Structural Characterization of Inorganic Nanoparticles for Clean Energy Applications

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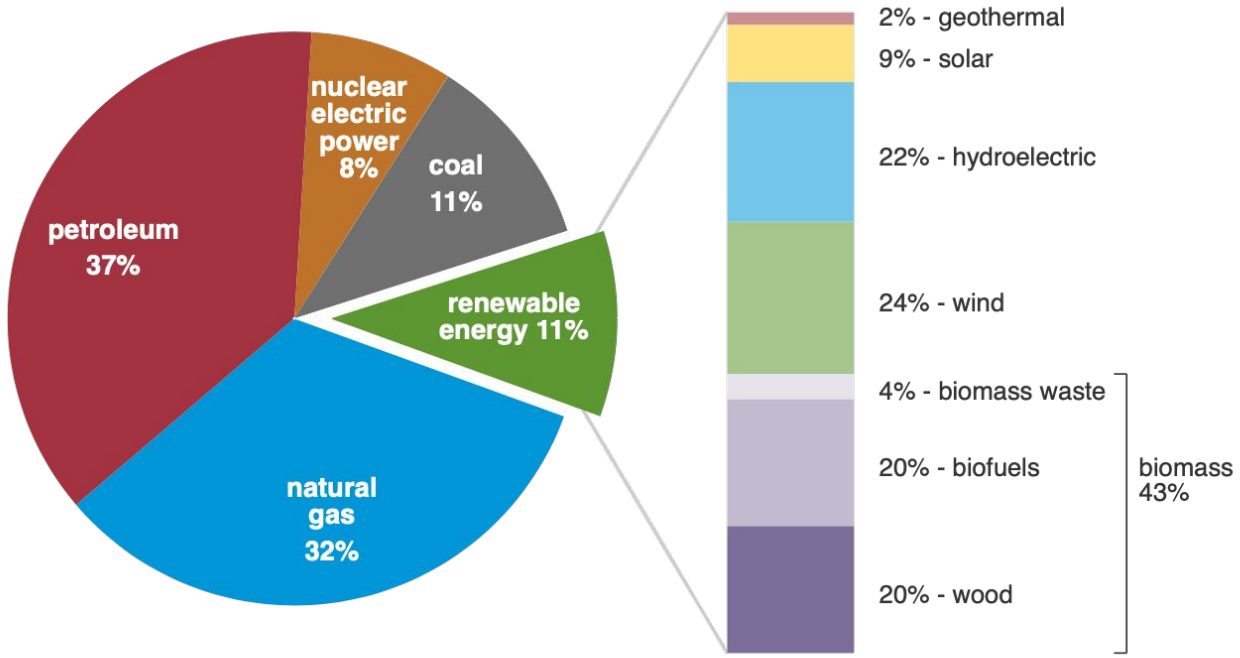
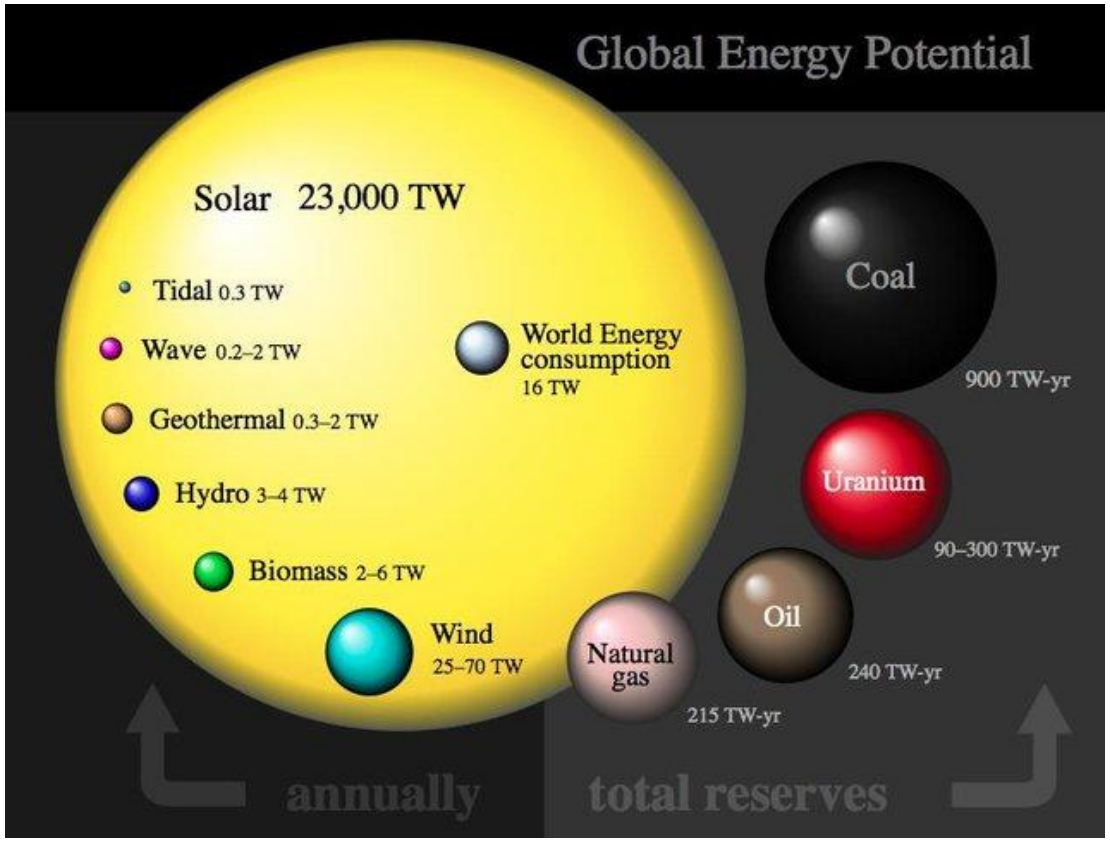
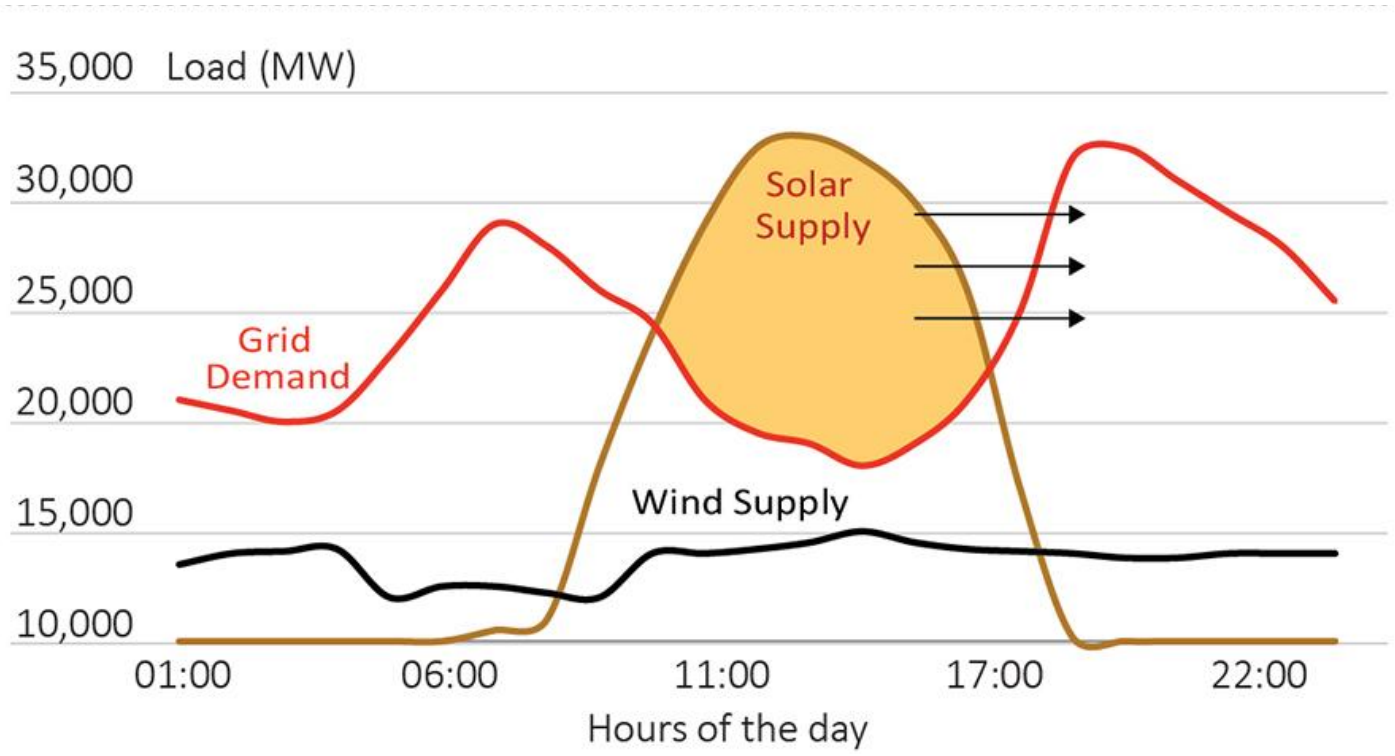
Renewable energy adoption is necessary to keep up with energy demands and lower emissions



