Trinity College Dublin
Coláiste na Tríonóide, Baile Átha Cliath
The University of Dublin

# Oxide-mediated self-limiting recovery of field effect mobility in plasma-treated $MoS_2$

Jakub Jadwiszczak

Trinity College Dublin, Ireland

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# Plasma functionalisation of $MoS_2$

## $O_2$ plasma

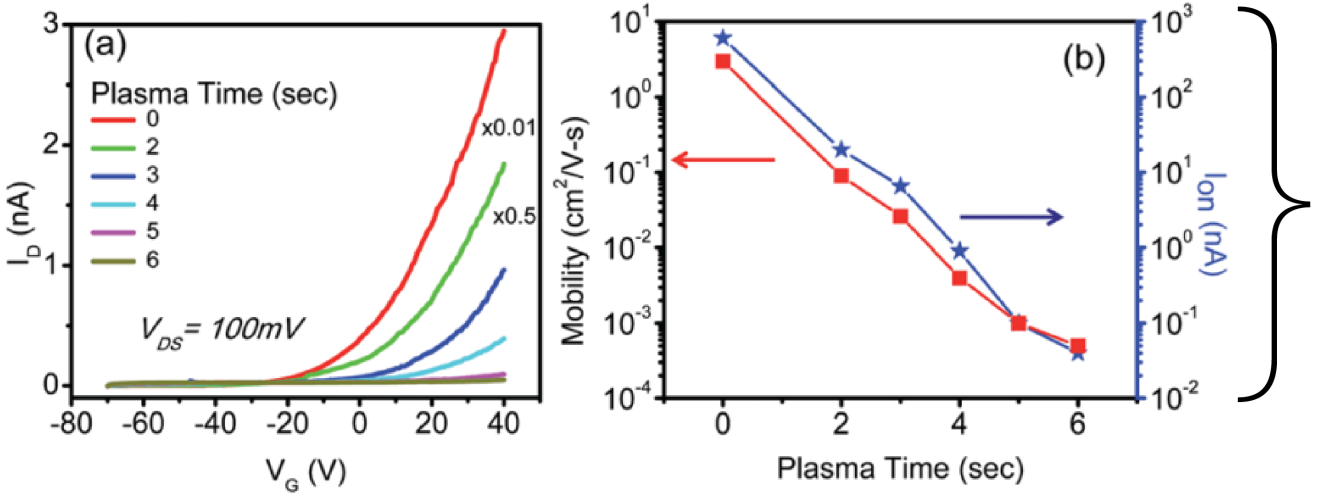
- Oxygen forms $MoO_3$ through sulfur-replacing reaction.
- This hampers device conductivity and causes p-type doping.

## Ar plasma

- Argon won't react chemically, but will make sulfur vacancies.
- It has been found to cause 2H $\rightarrow$ 1T polytype shift by displacing top sulfuric layer.

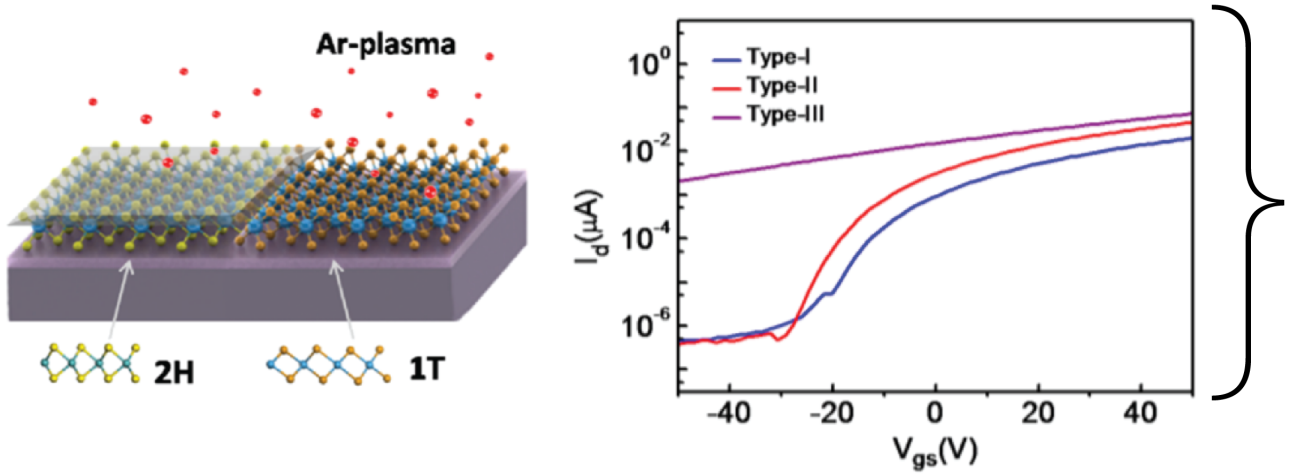
For our experiment we used a **1:3 mixture of $O_2$:Ar gas.**

