

Since 1959



Microdroplet Mechanochemistry

Thalappil Pradeep Institute Professor Indian Institute of Technology Madras, Chennai 600036 Email: pradeep@iitm.ac.in | Web: <https://pradeepresearch.org> **Thank you for this recognition!**

Honorary Professor

Jawaharlal Nehru Centre for Advanced Scientific Research, Jakkur, Bengaluru 560064

Chemo-Electro-Mechano Unification for Sustainability

DAE-BRNS 7th National Workshop on Materials Chemistry, November 20-22, 2025, DAE Convention Centre, Anushaktinagar, Mumbai 400094

Co-founder

InnoNano Research Pvt. Ltd.

InnoDI Water Technologies Pvt. Ltd.

VayuJAL Technologies Pvt. Ltd.

Aqueasy Innovations Pvt. Ltd.

Hydromaterials Pvt. Ltd.

EyeNetAqua Pvt. Ltd.

Deepspectrum Analytics Pvt. Ltd.

Professor-in-charge



International Centre for Clean Water



A close-up photograph of a campfire. Several logs are arranged in a teepee shape, with bright orange and yellow flames rising from the center. The background is dark, making the fire the central focus.

We transform matter with
fire

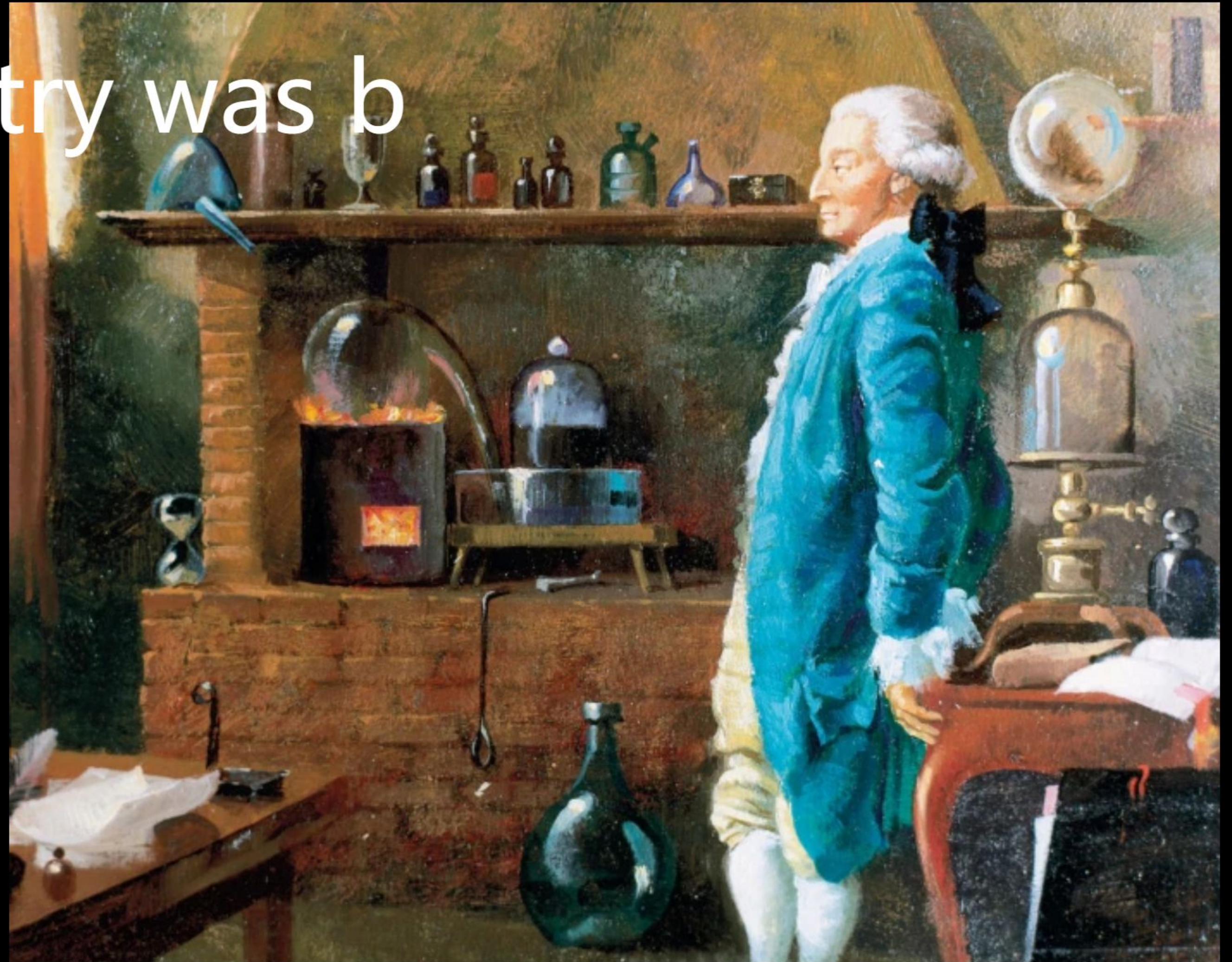
Taming fi
re

Thermodynami
cs

Kinetics

Engineering

Modern chemistry was born



Lowe, D. Laboratory history: The chemistry chronicles. *Nature* **521**, 422 (2015). <https://doi.org/10.1038/521422a>



