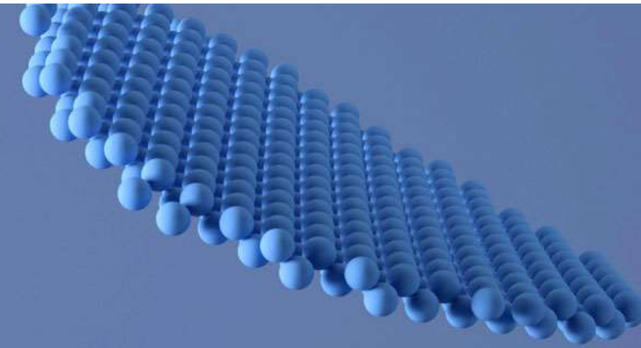

Visualizing 2D Sheets by Fluorescence Quenching Microscopy: An Update

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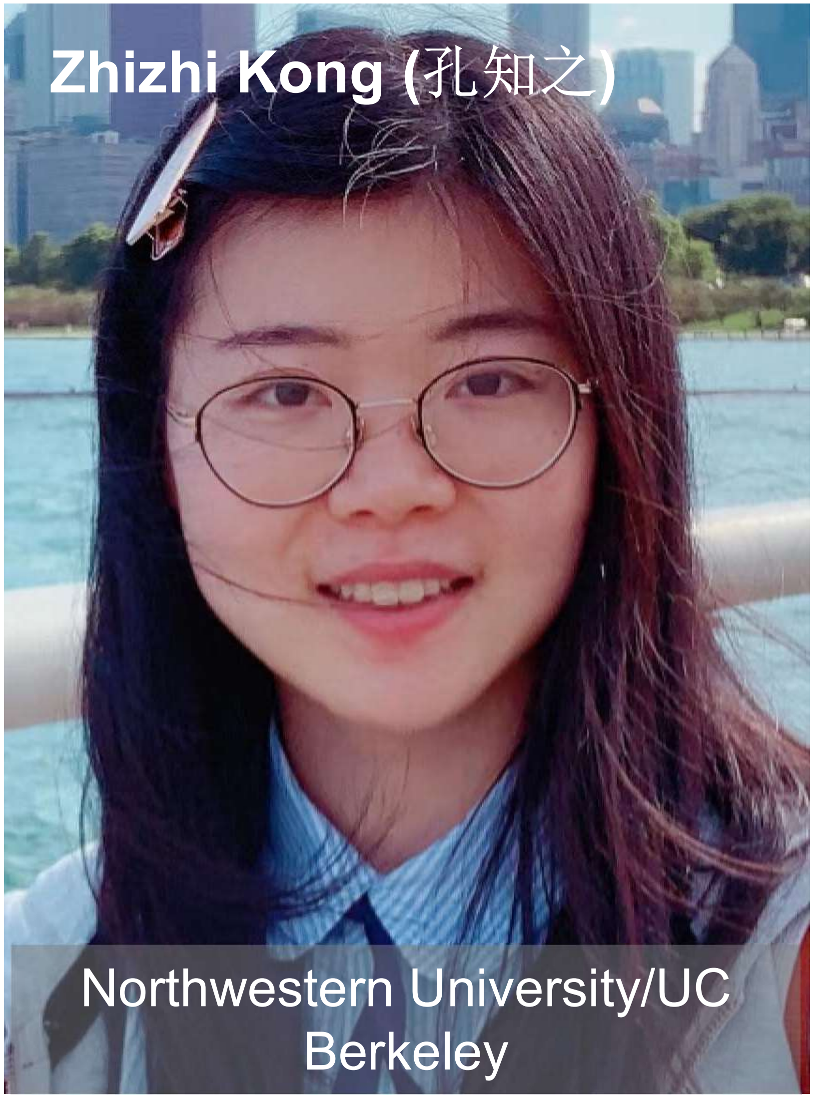
[1] Northwestern University