# $MoS_2$-plasma interaction in the literature




Oxygen plasma

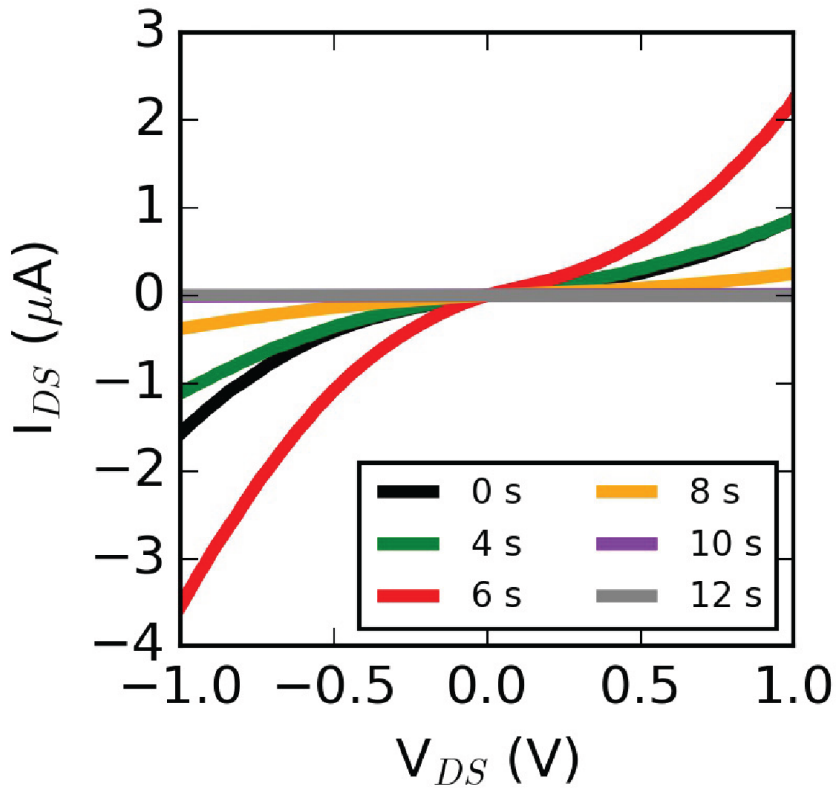
Islam, et al., Nanoscale, 6.17, 10033-10039 (2014)

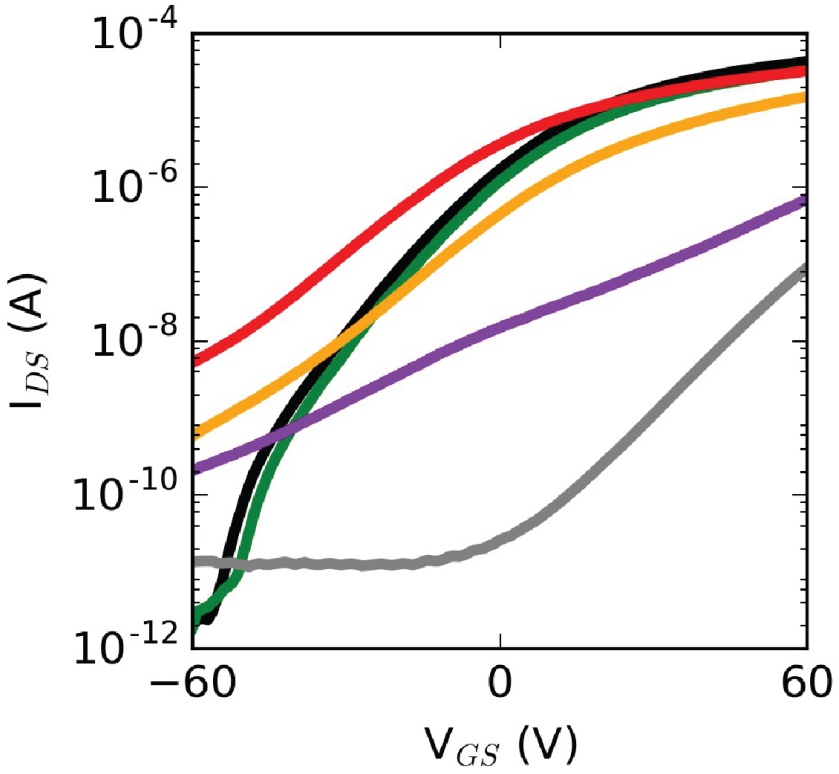



Argon plasma

Zhu, et al., Journal of the American Chemical Society, 139.30, 10216-10219 (2017)

