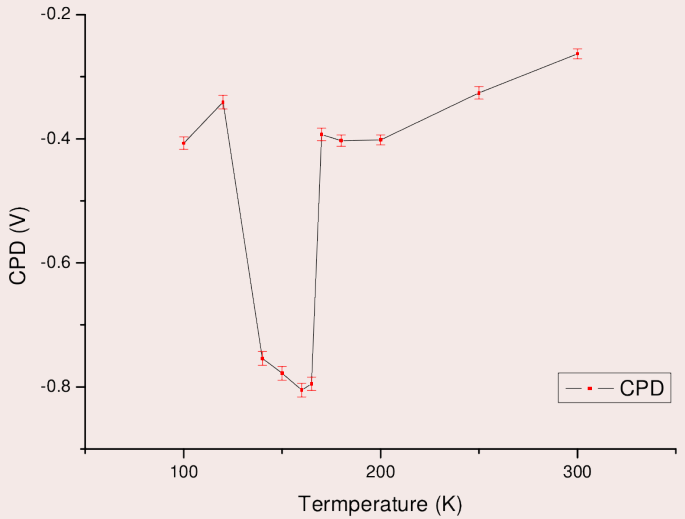


Probably no ice, even on very hydrophilic surface
SPV ∼12 % too low. Shadows on the sample?

Temperature Dependent CPD in W:VO_2

Temperature Sweep and precise Measurement

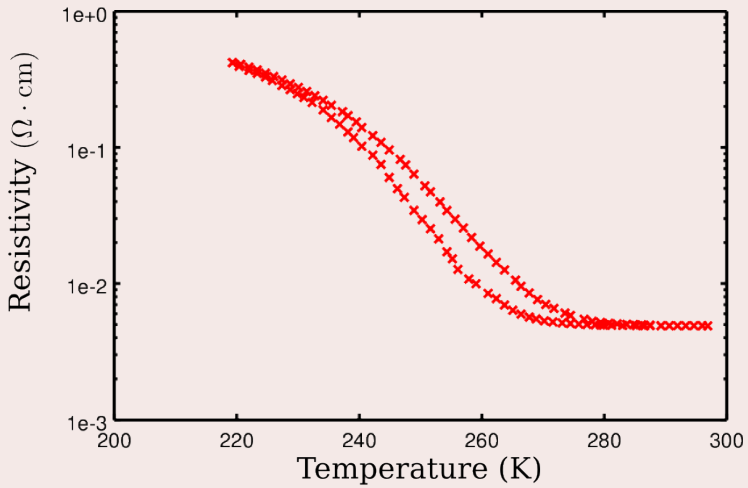


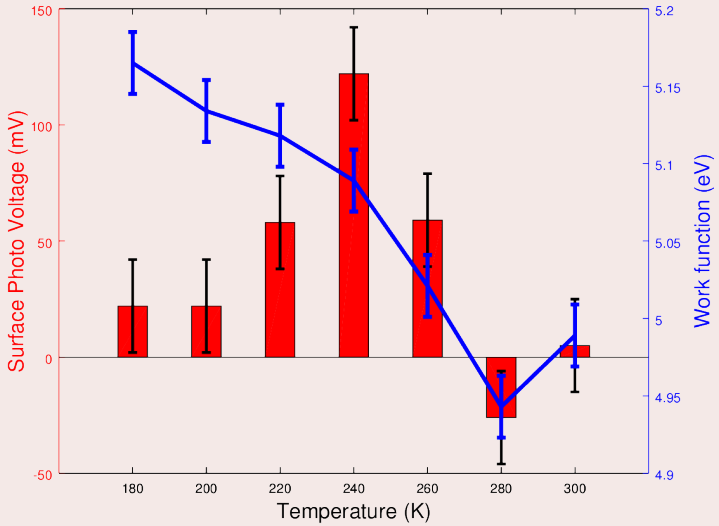


Curious behaviour in the range 120 K to 160 K, far below T_{MI}
Effect of substrate?

Temperature Dependent SPV in W:VO_2

ρ(T) and SPV(T)





Measurement by Nir Kedem

SPV identifies W:VO_2 as n-type material

Appearance of SPV and change in WF in accordance with resistivity and literature [2,3]

Discussion & Conclusion

We showed that...

- CPD is in excellent agreement with established systems
- SPV ∼12 % too low. Shadowing?
- CPD(T) reproducible and interesting
- SPV(T) shows expected behaviour for model system

→ Lakeshore + Mc Allister + LED is a viable system for SPV(T)

List of References

Literature and links

[1] SPV Technique, Helmholtz Institute Berlin
[2] Changhyun Ko *et al. ACS Appl. Mater. Interfaces*, 3(9):3396-3401, 2011
[3] Keisuke Shibuya *et al.*. *Phys Rev. B*, 82(20), 2010
[4] M. Nakano *et al.*. *Nature*, 487(7408):459-462, 2012
[5] Besocke Website
[6] Lakeshore Website
[7] LEDengine Website

Acknowledgements

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