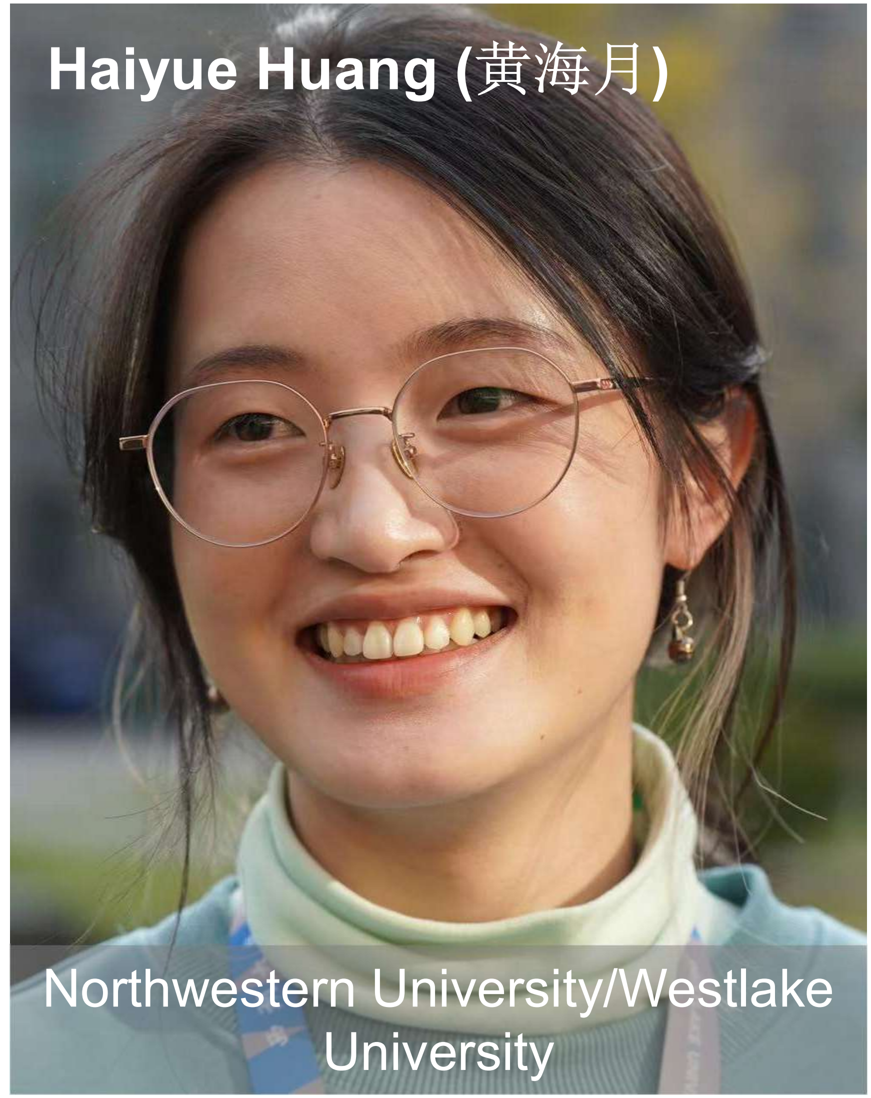
[2] UC Berkeley [3] Westlake University

6th Go to GO Symposium

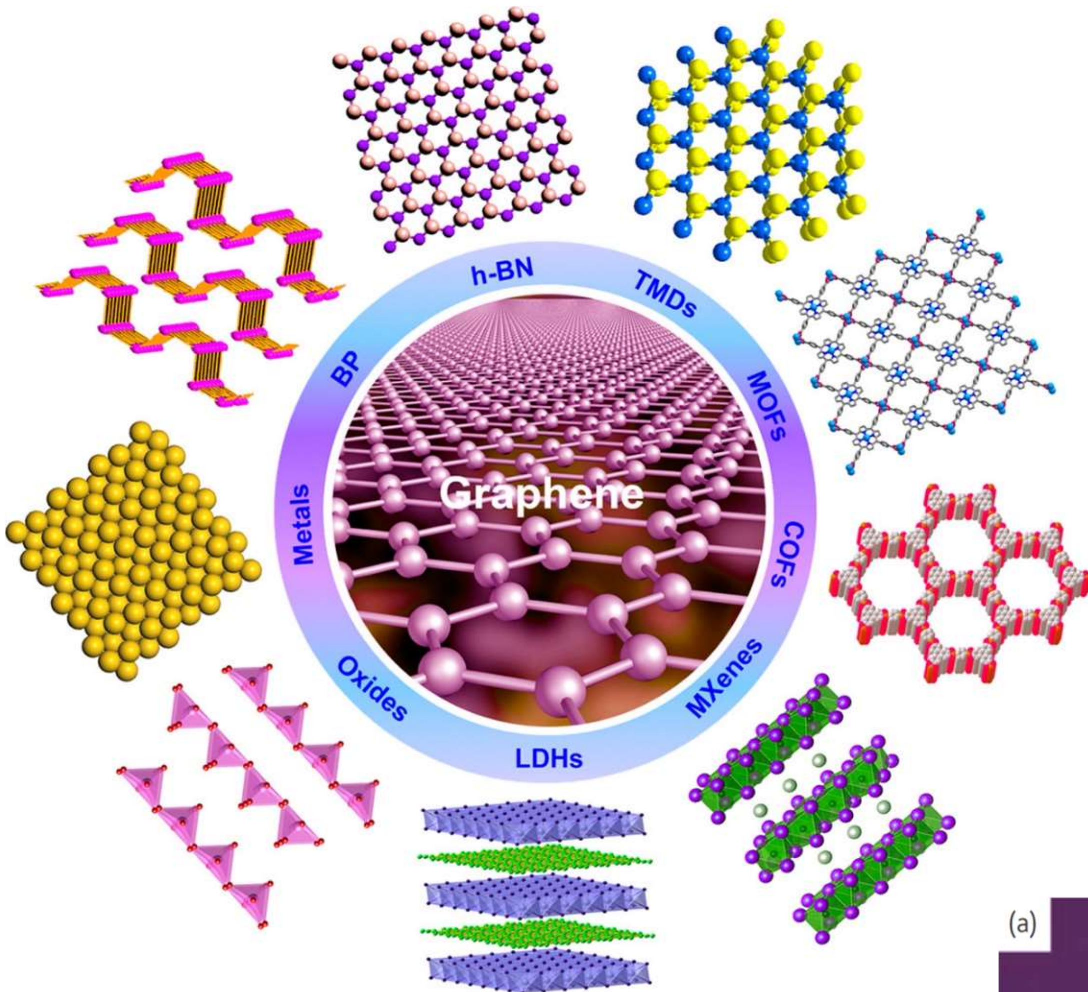
December 28, 2021

Co-presenters

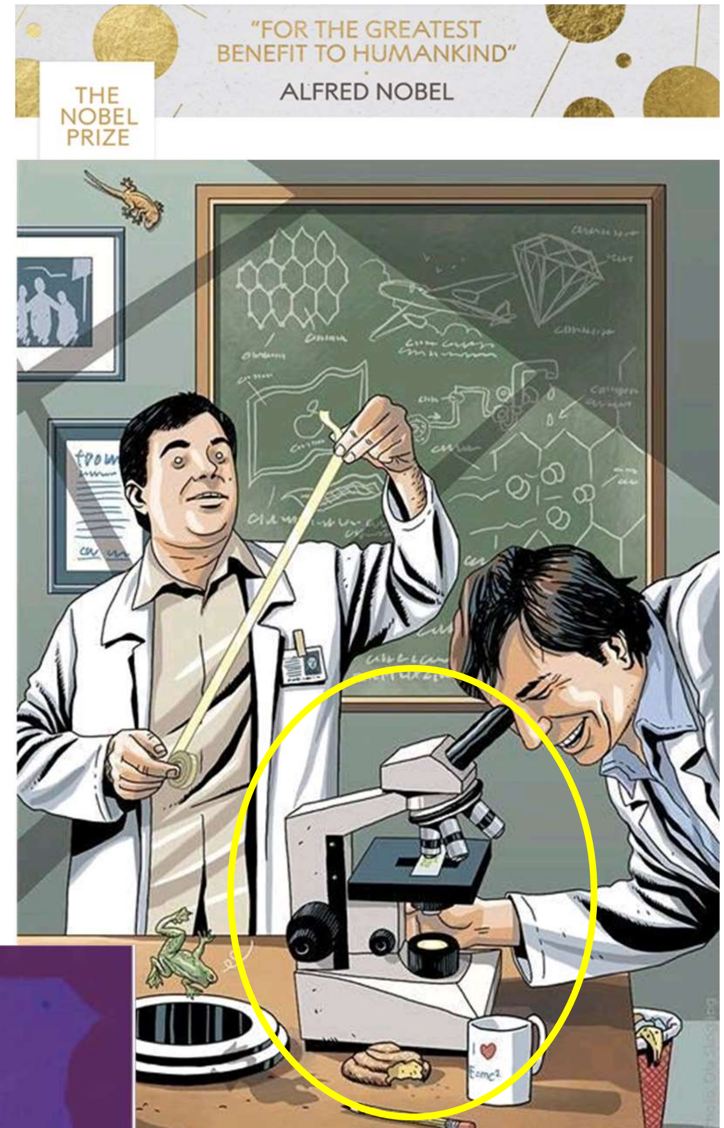


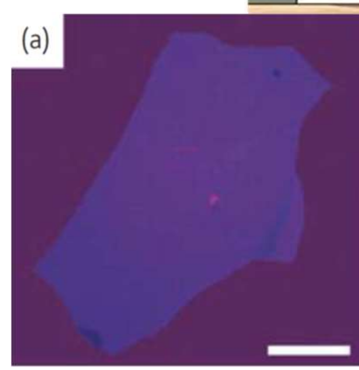


Seeing two-dimensional materials



ACS Nano **2015**, 10, 9451-9469

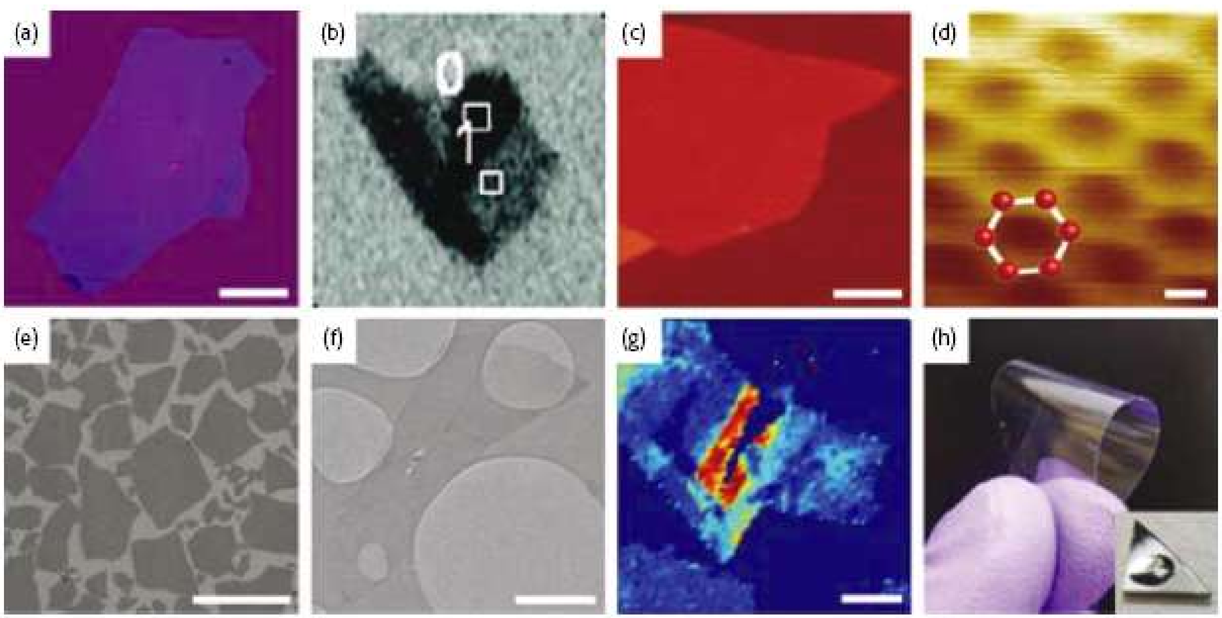




Novoselov, K. S., et al., Science **2004**

Seeing two-dimensional materials

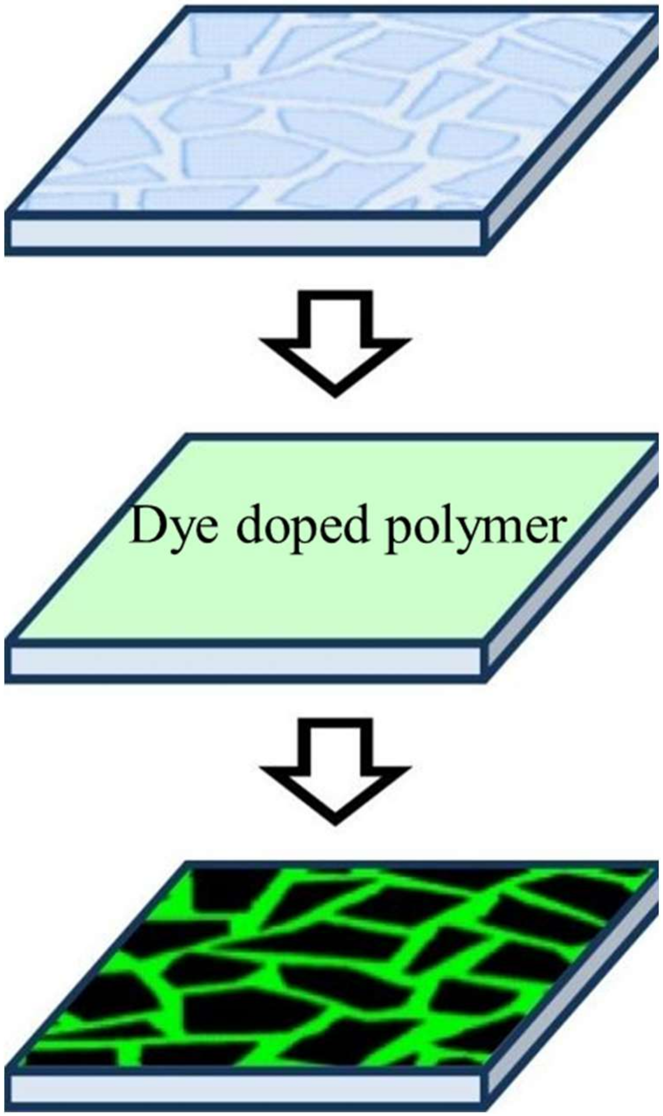
Techniques	Mechanism	Relative speed	Requirement on substrate	Solution observation	Other requirement