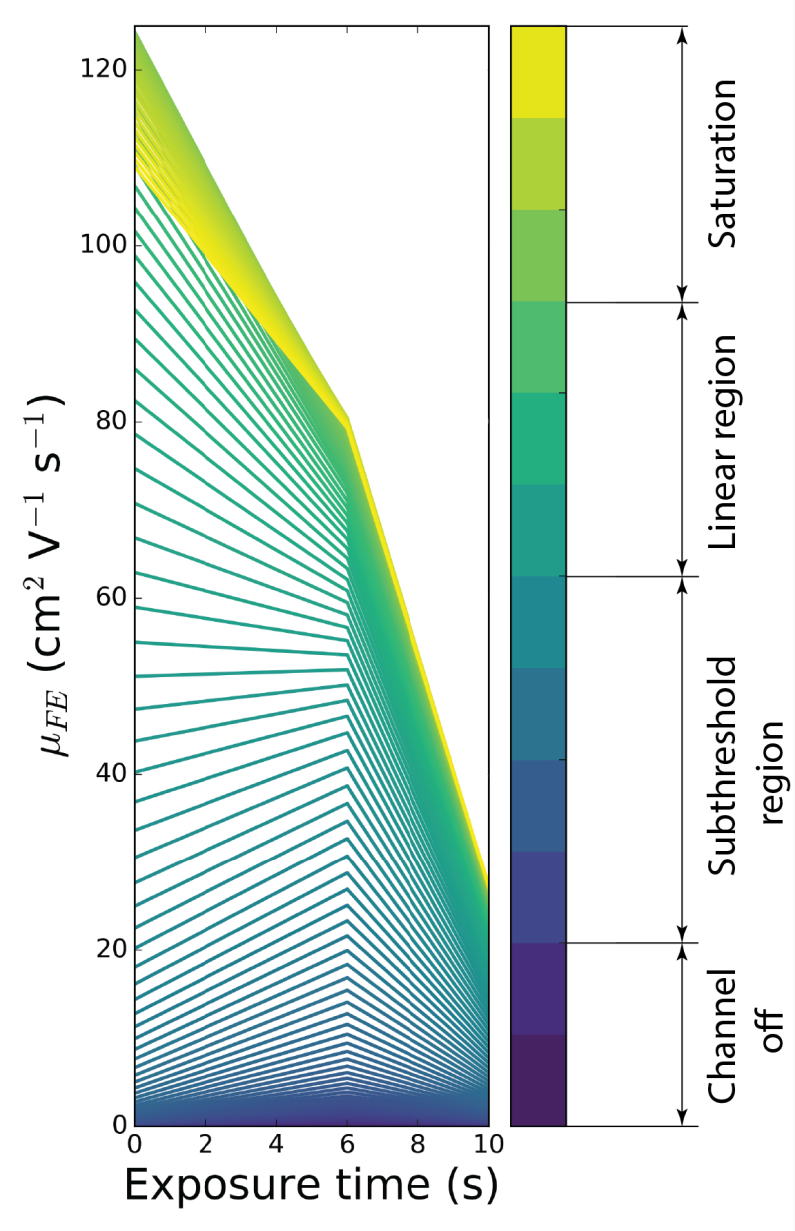
# Electrical testing with increasing plasma exposure



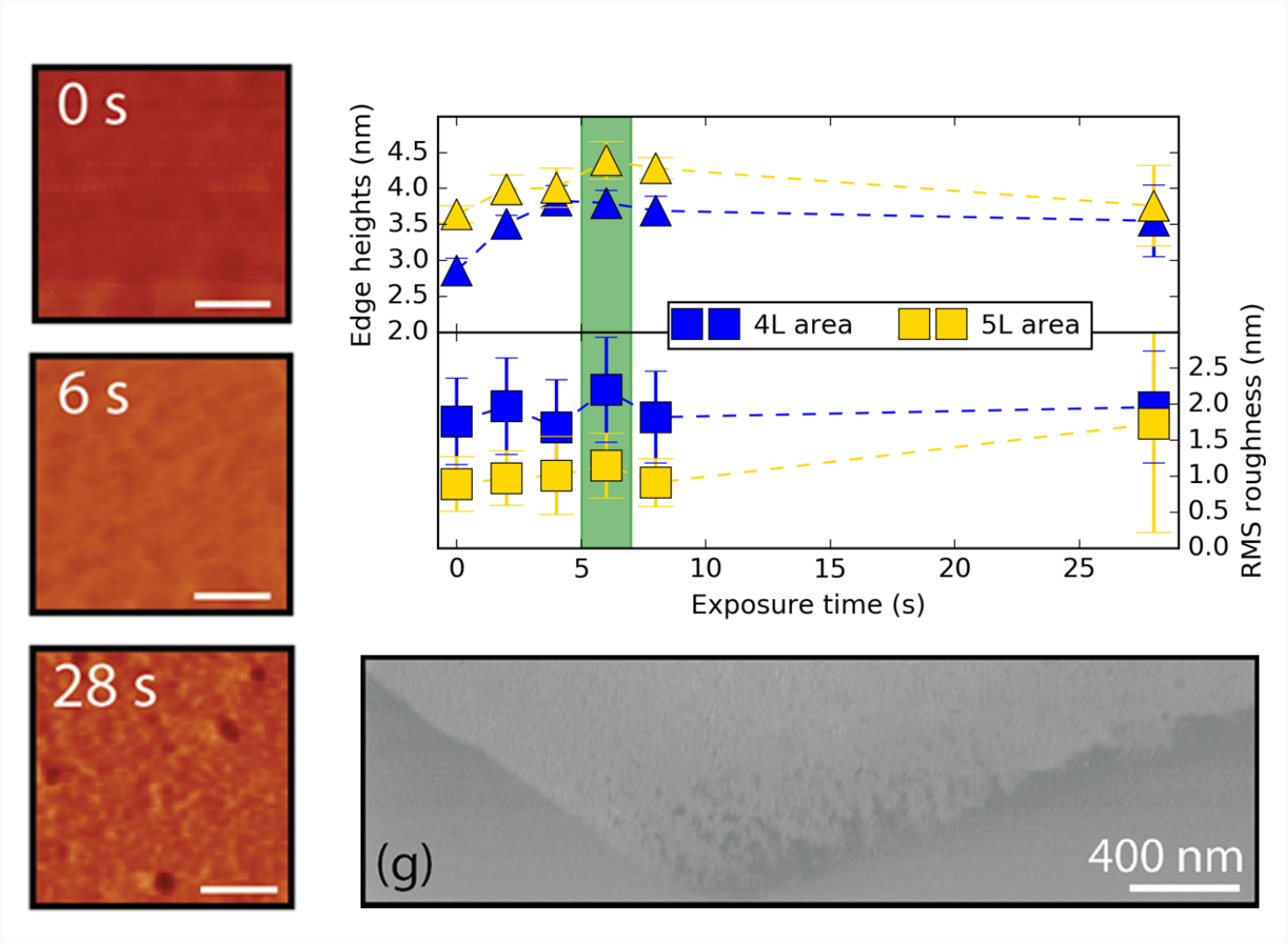




- Conductance increase at 6 seconds.
- Large $V_{th}$ shift and subthreshold swing increase after 6 seconds.