That gave materials and the modern
world

And many problems



<https://www.tatasteel.com/media/23748/tata-steel-crm-complex-jamshedpur.jpg>

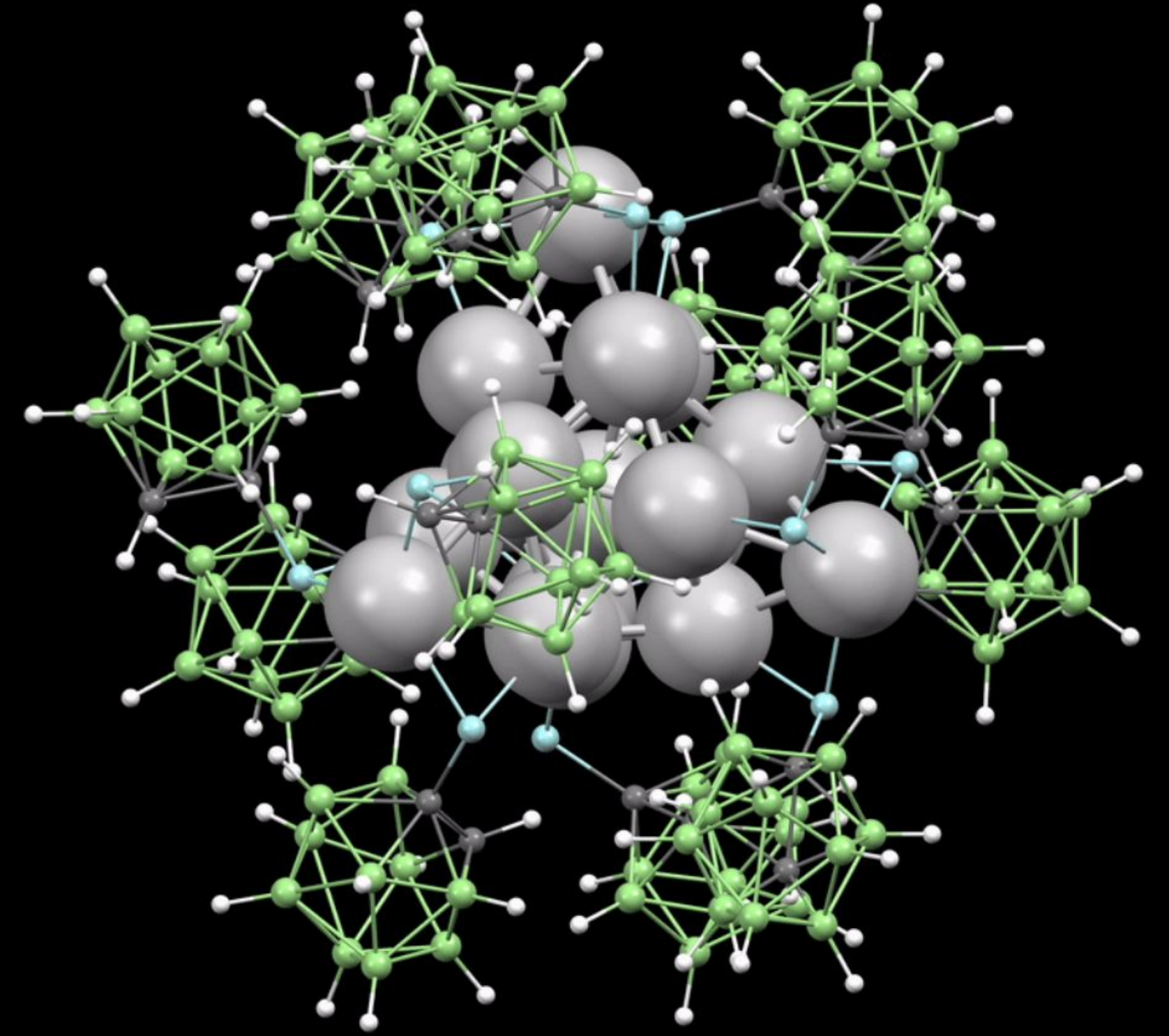
Microdroplet Chemistry



Matter in confinement for
sustainability



But, matter is becoming