Optical Microscopy	Interference	Fast	Dielectrics coated Si	No	Optimized dielectric thickness and wavelength
	Ellipsometry	Fast	Dielectrics coated Si	No	
AFM	Force between sample and tip	Low (scanning)	Smooth surface (e.g., Si, mica, quartz)	No	Vibration isolation
STM	Electron tunneling	Low (scanning)	Conductive, atomically smooth	No	Vacuum
SEM	Secondary and scattered electrons	Medium (scanning)	Conductive	No	Vacuum
TEM	Absorbed electrons	Slow	Transparent to electron	No	Vacuum
Raman	Inelastic photon scattering	Fast	Low fluorescence, effective heat dissipation	No	Laser

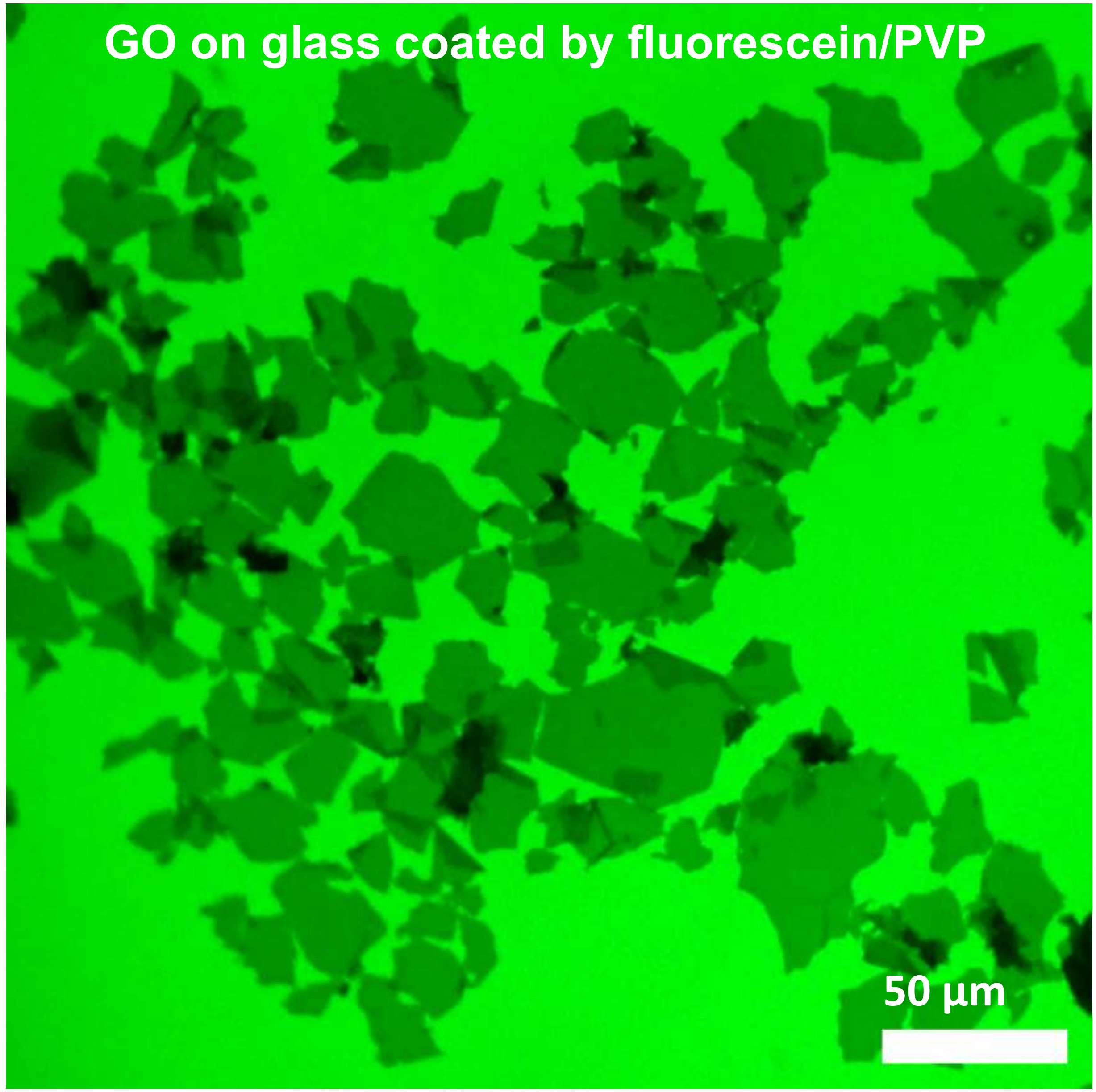


SEM and AFM are the main workhorse techniques

Mater. Today, **2010**, *13*, 28-38

Fluorescence quenching microscopy (FQM)





Kim, J. *et al., JACS,* **2010**

Mechanism

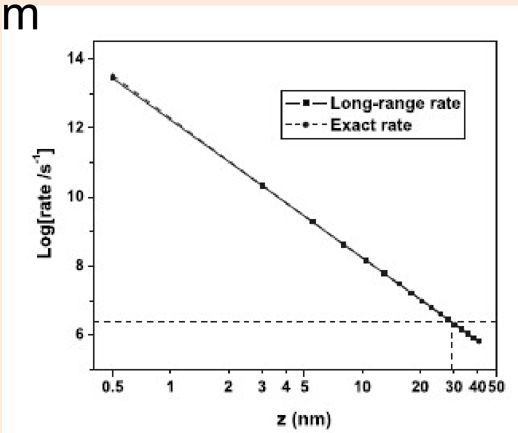
Swathi, R. S., and Sebastian, K. L., *J. Chem. Phys.* **2009**, 086101

Long range resonance energy transfer from a dye molecule to graphene has (distance)$^{-4}$ dependence

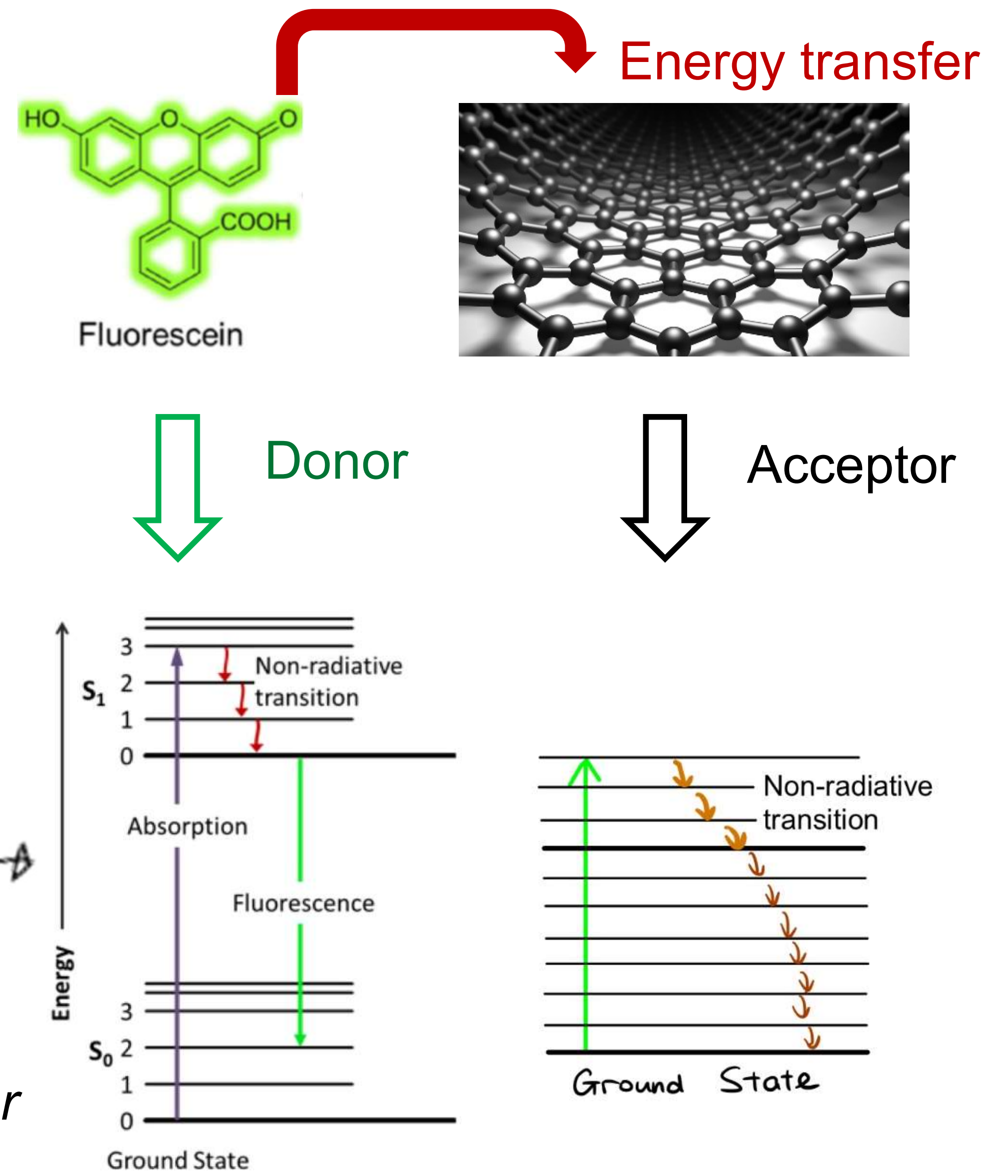
R. S. Swathi and K. L. Sebastian[a]
Department of Inorganic and Physical Chemistry, Indian Institute of Science, Bangalore 560012, India