# Mobility boost observed at 6 seconds

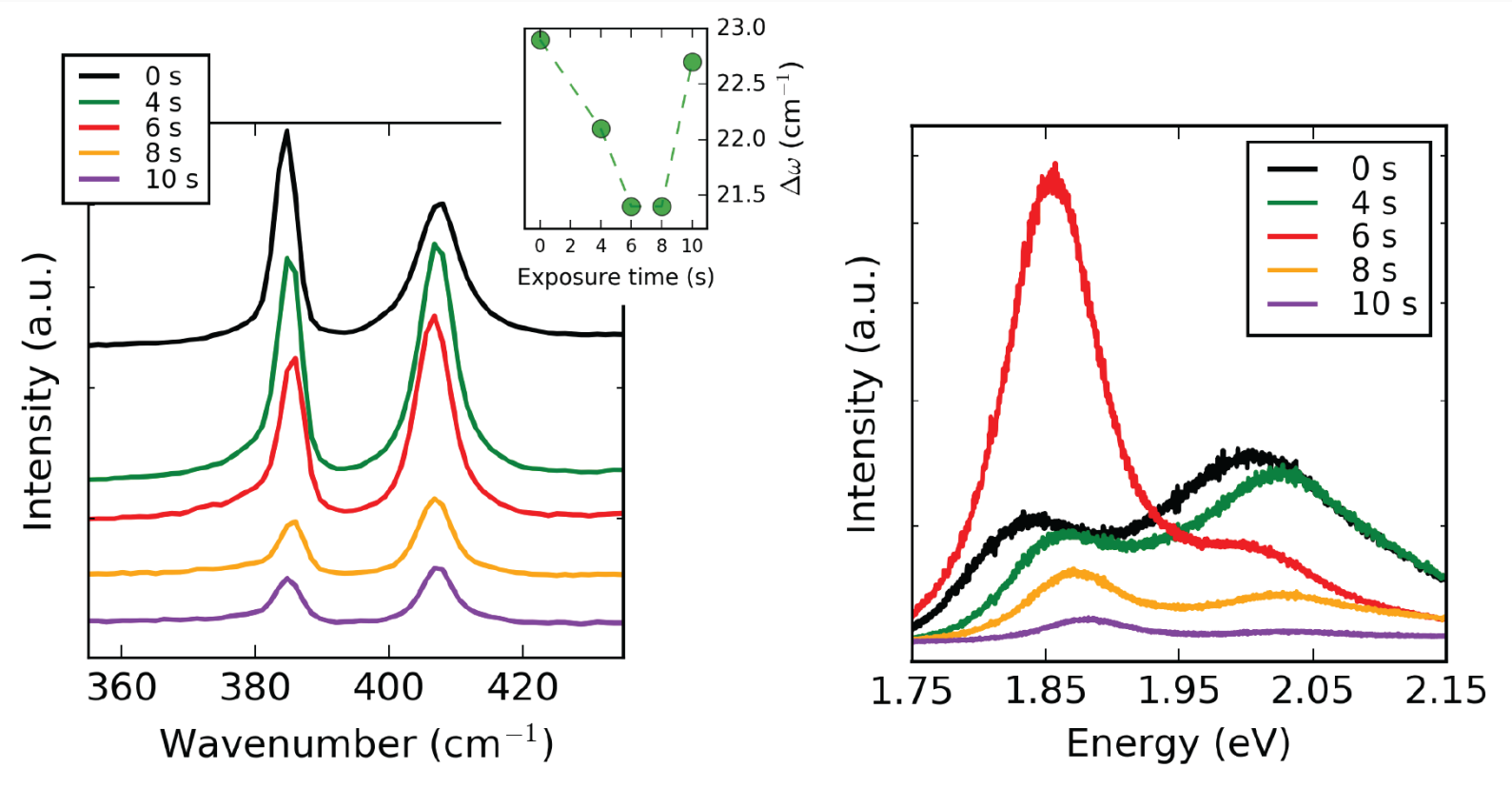


# AFM & SEM indicate material change to flake surface



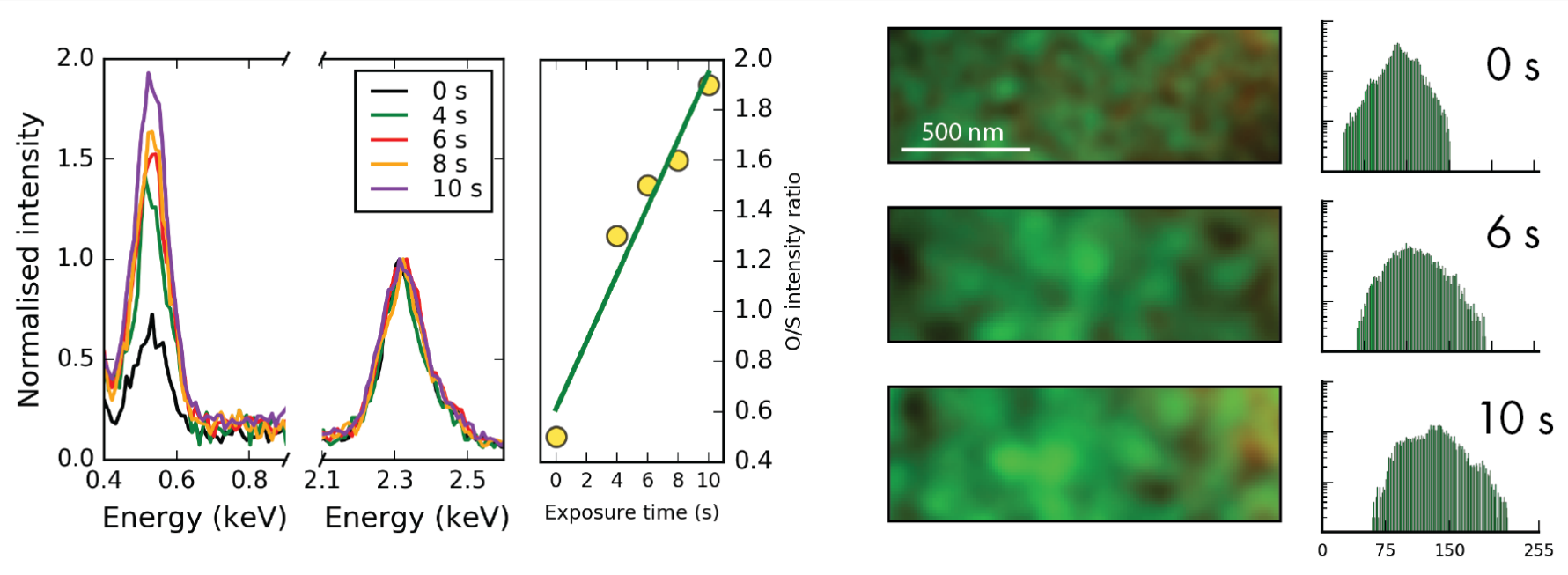

- Material contrast in phase AFM and SEM.