ATOMICALLY PRECISE



Vivek Yadav, et. al. *Nature Communications*
2025

Organic and inorganic matter too are becoming atomically precise

Science

**A scale of 10
00**

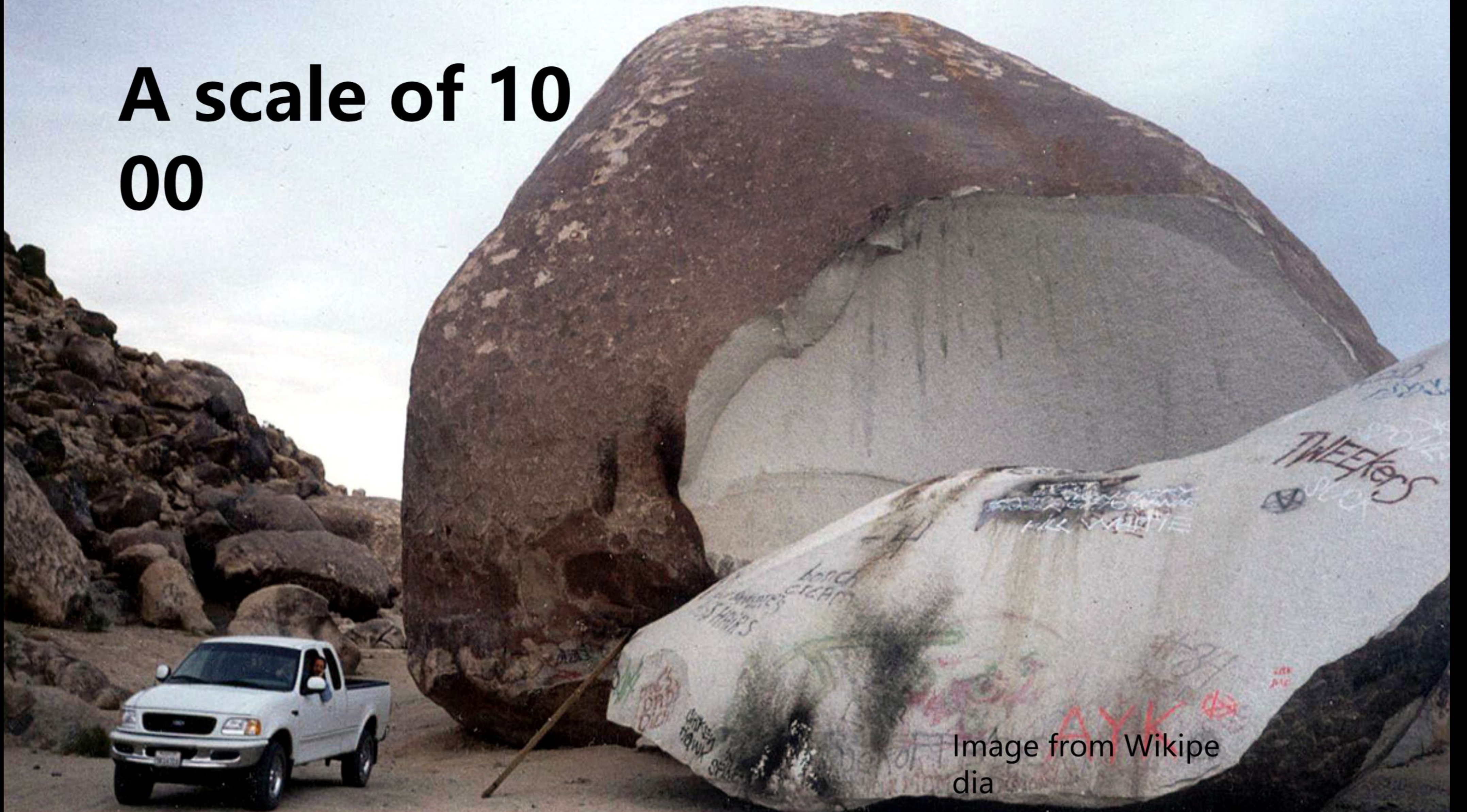
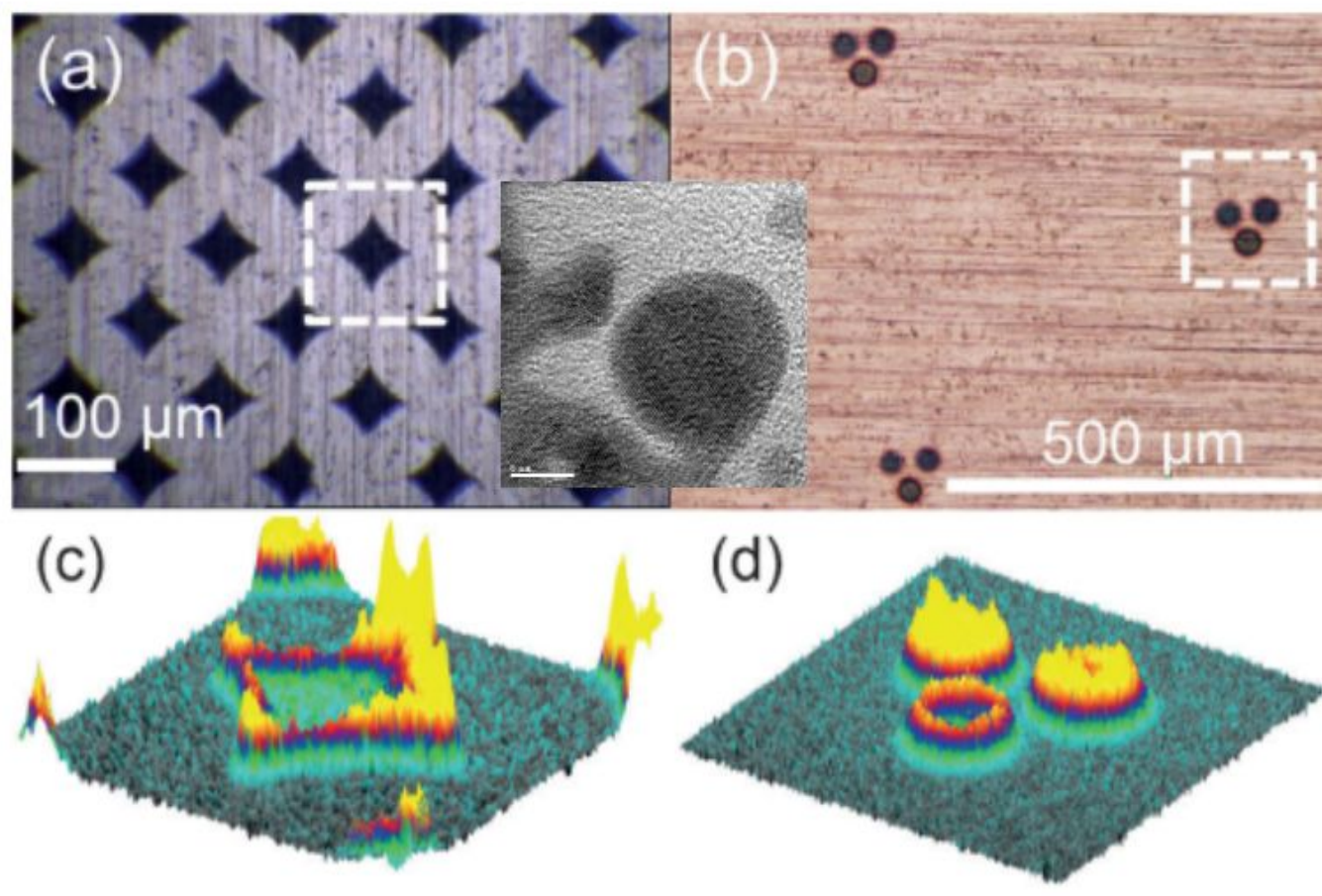
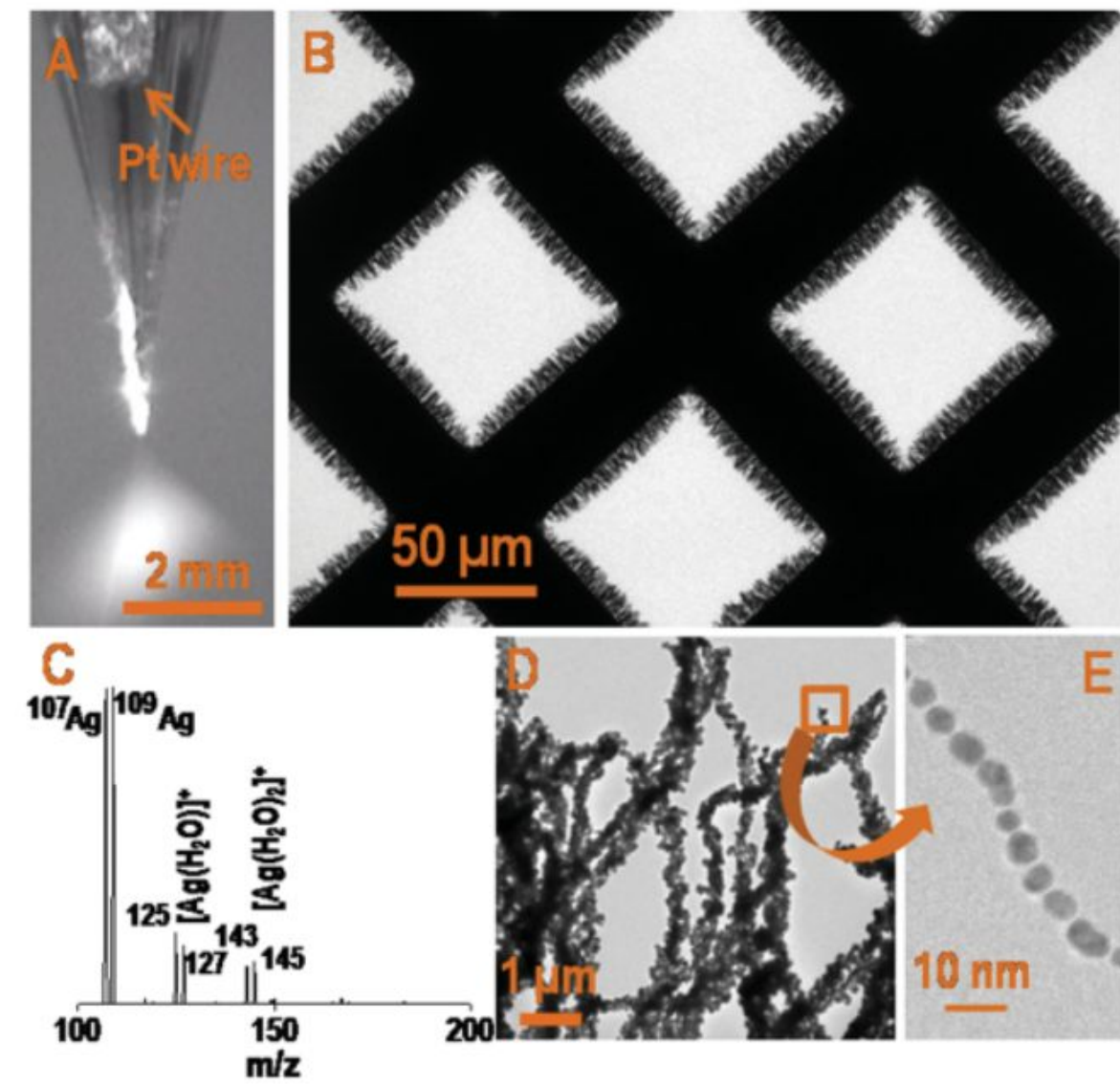