We estimate that quenching would be observable up to a distance of about 300 Å, which is much longer than for any other surface, suggesting interesting possibilities for having a ruler for measuring distances at the nanoscale.

Quenching distance: Observable up to 30 nm

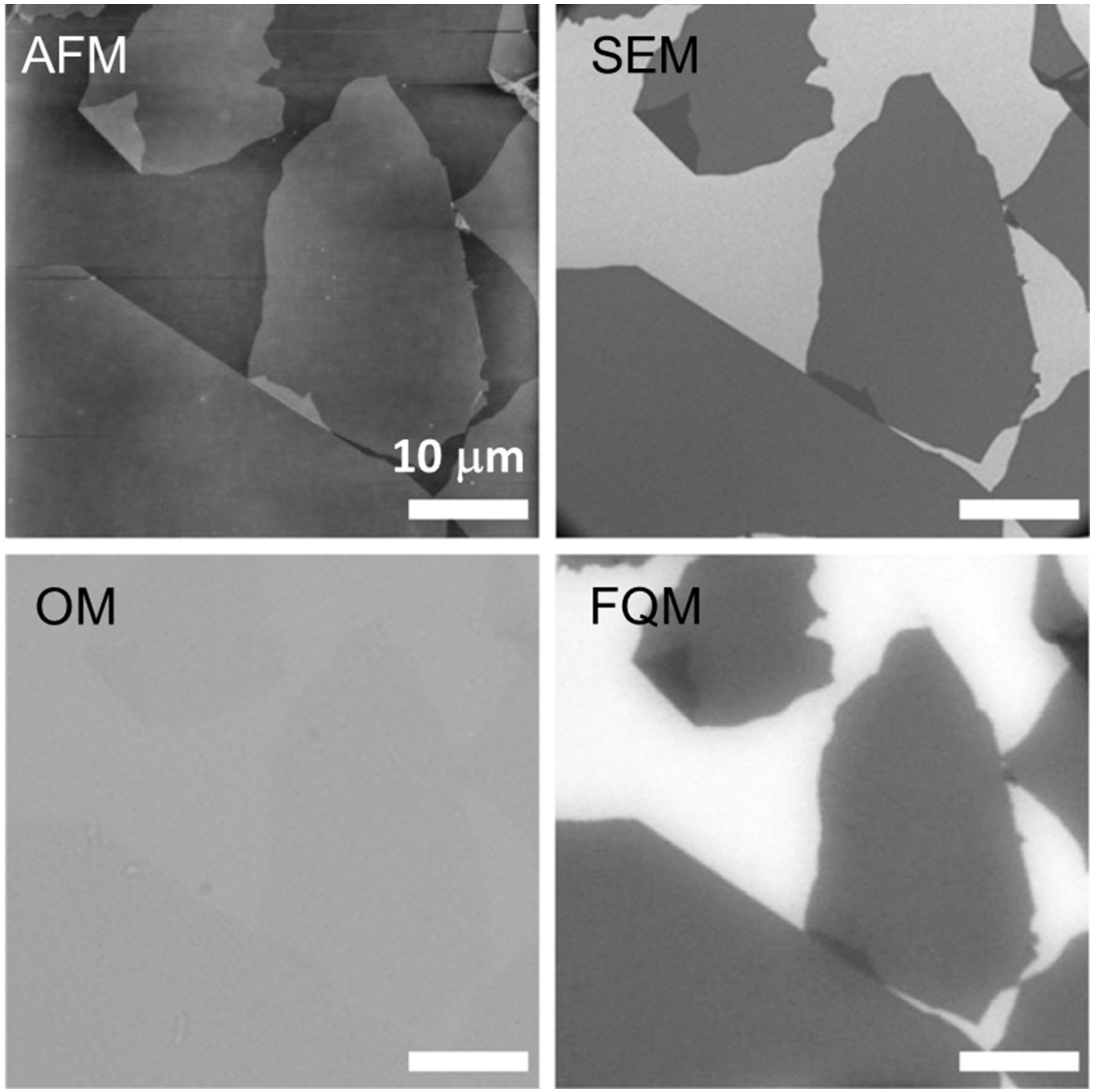


FRET
(Forster resonance energy transfer)



Turro, N. J., *et al., Principles of molecular photochemistry : An introduction*

High contrast and layer resolution of FQM images

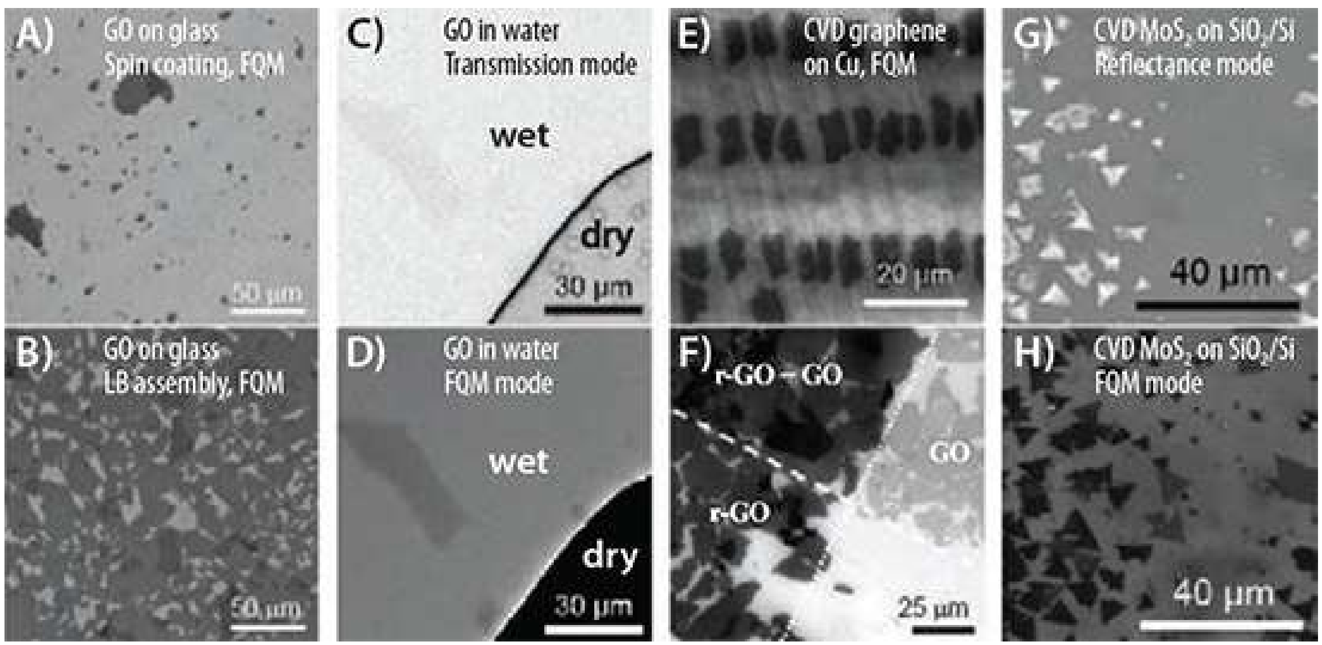


- High contrast and layer resolution comparable to AFM and SEM

Fluorescence quenching microscope (FQM)