- Flake height increases while surface roughness stays constant.

# Raman & PL of 4L flake



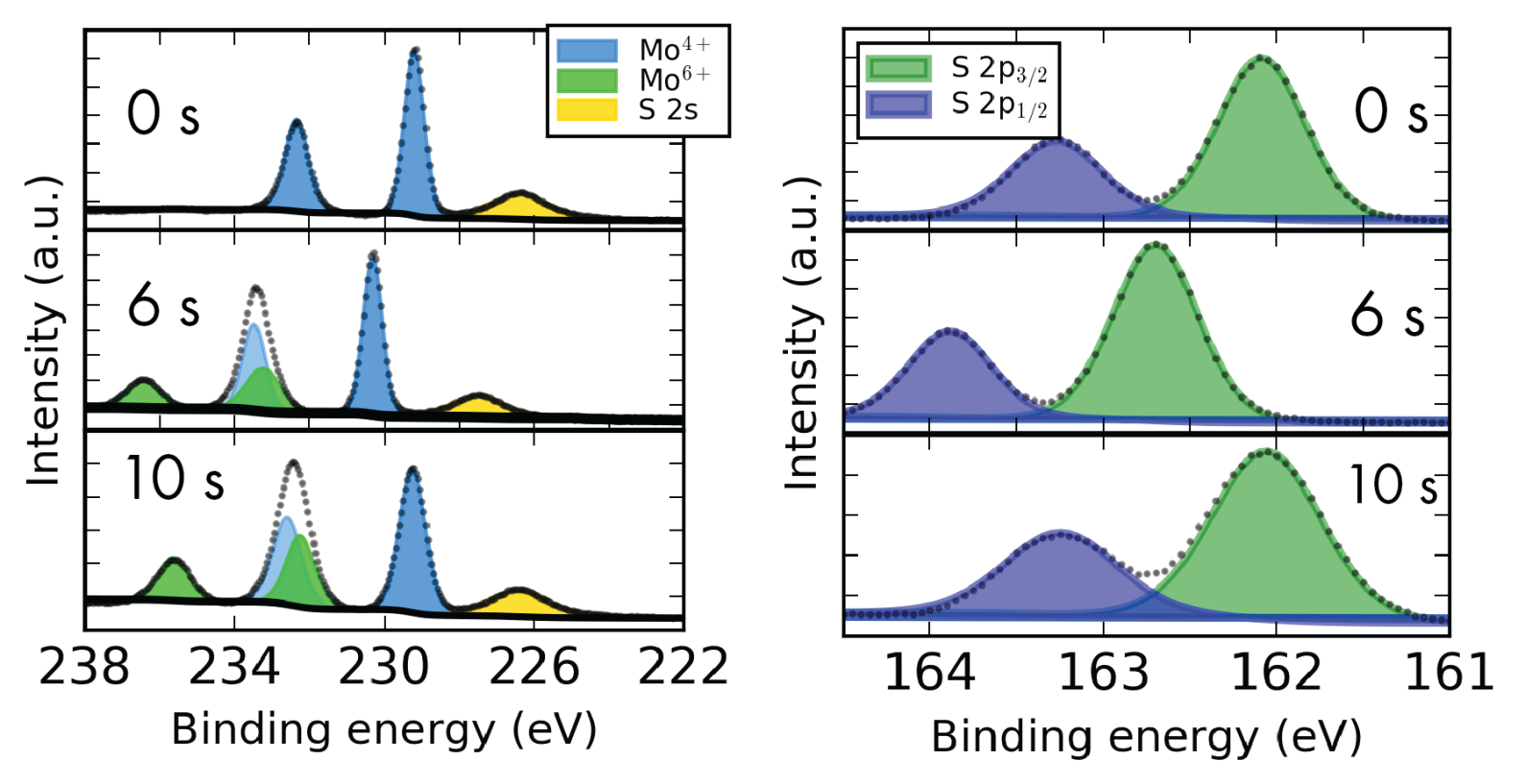

- Quenching of both Raman modes.
- Indirect $\rightarrow$ direct PL emission shift after 6 seconds.