Image from Wikiped
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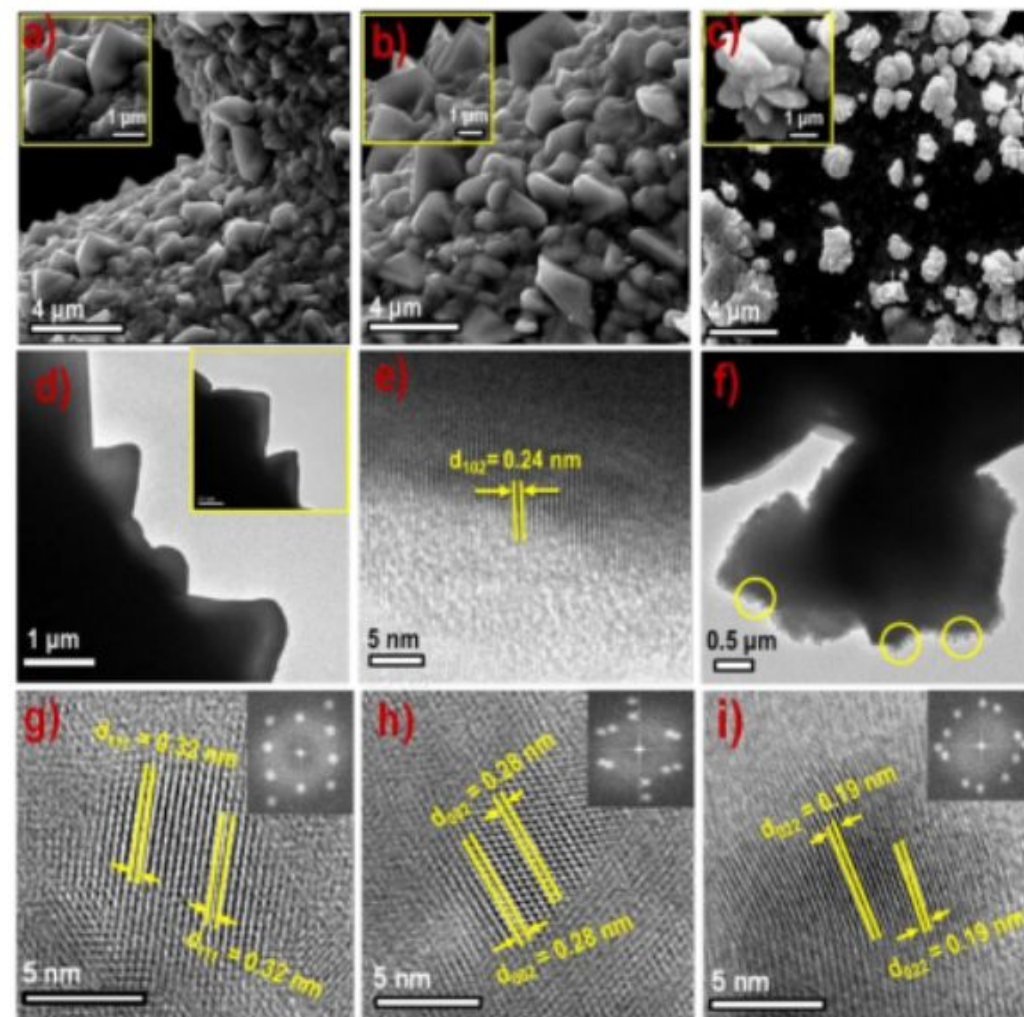
Functional Nanomaterials



Anyin Li, et. al., *Angew. Chem. Int. Ed.* 2014, 53, 12528–12531.