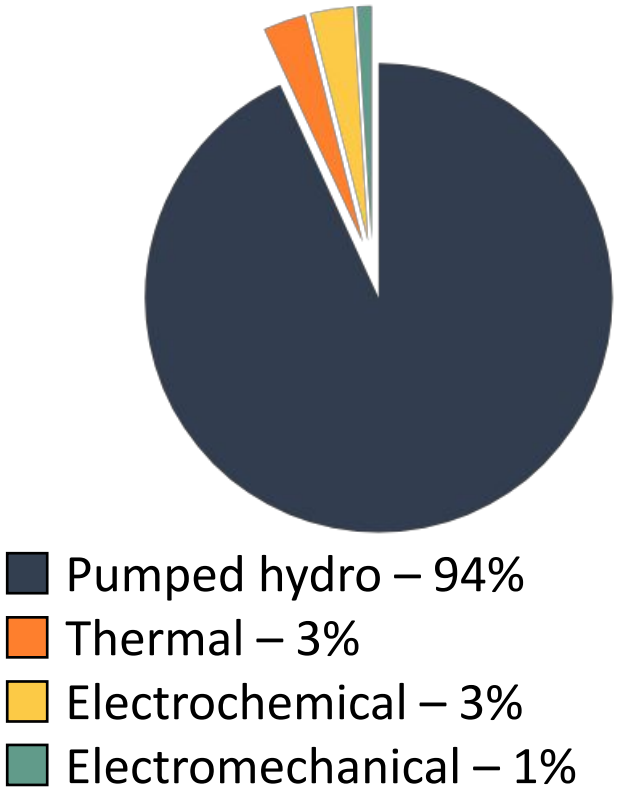


R. Perez, M. Perez *The IEA SHC Solar Update* **50**, 2, 2009
UIA, 2019

Renewable energy sources suffer from a supply demand imbalance



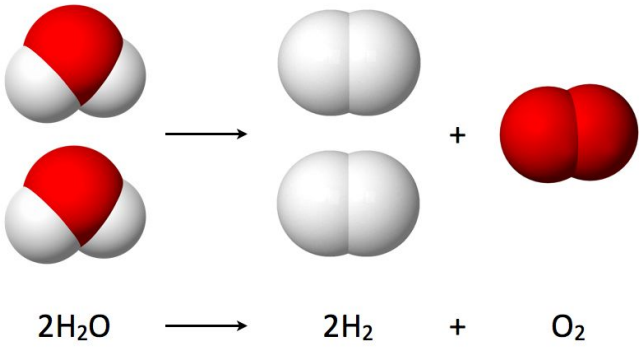
US - Energy storage

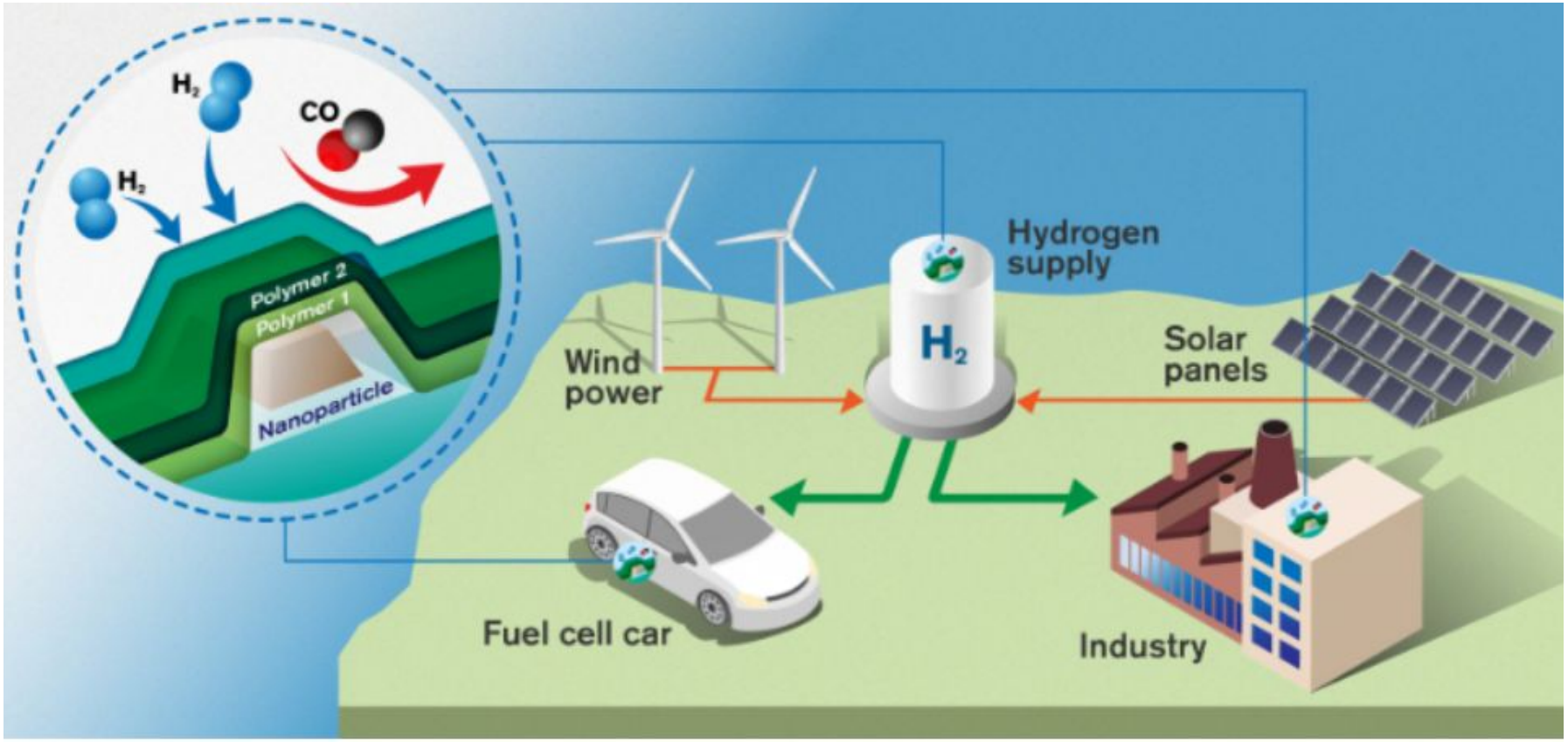


Left: QIC, 2019
Right: Center for Sustainable Systems, University of Michigan. 2020. "U.S. Energy Storage Factsheet." Pub. No. CSS15-17.

Surplus energy generated by clean sources can be stored as chemical energy in the form of hydrogen gas (H_2)

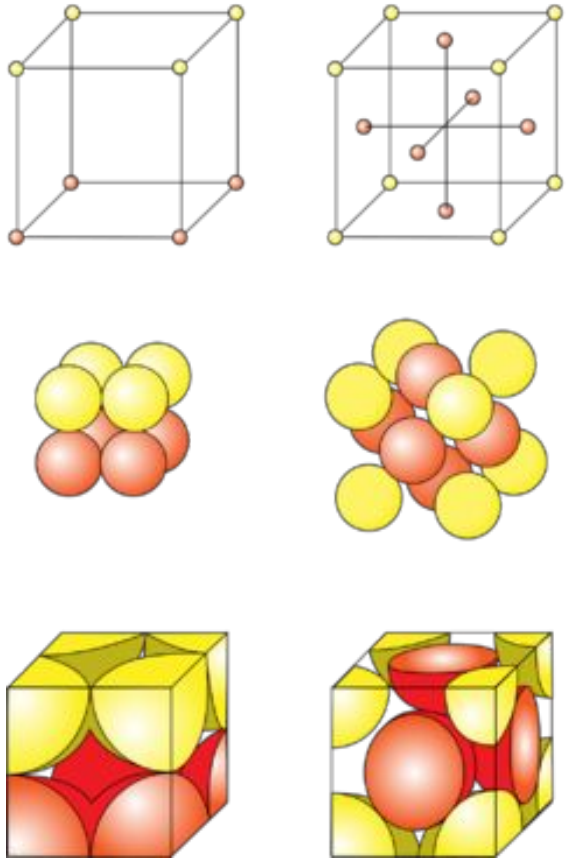
Water splitting:



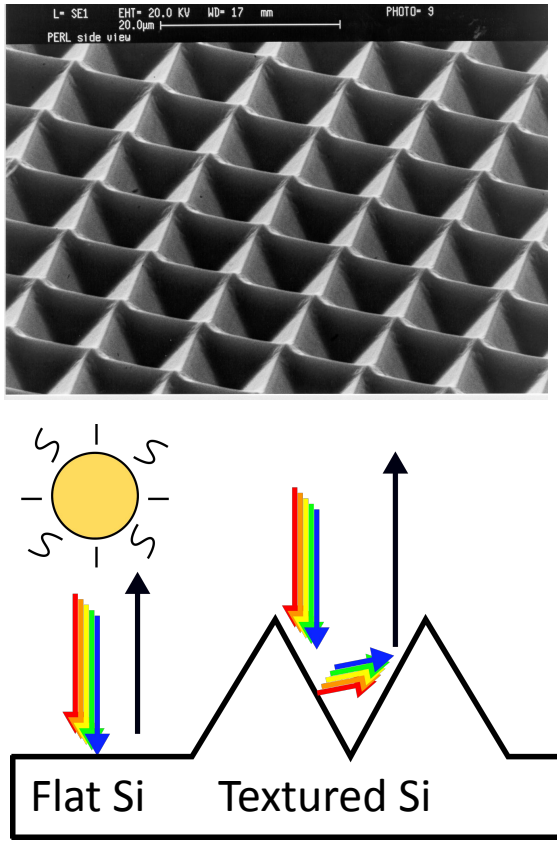


Fuel Cells Works, 2019

Structured inorganic materials found in clean energy applications



Atomistic Structure



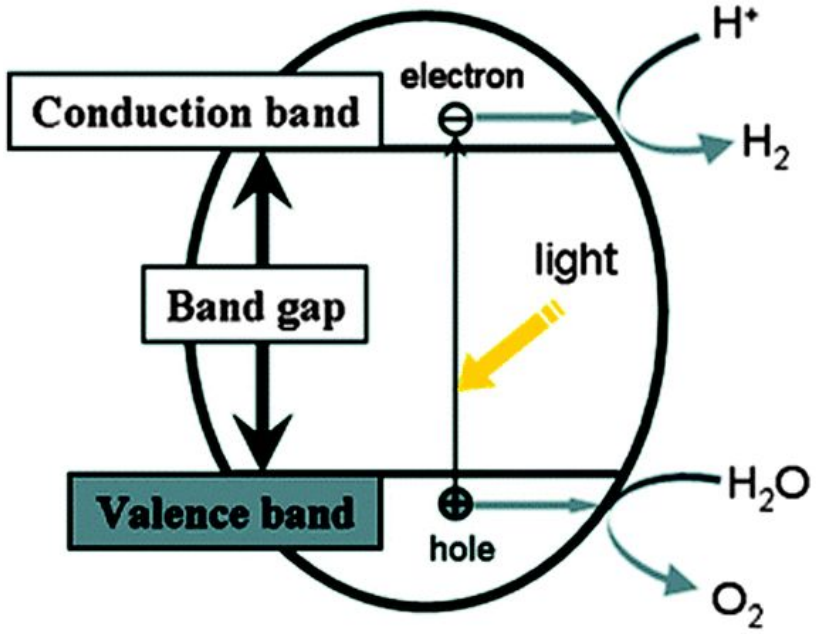
Microscale Structure

Macroscale Structure

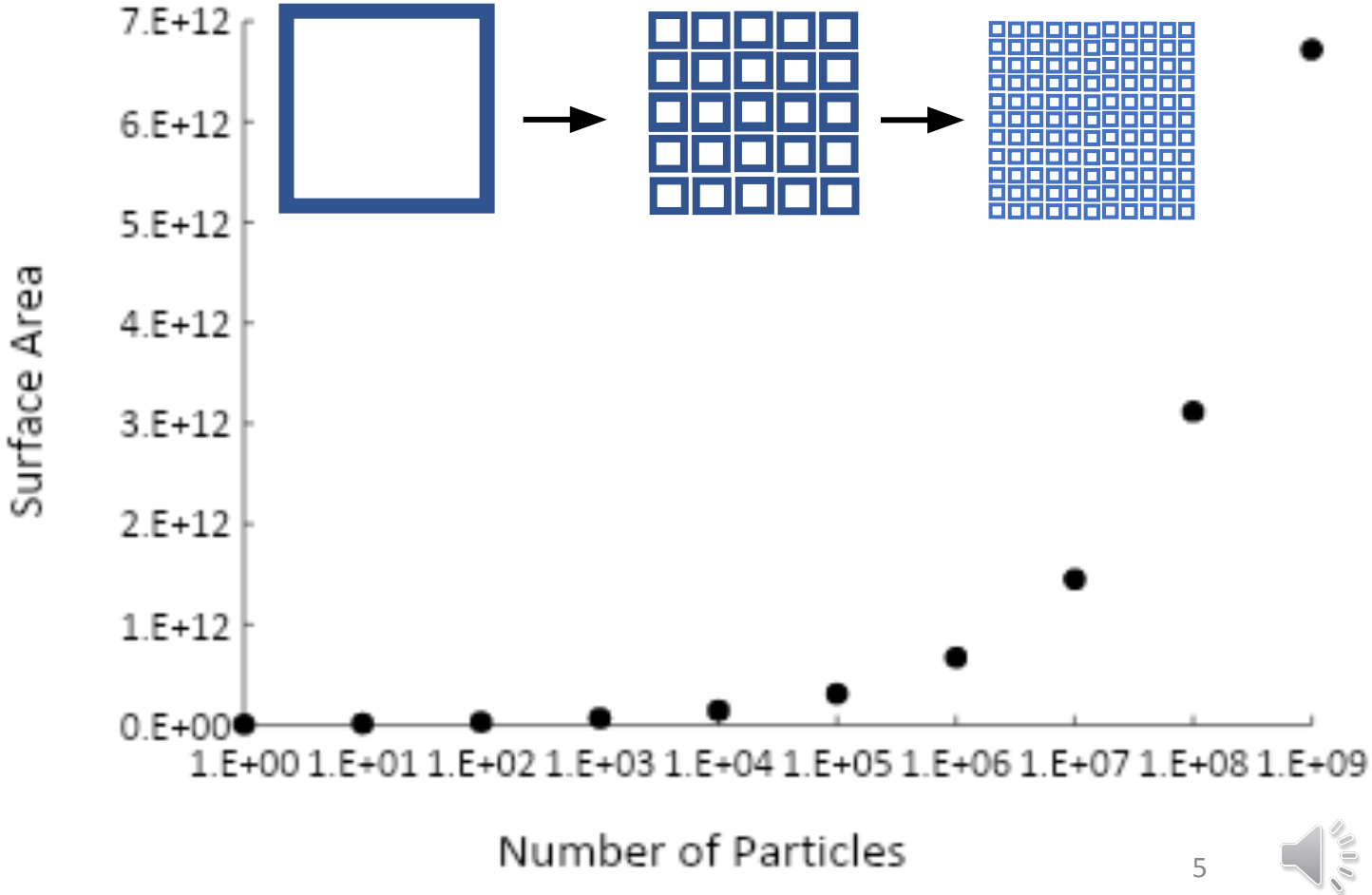