# EDX mapping of freshly treated 4L sample



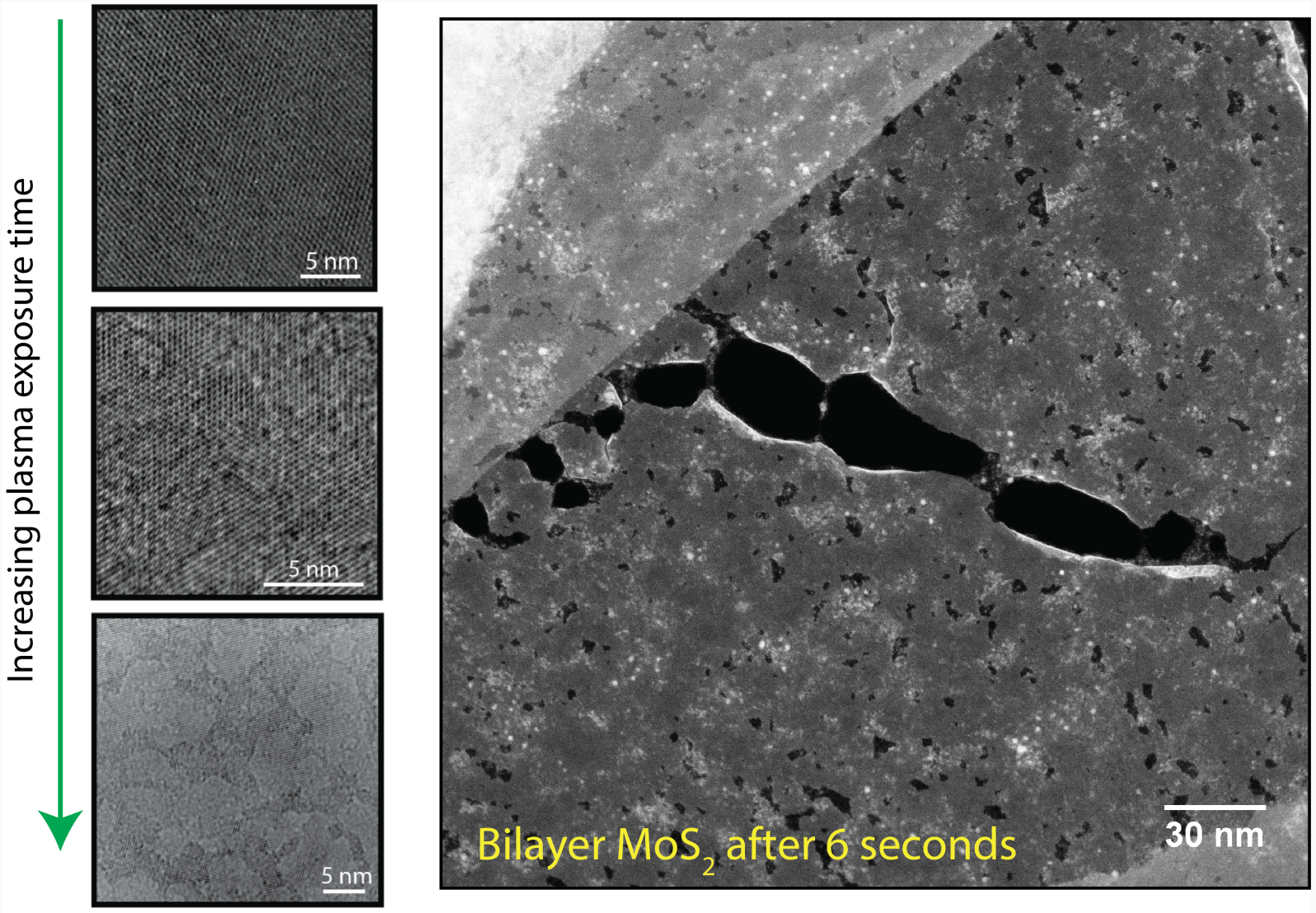

- Oxygen content increases relative to sulfur.