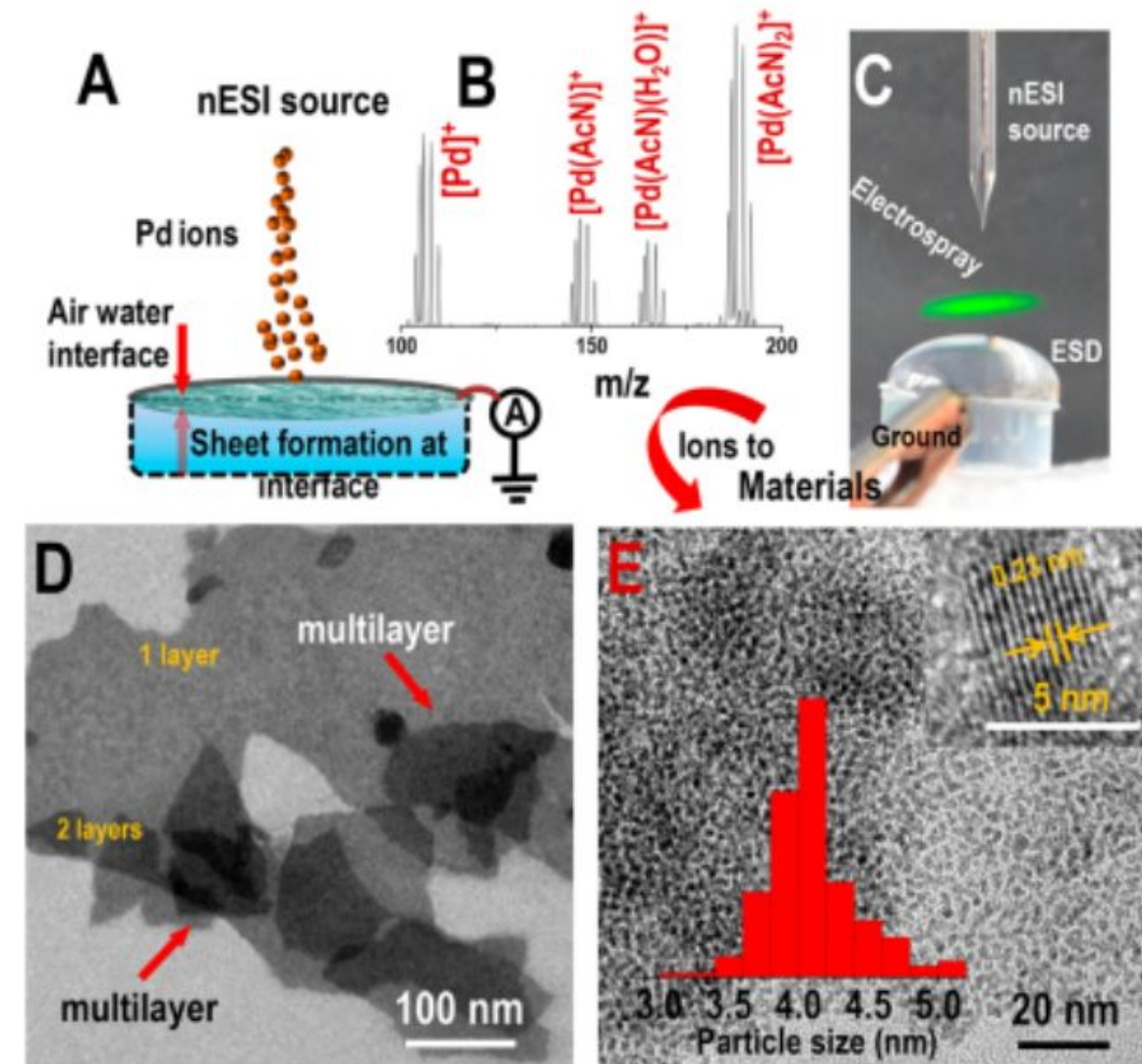


Depanjan Sarkar et. al., *Adv. Mater.* 2016, 28, 2223–2228.



Arijit Jana et. al., *J. Mater. Chem. A*, 2019, 7, 6387–6394.

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Microdroplets
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Depanjan Sarkar, et. al., *J. Phys. Chem. C* 2018, 122, 17777–17783.