Lumen Learning, PV Education, Ethan Miller

Materials properties affecting the photocatalysis efficiency

Band gap energy

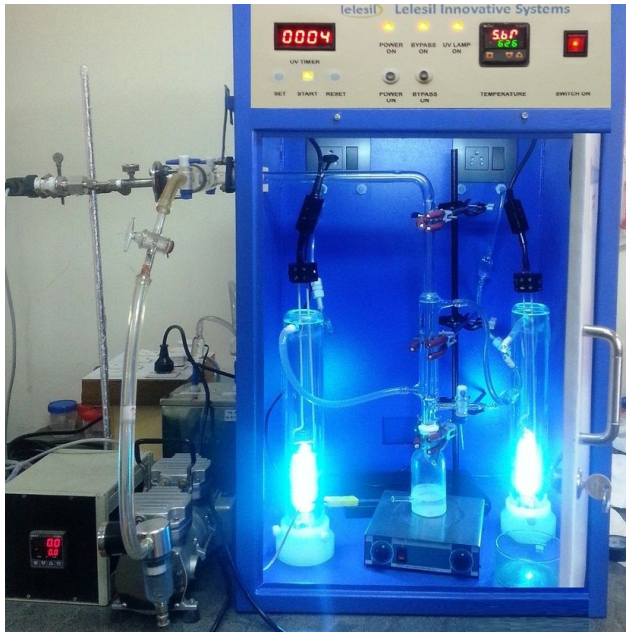


Area to volume ratio

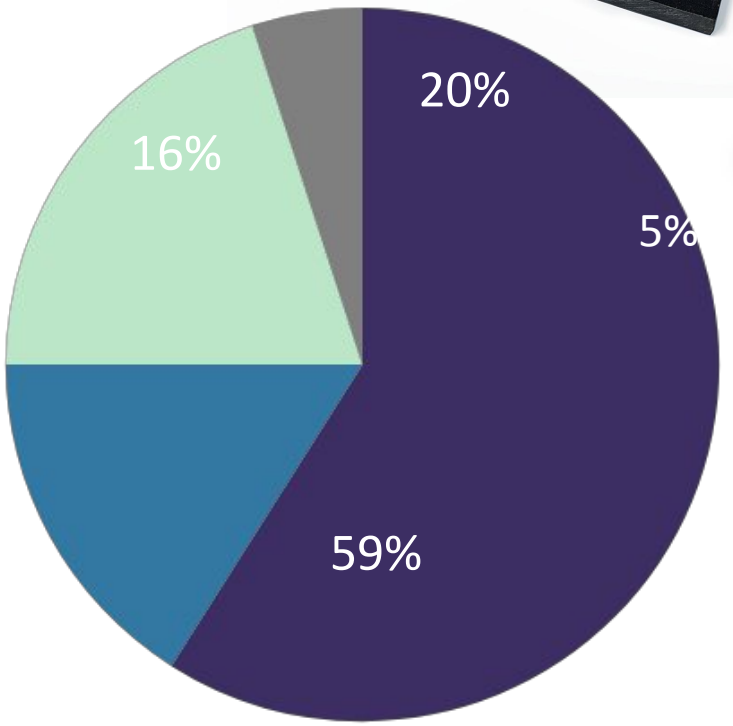


Energy Environ. Sci., 2016, **9**, 709-728

Commodity uses of TiO_2 (titania)