Apply (or pre-apply) a layer of fluorescent sensitizer, above or below the graphene layer → Observe under a common fluorescent microscope

Works well for graphene family and TMDCs on arbitrary substrates and even in solution

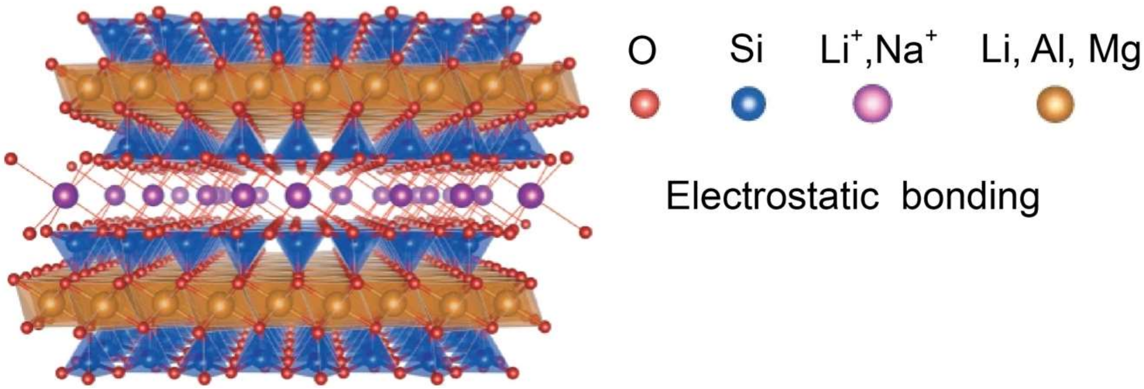


Small, **2013**, *9*, 3253–3258 *Materials Matter*, **2015**, 10, 64-66

Weakly quenching sheets: Clay and metal oxides

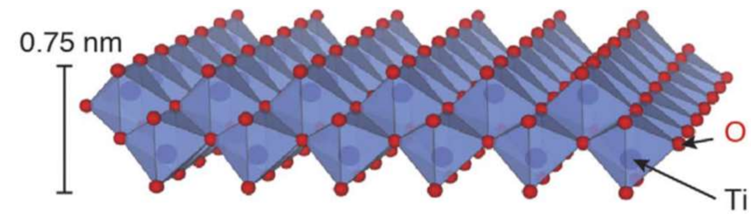
Silicate

$Na_{0.75}{}^{inter.}[Mg_{2.25}Li_{0.25}]^{oct.}\langle Si_4\rangle^{tetr.}O_{10}F_2$



Titania

$Ti_{0.87}O_2^{0.56-}$



Clay nanosheets

- Great cation exchange capacity
- High surface reactivity and adsorption
- ……

Metal oxide nanosheets

- High-κ ferroelectricity
- Superconductivity
- Great photocatalytic properties
- ……

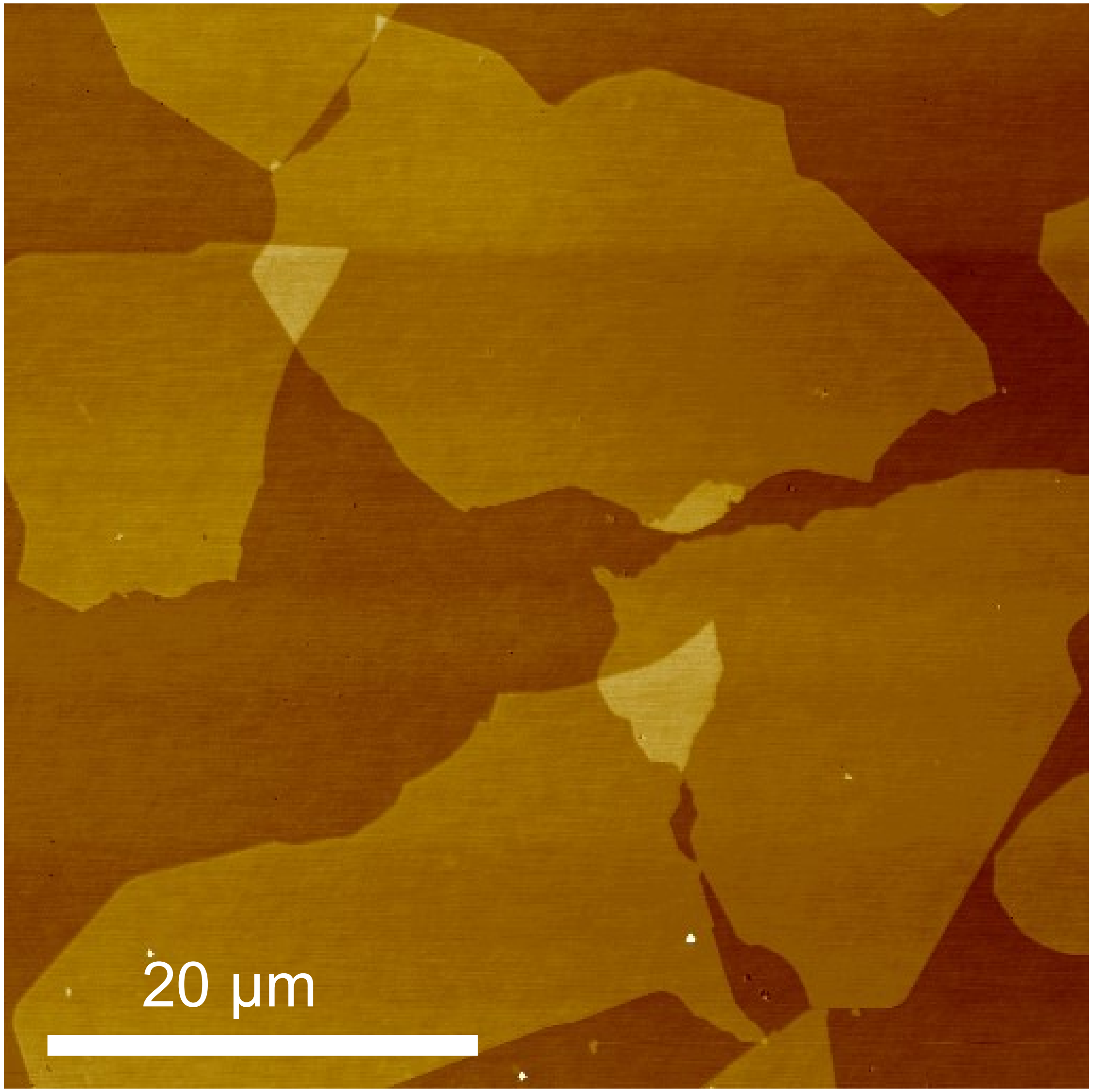
Alexander von Humboldt
Stiftung / Foundation