Understanding Microdroplets

Transformation of Materials in Microdrop lets

Synthesis of polydisperse NPs





Thanks to ChatGP

T

Weathering in Nature

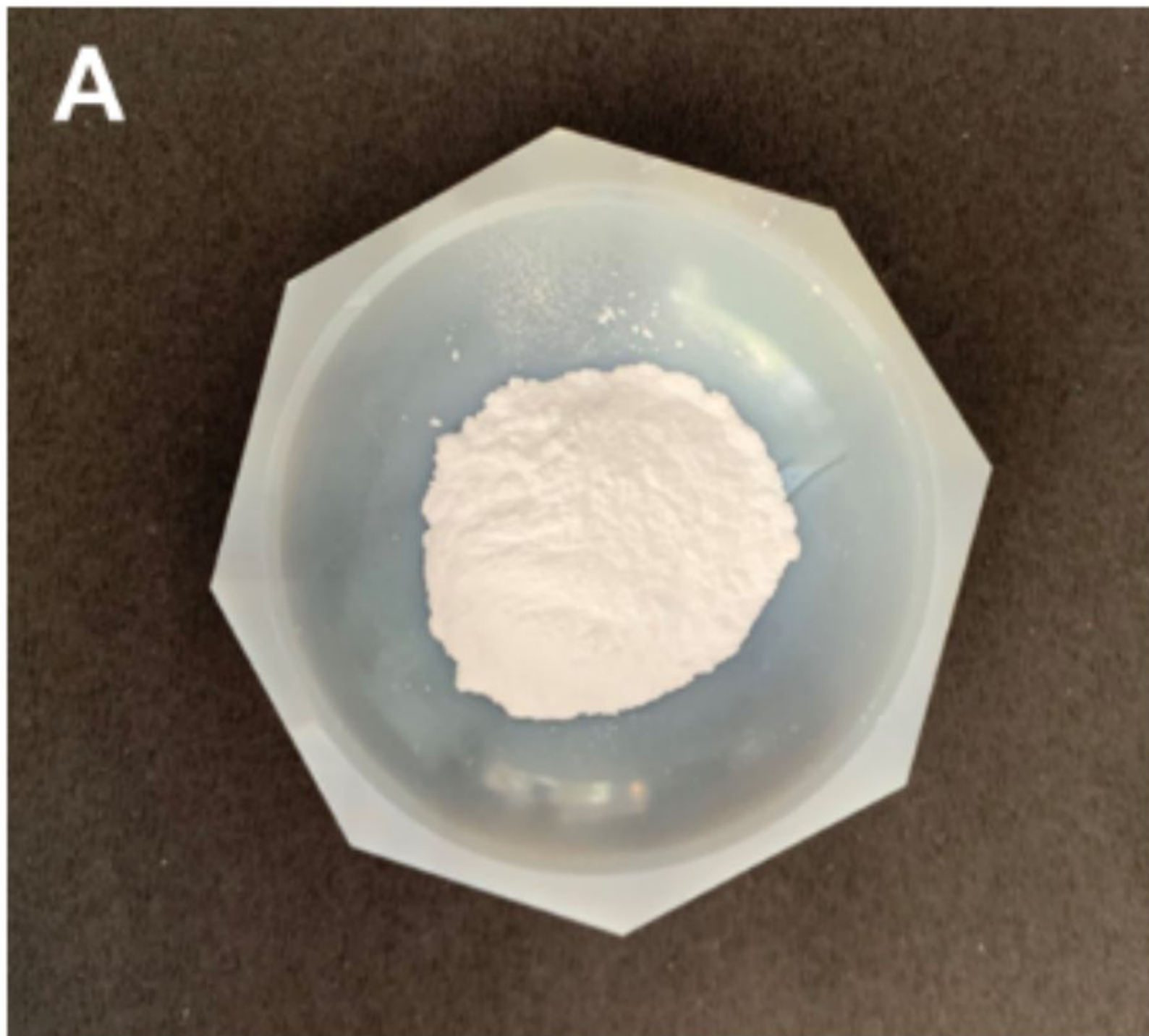


Sand, the Ubiquitous Material

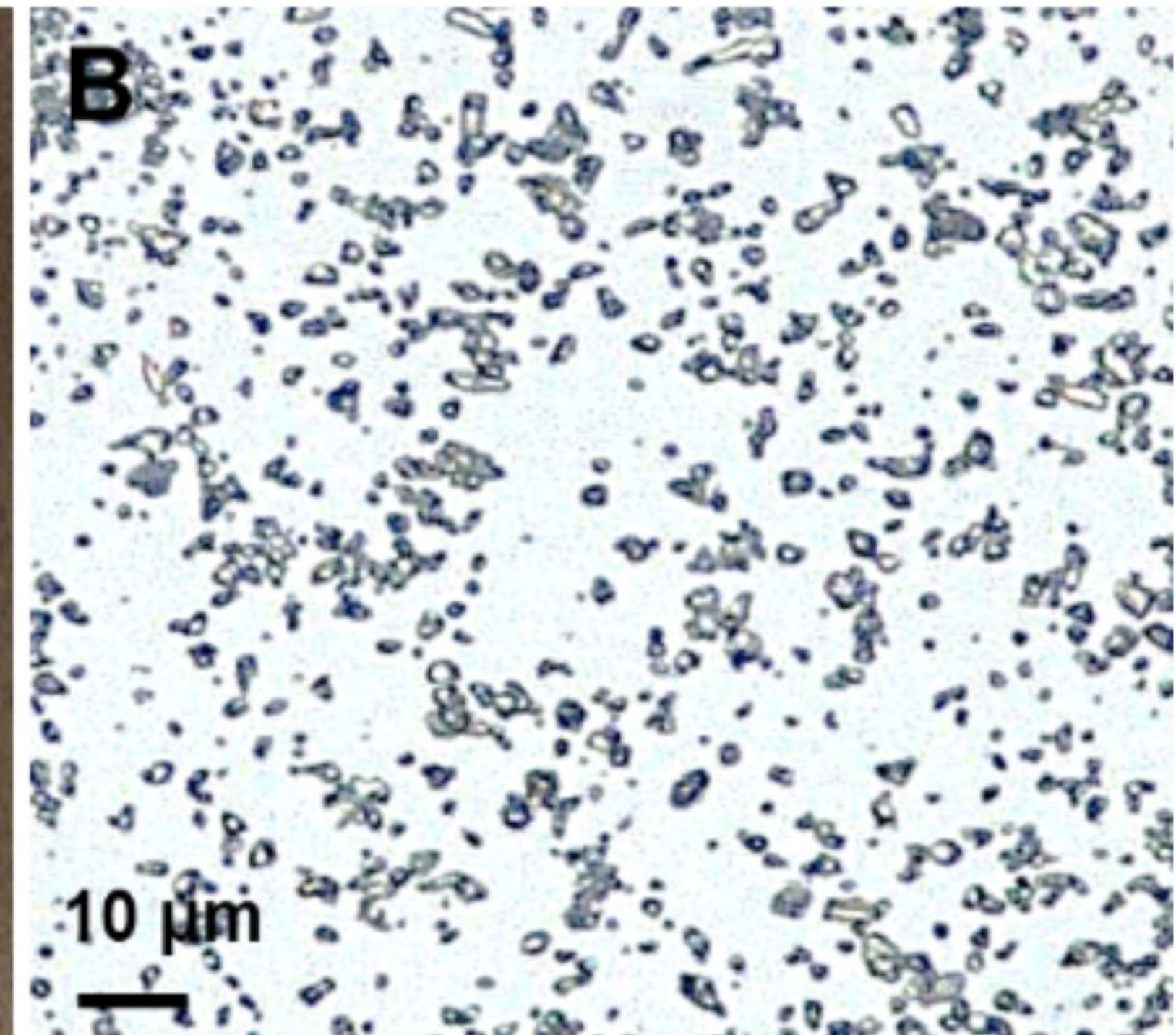


Images from Wikipedia
dia





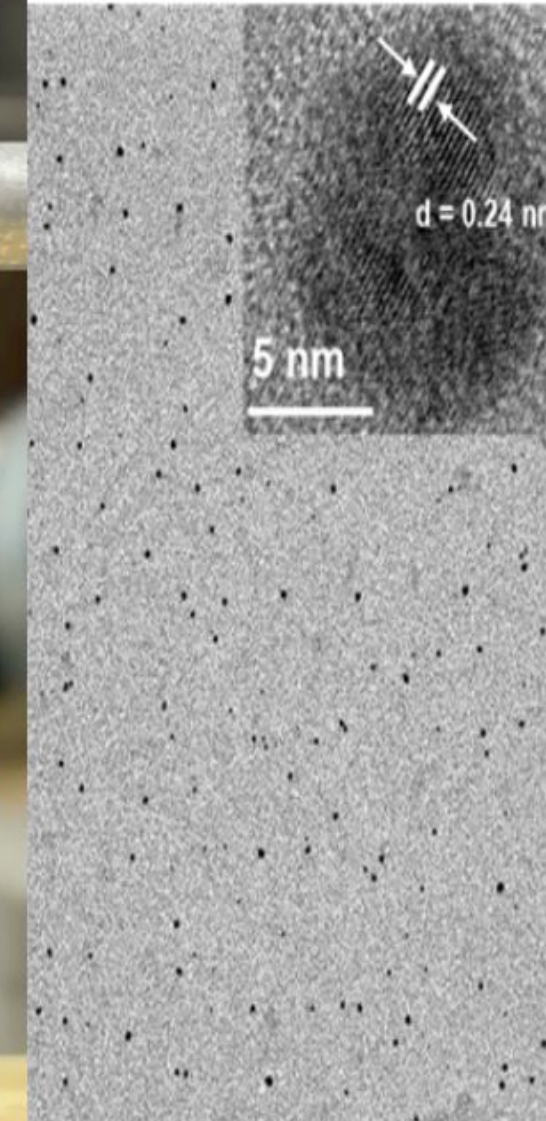
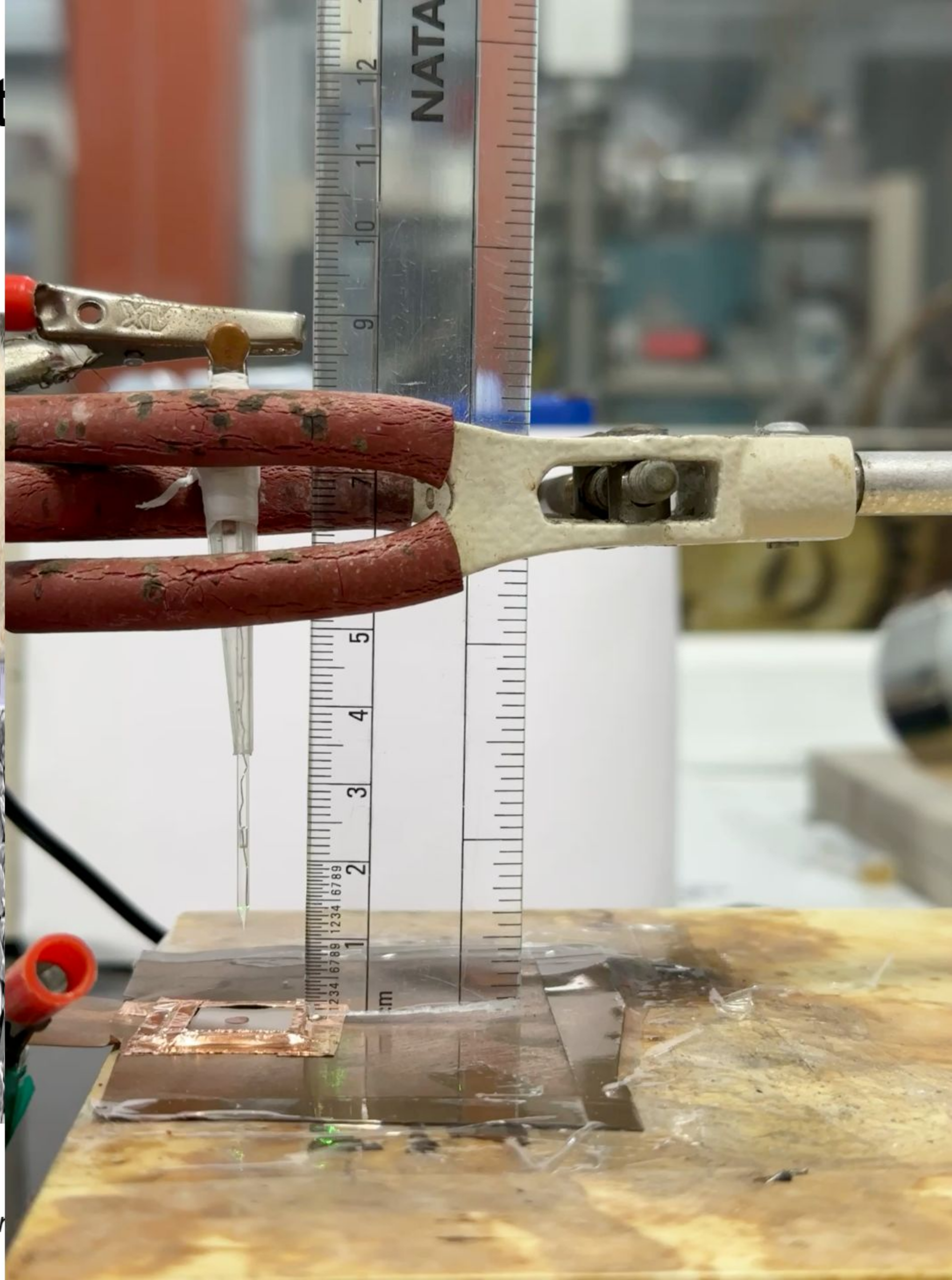
Ground silica