Others e.g. photocatalysis

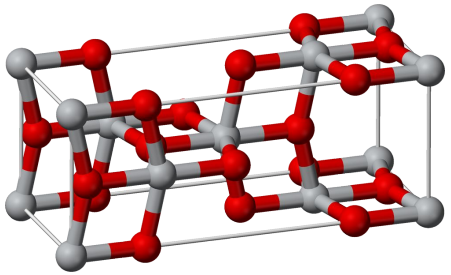


Paints

U.S. Geological Survey, Mineral Commodity Summaries, January 2020

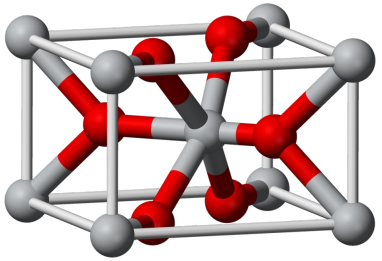
Titania polymorphs

Anatase



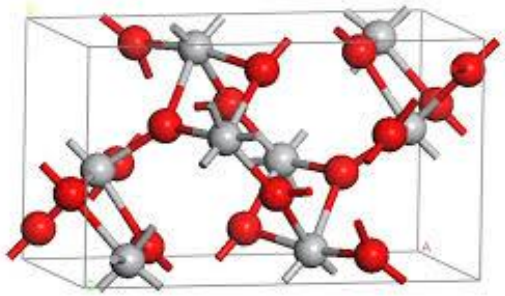
Widest band gap,
Favored for NPs < 14 nm

Rutile



Most stable

Brookite

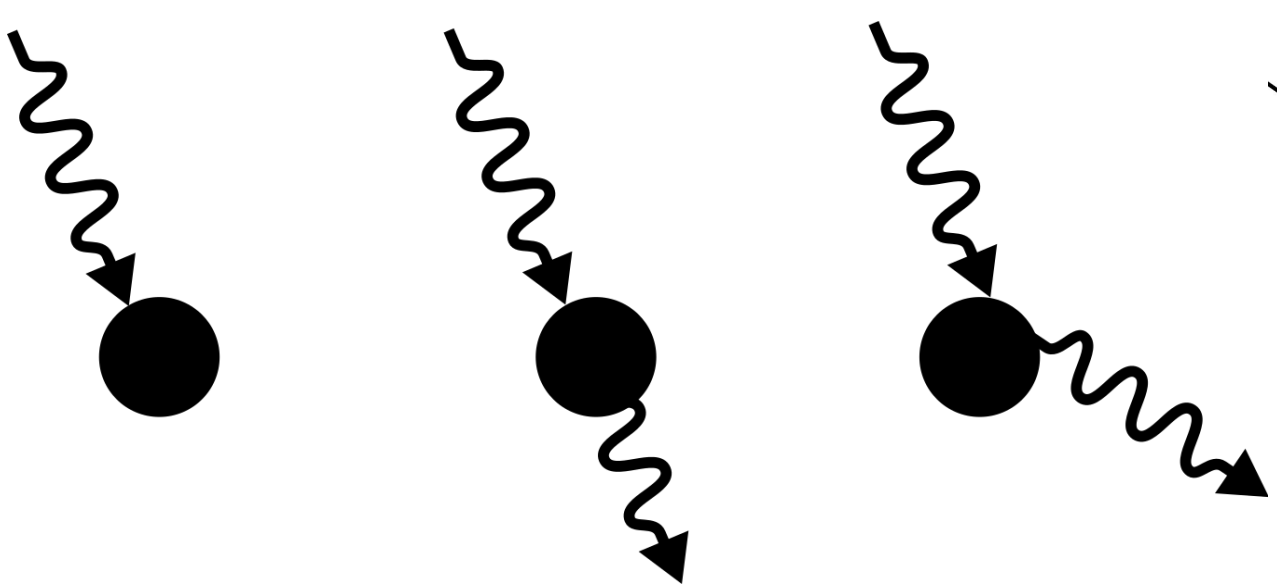


Rare

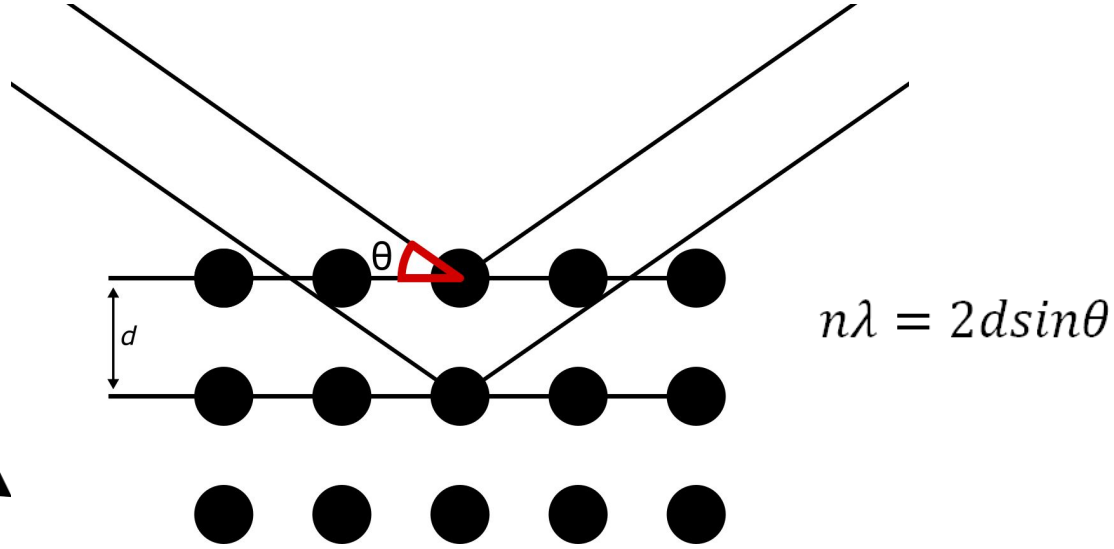
Red = O
White = Ti

Kharissova. *Handbook of Nanomaterials and Nanocomposites for Energy and Environmental Applications*. Springer International Publishing, 2020.