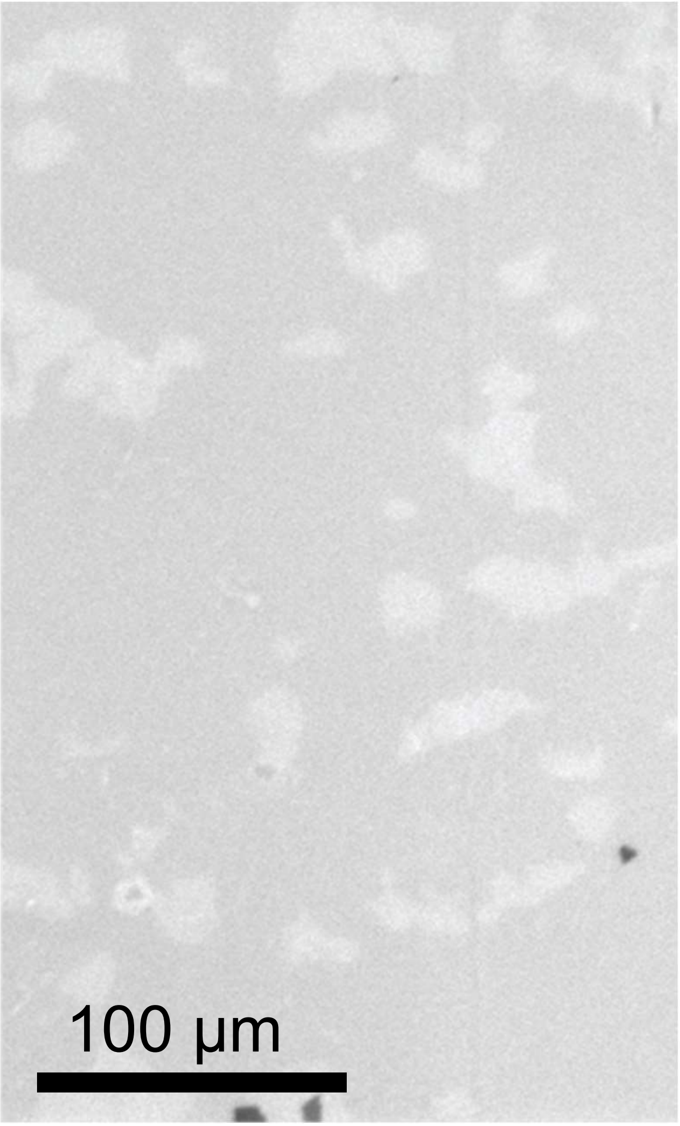
Prof. Josef Breu

JSPS

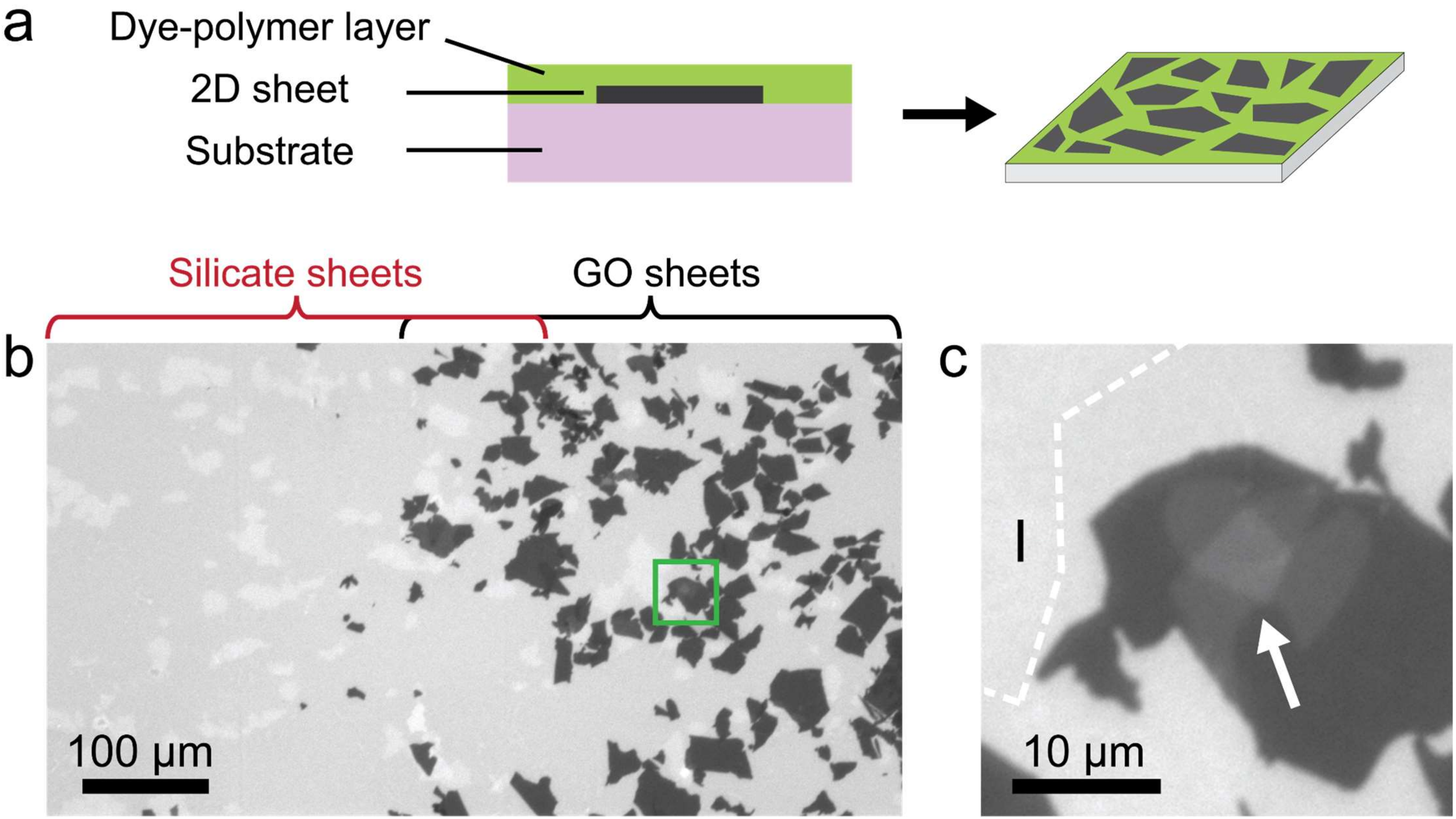
Prof. Takayoshi Sasaki

Visualizing transparent 2D sheets by FQM



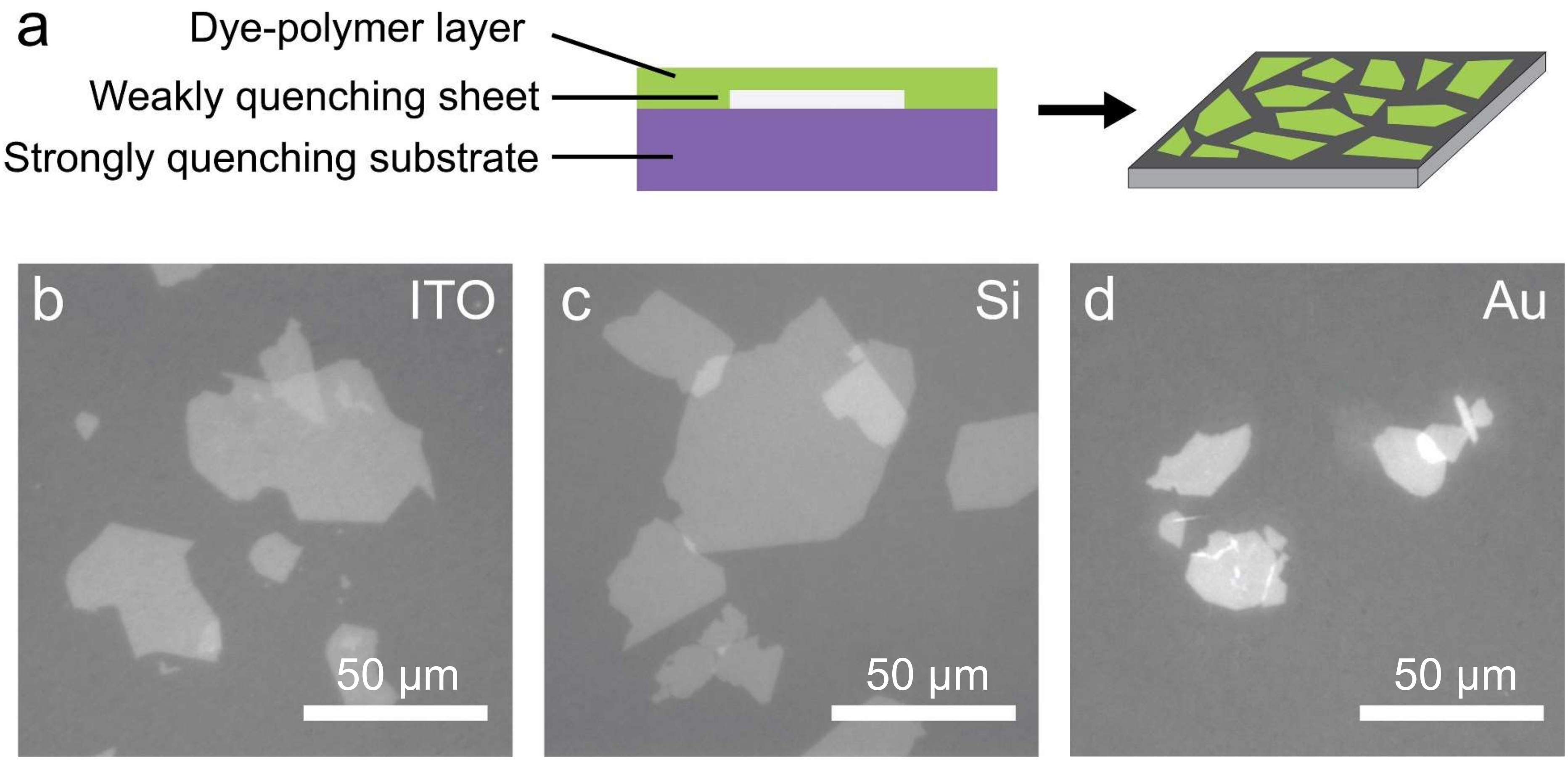


Visualizing transparent 2D sheets by FQM



Small Methods **2020**, *4*, 2000036

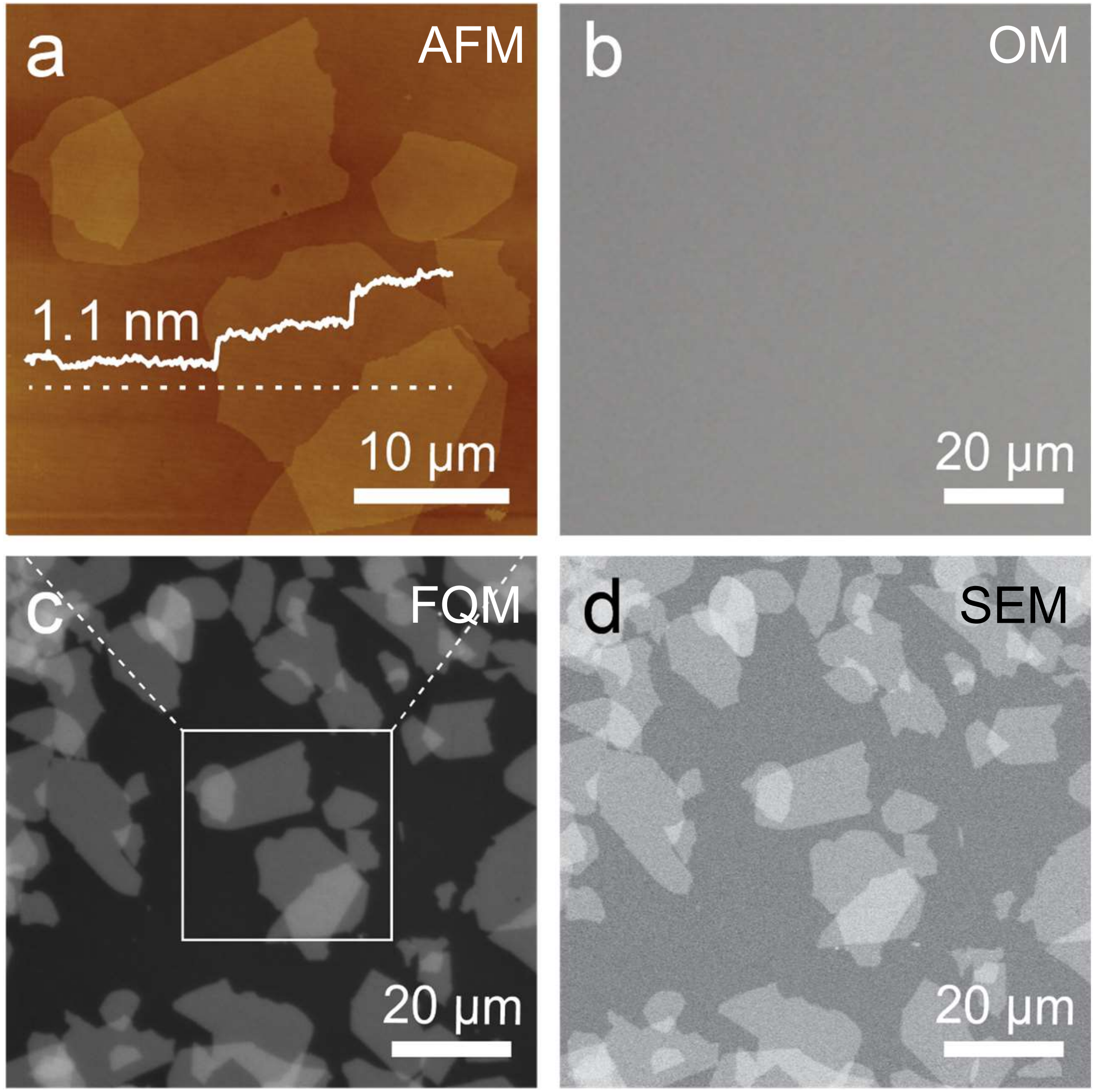
Exploring different strongly quenching substrates



- When deposited on a strongly quenching substrate, these dielectric sheets can act as a separator to reduce the degree of fluorescence quenching by the substrate, thus appearing as bright sheets in a dark background