Optical image of silica

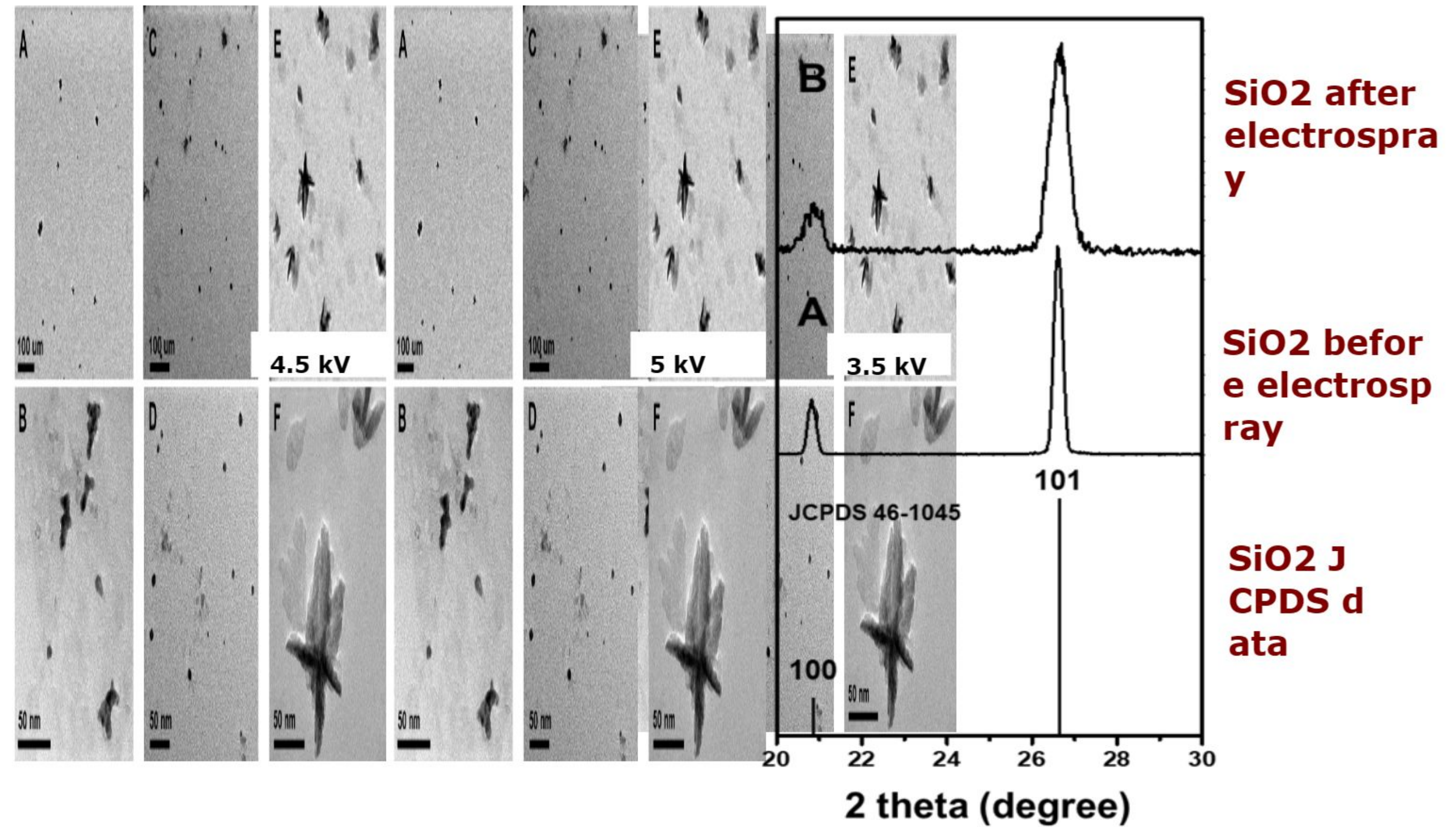
Weat

plets



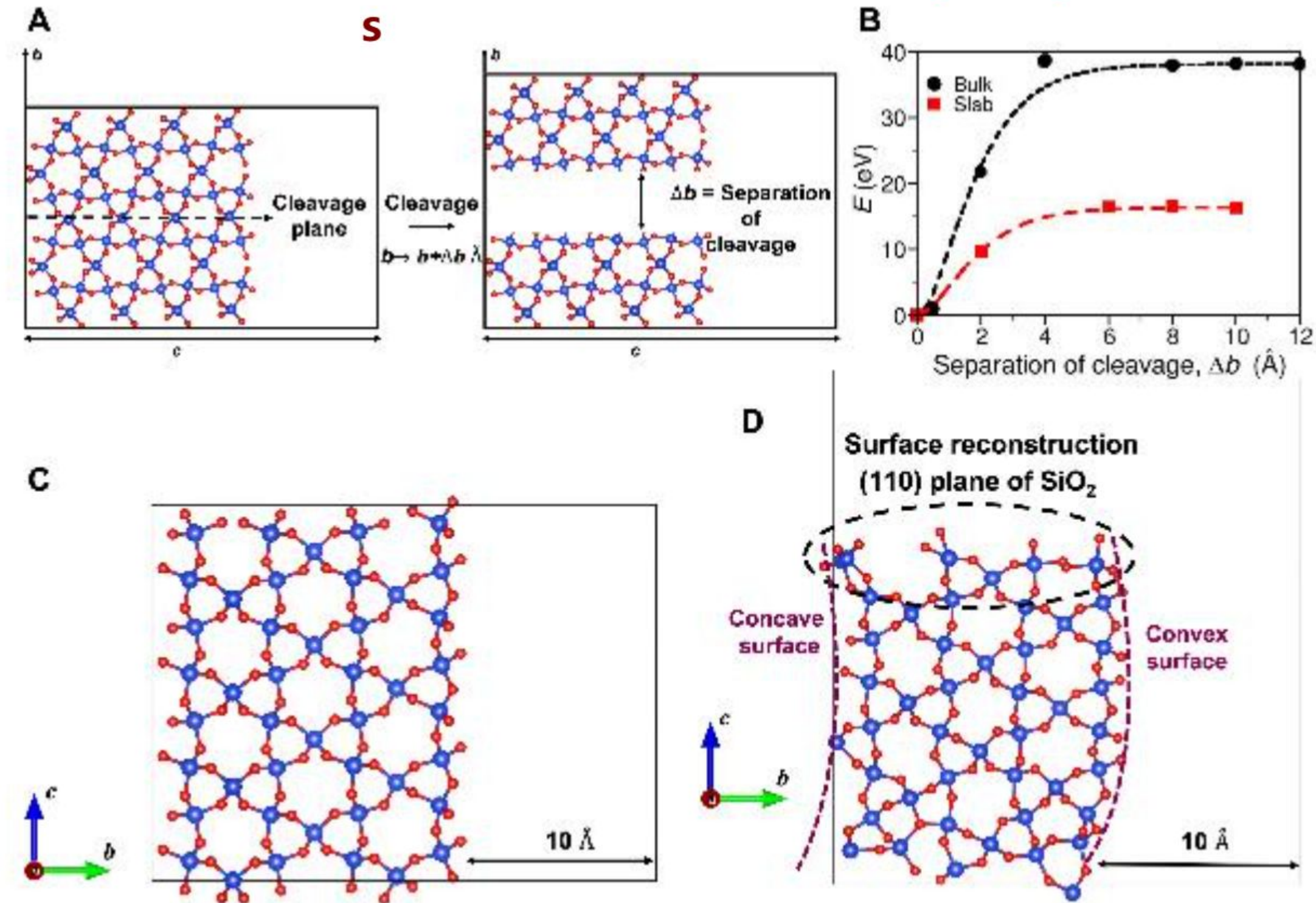
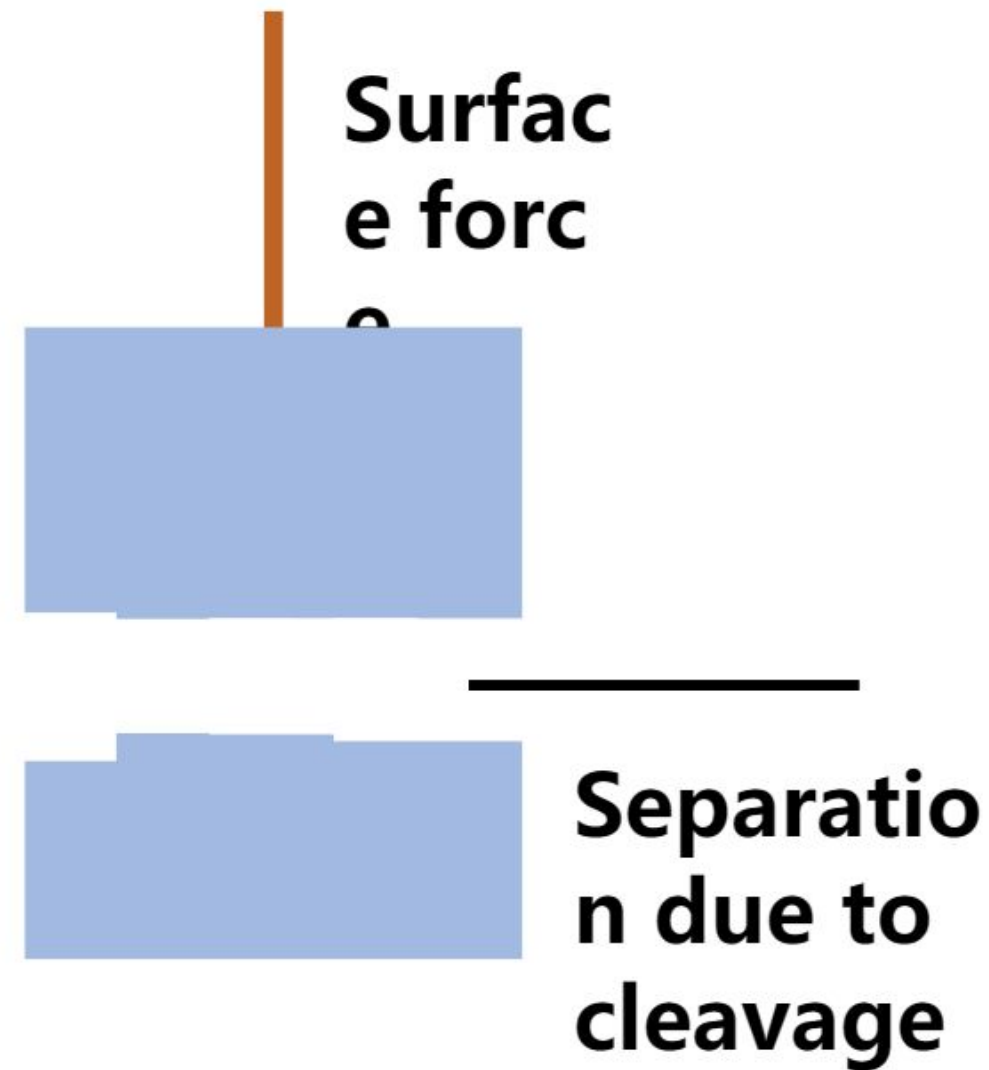
Ruby, Fused Alumin a