Structural characterization fundamentals



Absorption **Transmission** **Scattering**



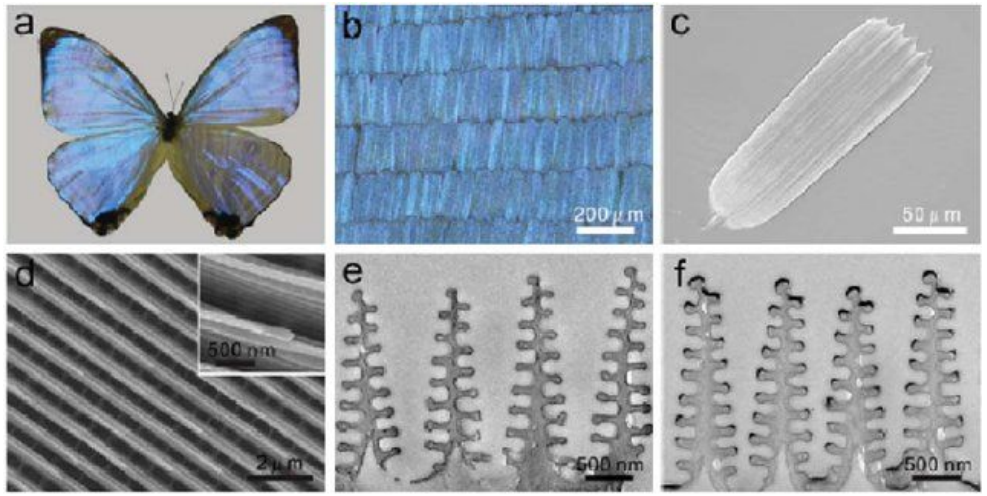
Bragg Diffraction

Beam (e.g. light) interacts with matter

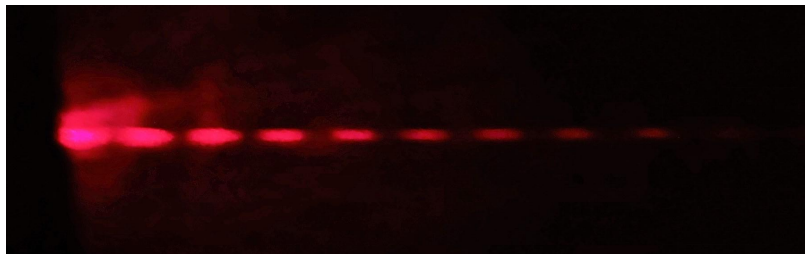
Atoms diffract beam leading to constructive and destructive interference

Light scattering and diffraction examples

Light scattering from particles (e.g. lake sediment)



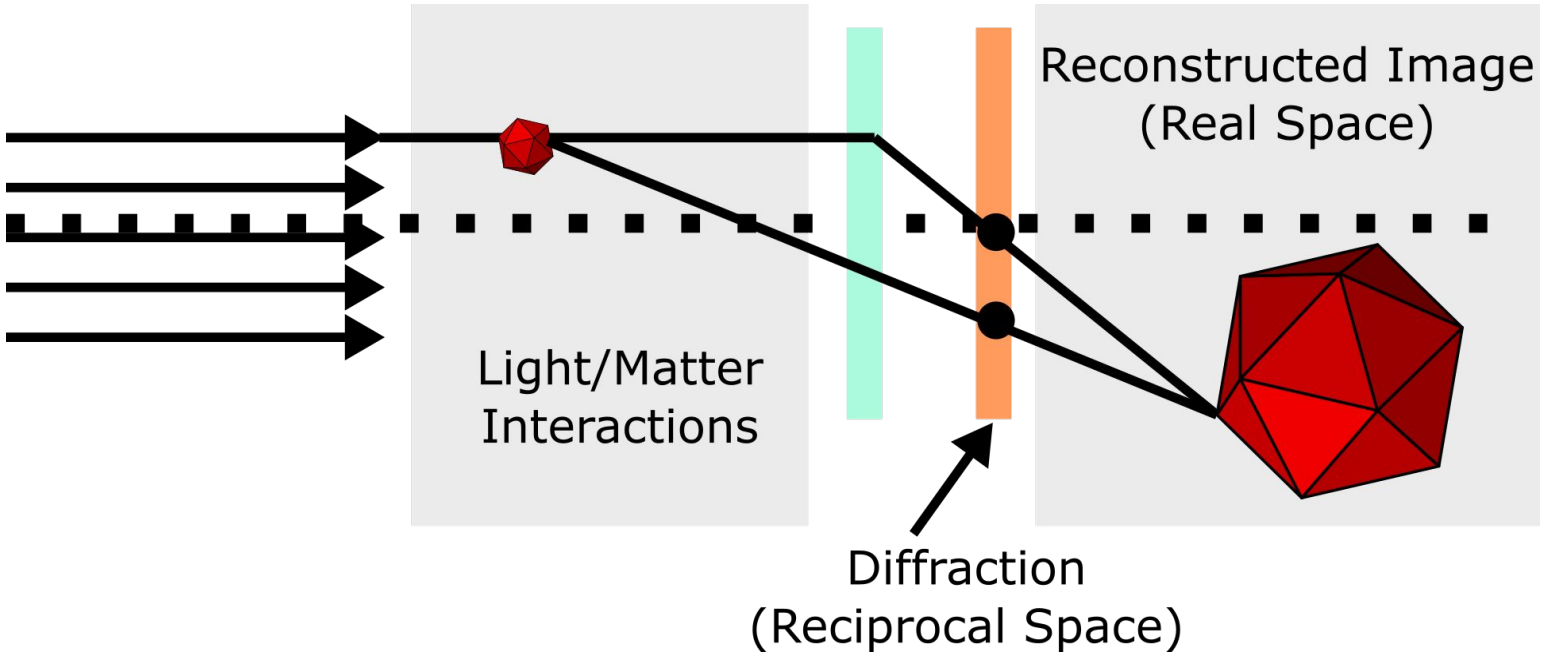
Morpho butterfly structural color



Laser diffracted by hair

Top right: J. He *RSC Advances*, **8**, 32395-32400, 2018

General comparison of reciprocal vs. real space structural characterization techniques