Small Methods **2020**, *4*, 2000036

High contrast and layer resolution of FQM images

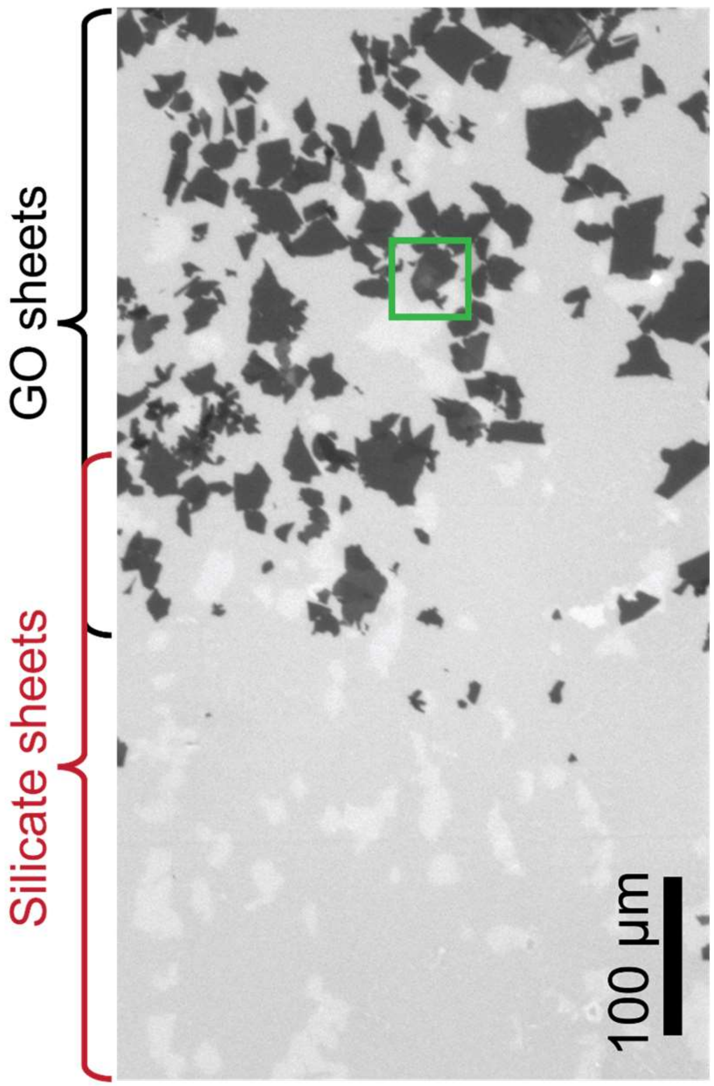


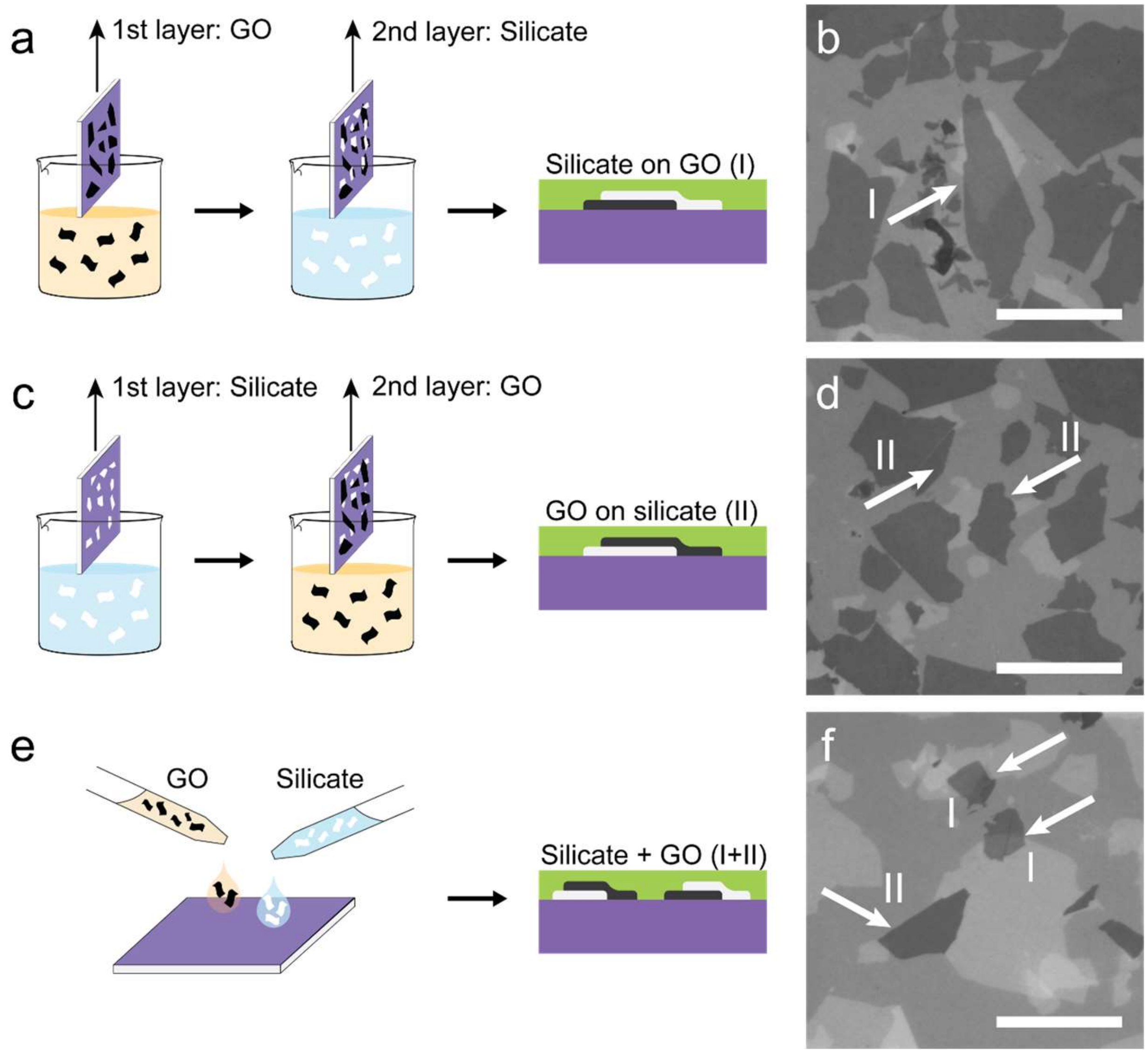
Substrate: Si

- FQM can image these sheets with high contrast and layer resolution comparable to AFM and SEM

Small Methods **2020**, *4*, 2000036

Visualizing 2D heterojunctions by FQM

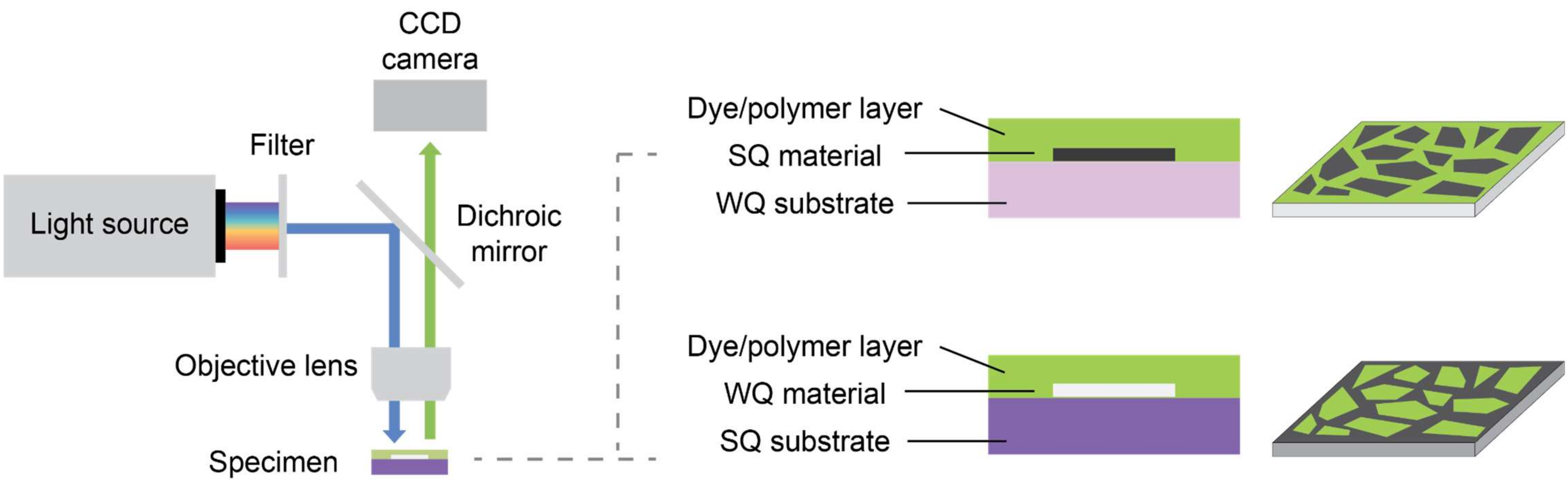




- FQM can resolve stacking sequence in vertical heterojunctions made of different 2D materials

Small Methods **2020**, *4*, 2000036

Summary: FQM imaging of strong quencher (SQ) and weak quencher (WQ)

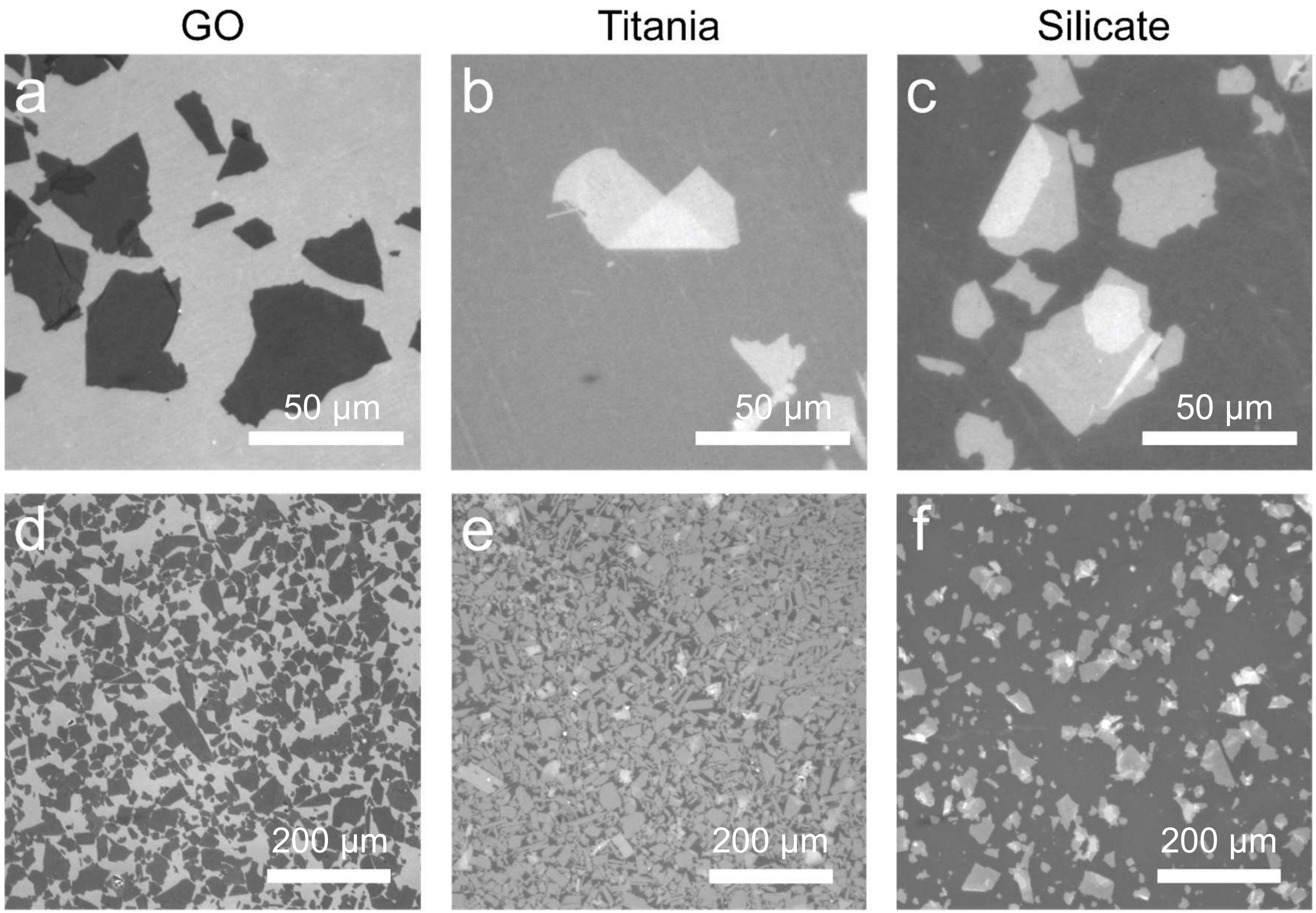


SQ material on WQ substrate (e.g., graphene on glass): sample looks dark

WQ material on SQ substrate (e.g., clay on graphene/metal/ITO/doped Si): sample looks bright

Small Methods **2020**, *4*, 2000036

Recommendation: ITO substrates



- ITO is found to have intermediate quenching capability, making it a suitable type of FQM substrate for seeing a broad range of 2D materials

Small Methods **2020**, *4*, 2000036

Acknowledgements

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Dr. Matthias Daab
Dr. Hitomi Yano
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Prof. Takayoshi Sasaki
Prof. SonBinh T. Nguyen

Group: https://www.jxhuang-lab.com/