# XPS confirms presence of $MoO_3$

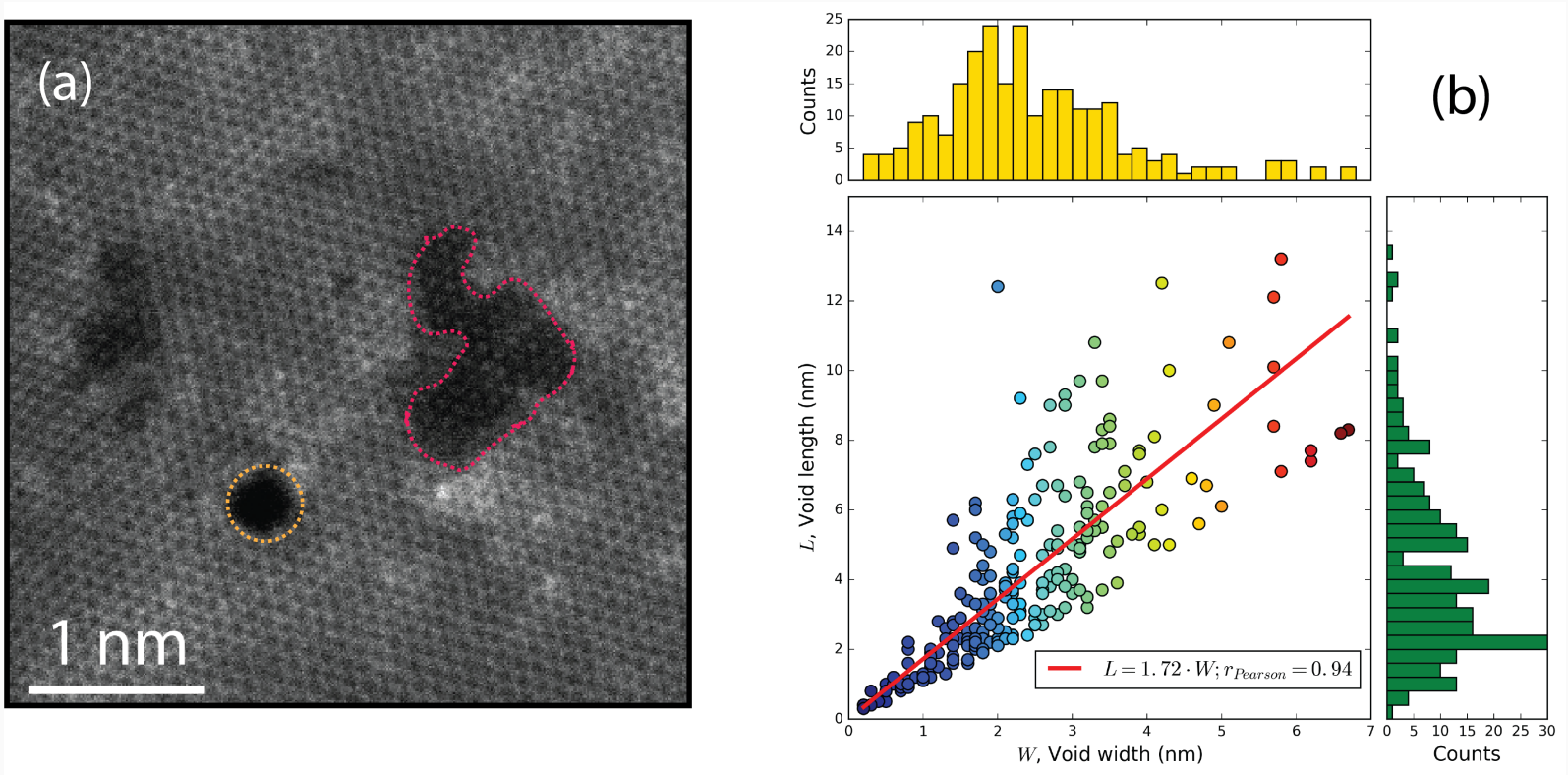



- Rise in $MoO_3$ concentration & improved stoichiometry.
- Large shift to higher binding energies indicative of n-type doping.