Reciprocal Space

Representative of whole sample

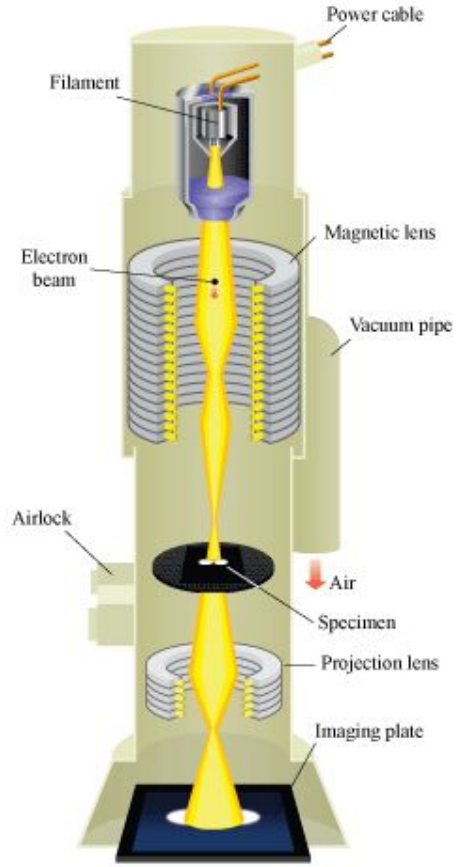
Ambiguous results

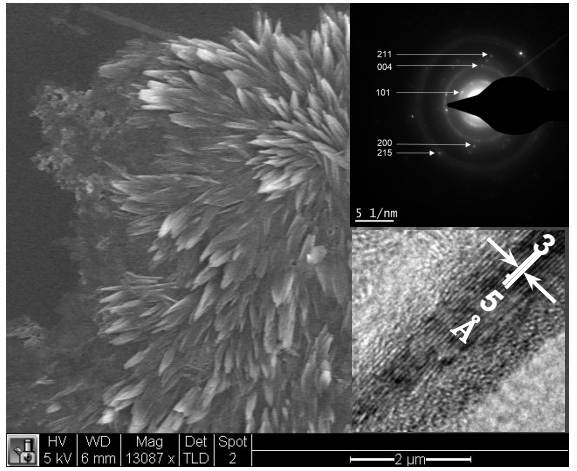
Real Space

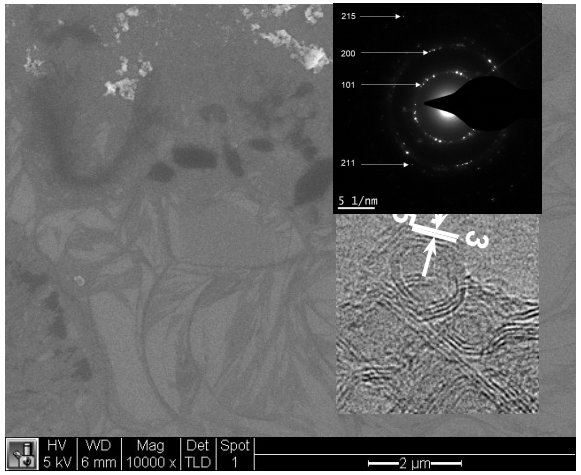
Not representative of whole sample

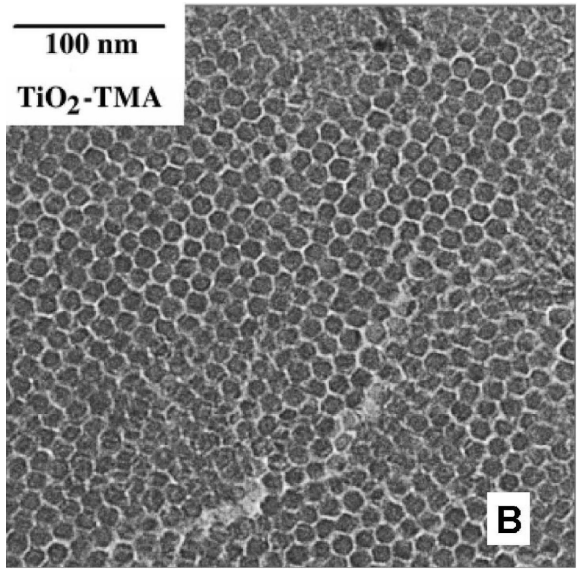
Unique results

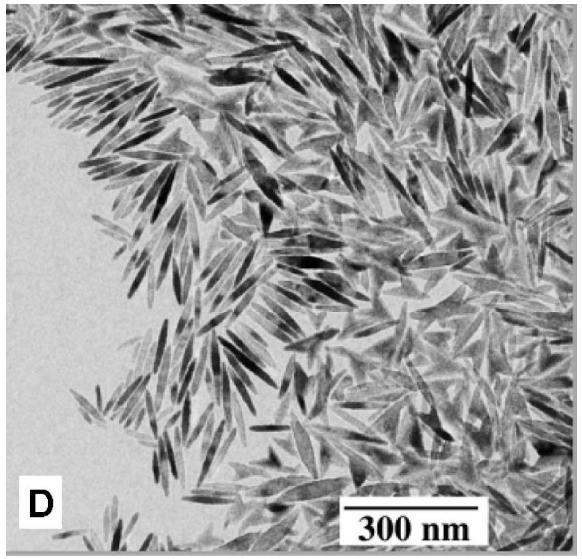
Transmission electron microscopy (TEM) of titania nanoparticles





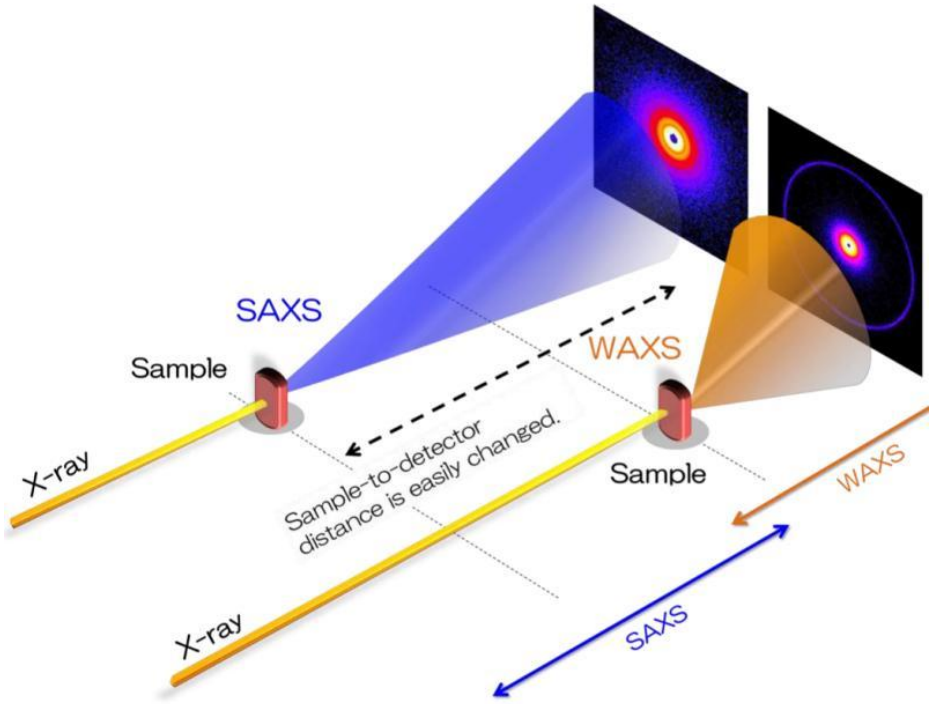




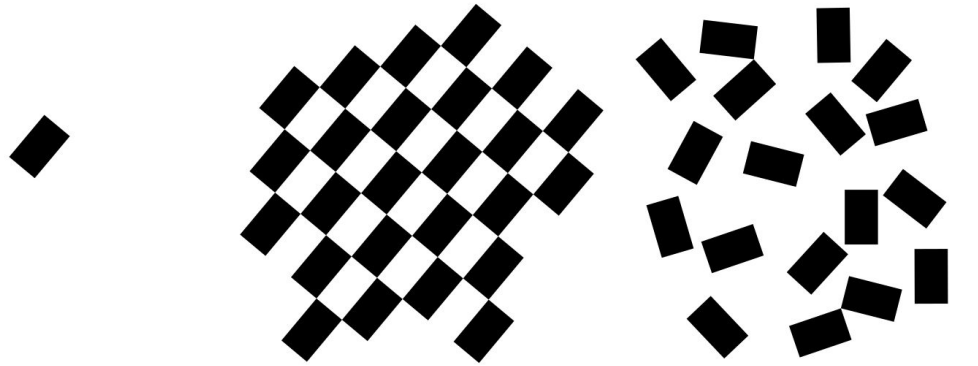


Left: HK-phy.org
Top right: K. Pushpavanam, *Chem. Commun.*, 2021
Bottom right: X. Chen, *Chem. Rev.* **107**, 2891-2959, 2007