# Surface damage surveyed by TEM

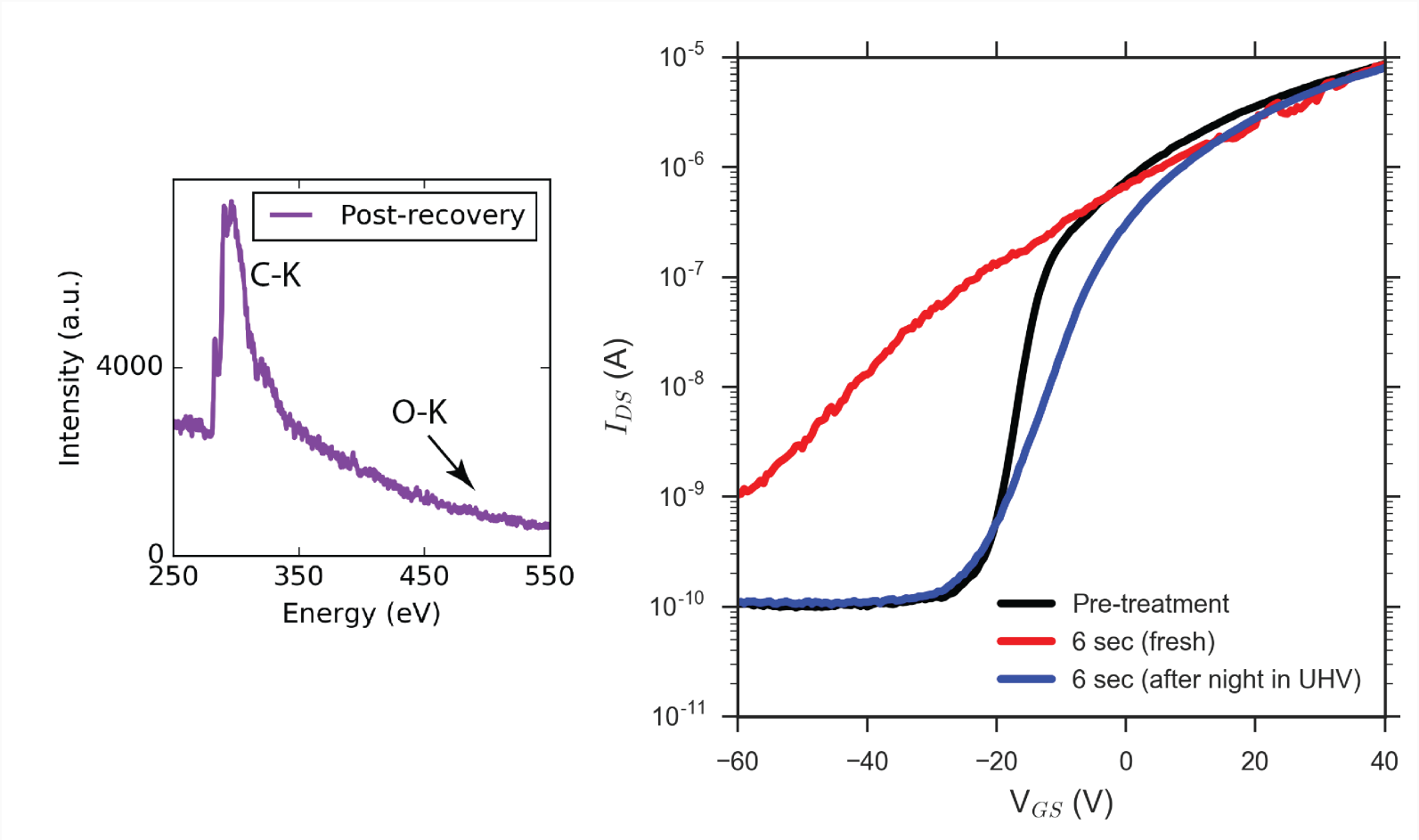


# Size distribution of oxide-mediated etched pits at 6 seconds



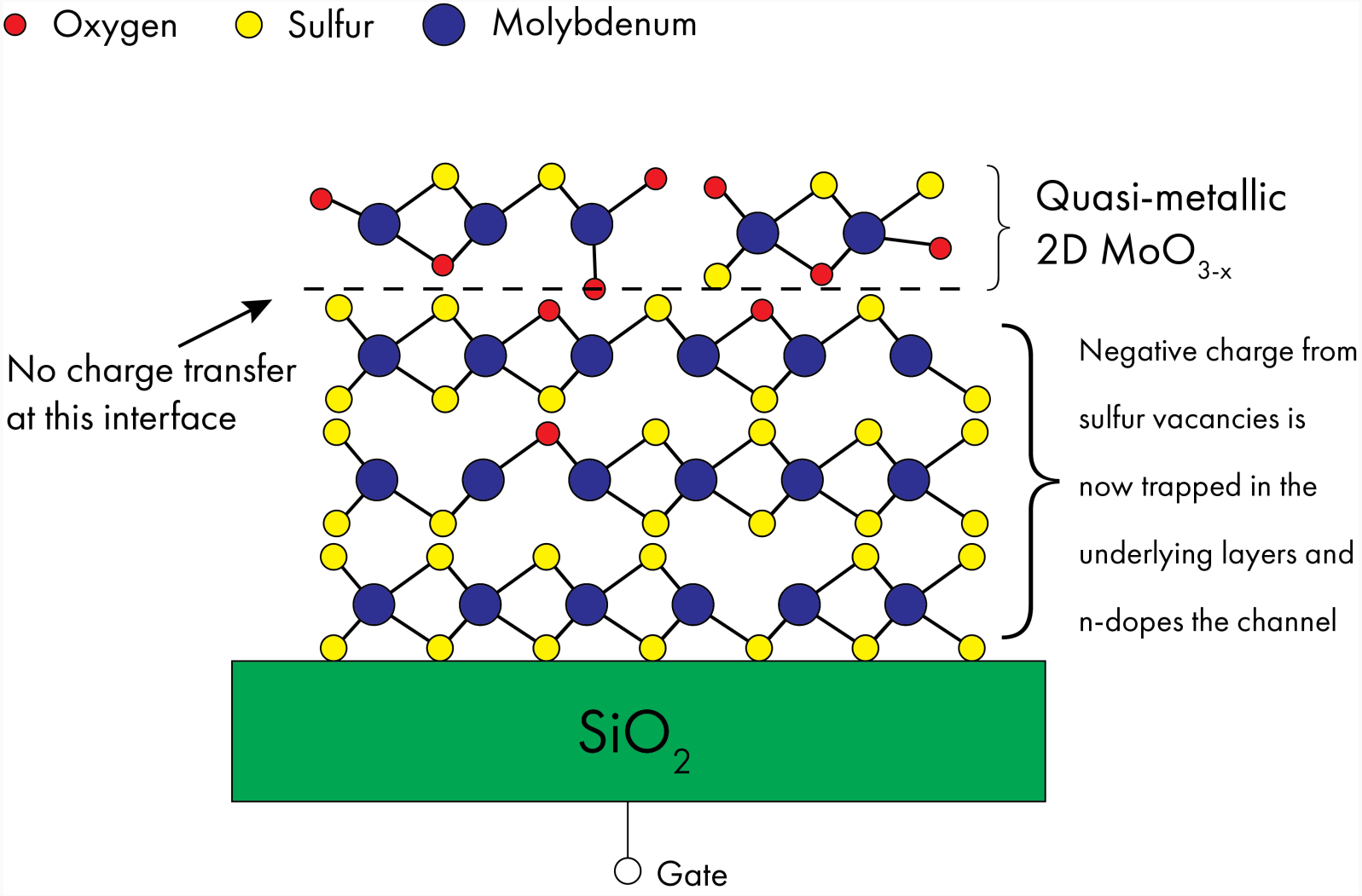

- Perforations and pits form on the surface.
- They increase in area with increasing plasma time.

# Oxides desorb from pits over time at UHV




- EELS & EDX mapping show no oxygen.
- Mobility boost is reversed after 12 hours in UHV.

# Proposed model of mobility enhancement



## Conclusions:

2D $MoO_{3-x}$ phase forms at 6 seconds on the top layer.

It enhances $MoS_2$ FET performance by screening charged scattering centres.

Its existence may be exploited in future van der Waals devices.

Mixed plasma treatment is a promising avenue for device functionalisation.

Acknowledgements:

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# Resistive network simulation