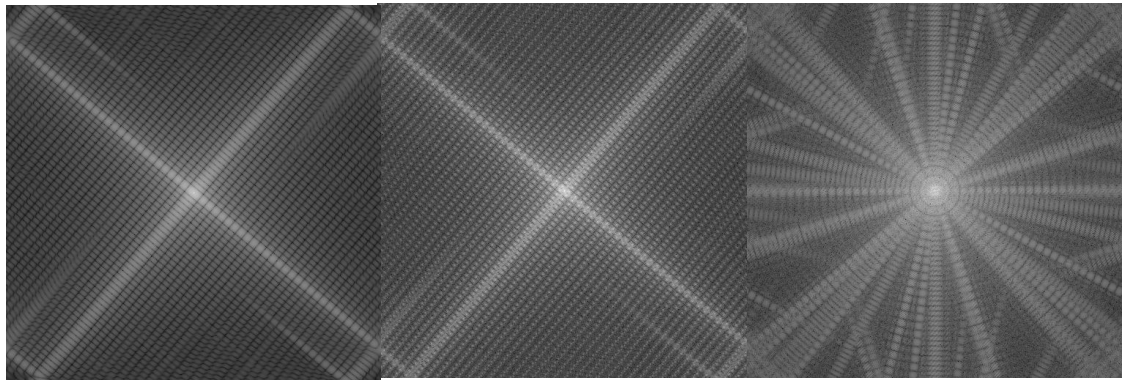
Small angle scattering and diffraction



Original image

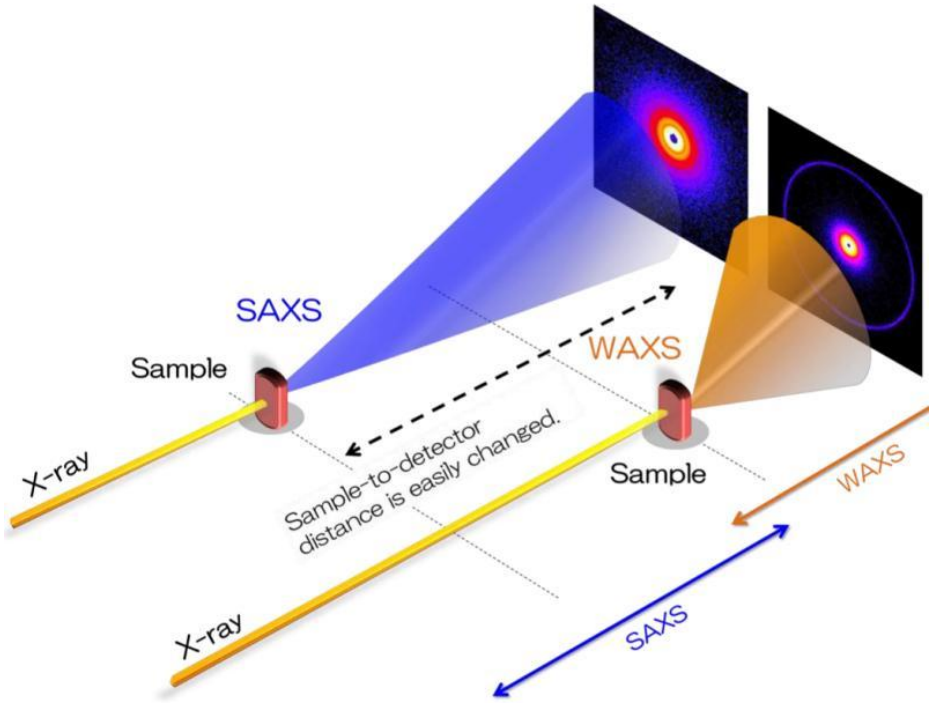


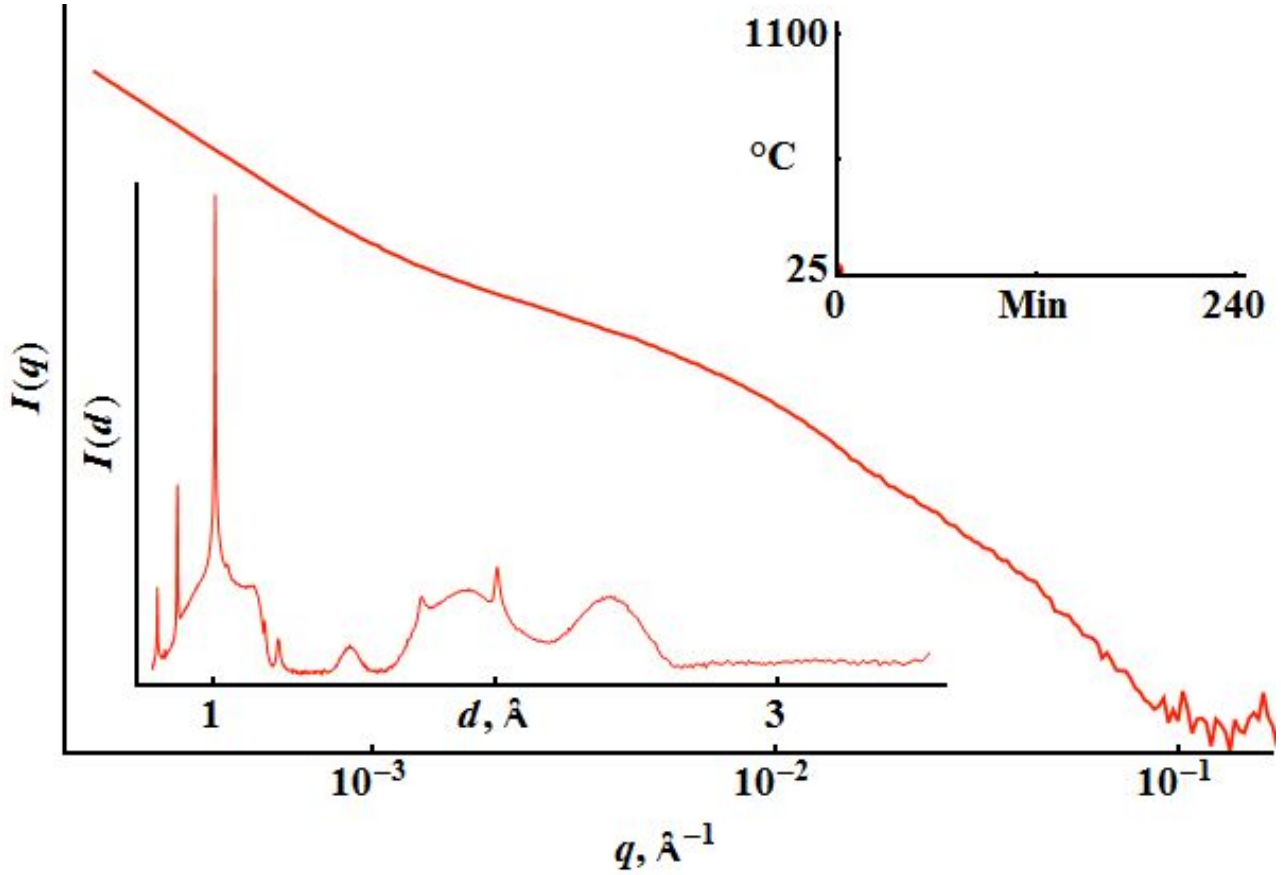
FFT (reciprocal space)



Left: Rigaku, 2020,
Right: Dr. G. Muralidharan, ORNL

Small angle scattering and diffraction





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