Fragmentation of Silica – Varying Conditions

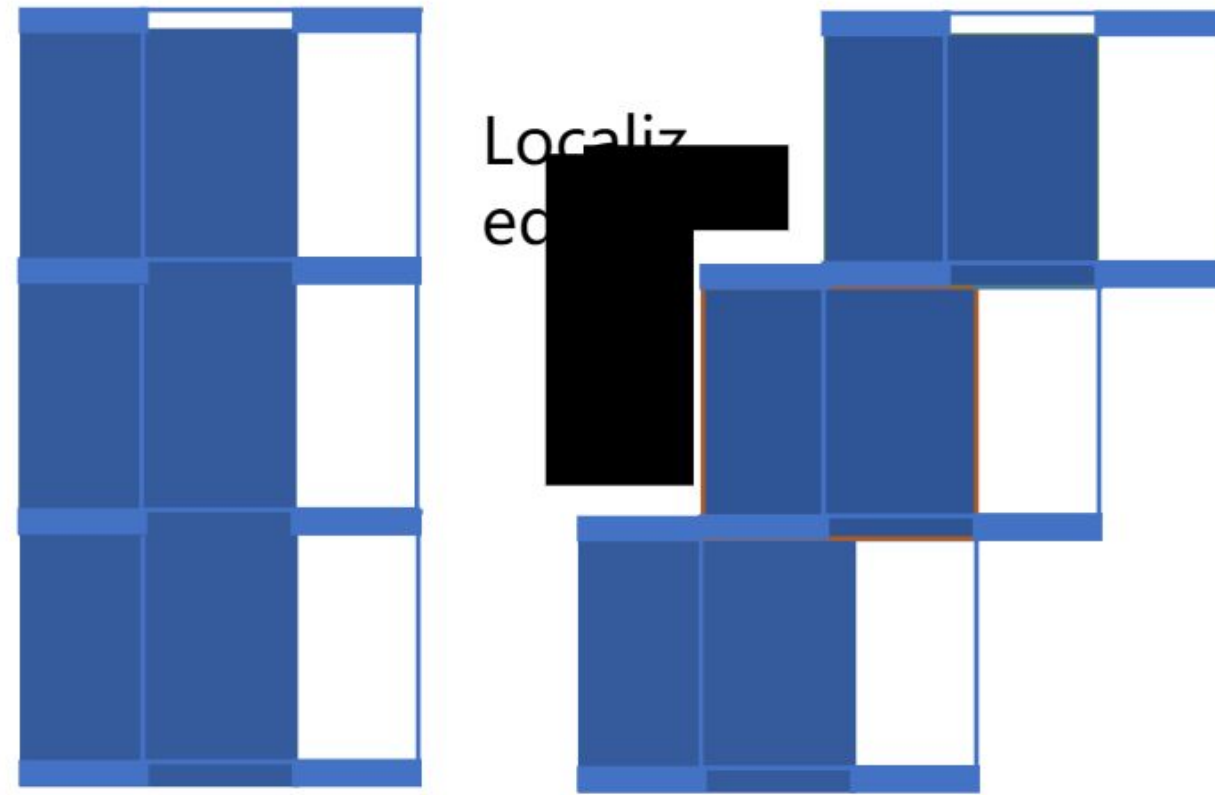


Mechanism: Cleavage

The process of cleavage and surface reconstruction visualized with first-principles simulation



Mechanism: Slip



This instability leads to the formation of a stacking fault on the (010) plane, achieved with slip localized at (010) plane

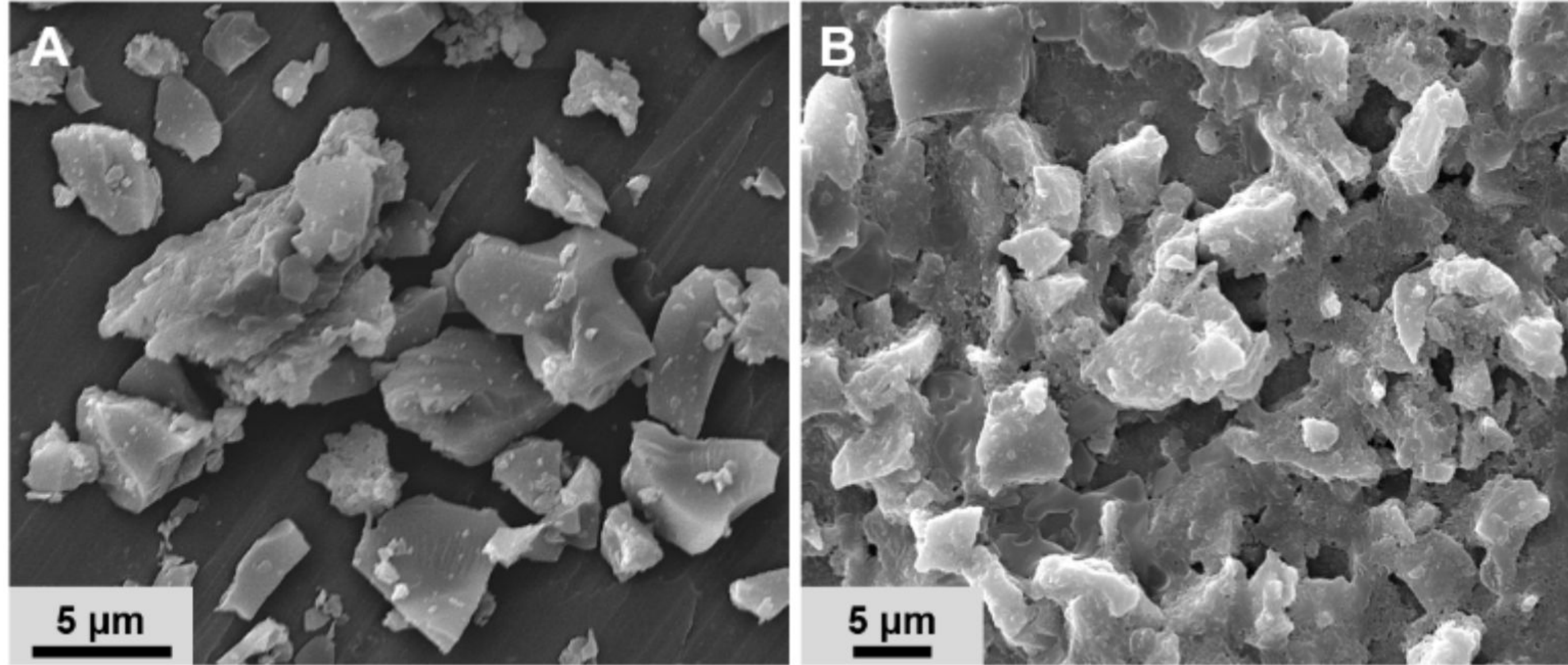
Stacking fault
 $\vec{b} \rightarrow \vec{b}_0 + (x, 0, z)$

$(\diamond\diamond, \diamond\diamond \in [0,1])$ - fractional coordinates

SFEs of (010) direction with (0, 0), (0, 0.5), (0.5, 0) and (0.5, 0.5) slip configurations
on the (110) plane of SiO₂

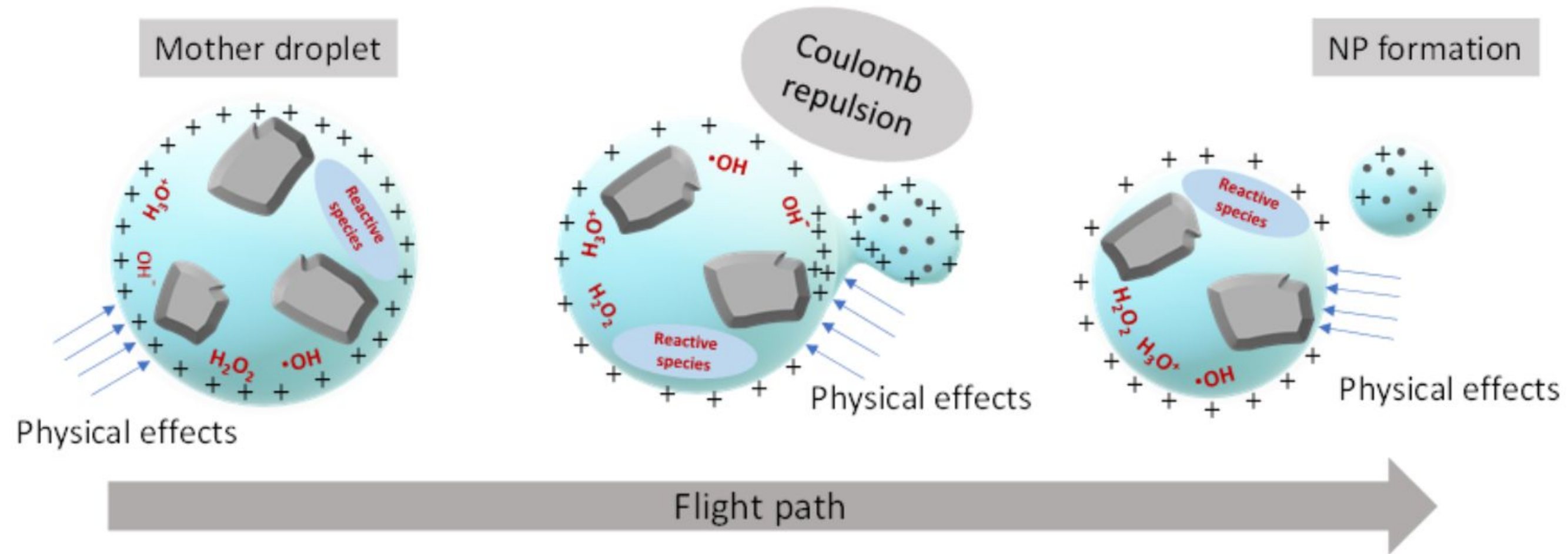
Mass Spectrometry of the Fragmen ts

Effect of charged microdroplets on quartz



Increased surface roughness after the spray

Mechanism of nanoparticle formation



Understanding Microdroplets

Droplets



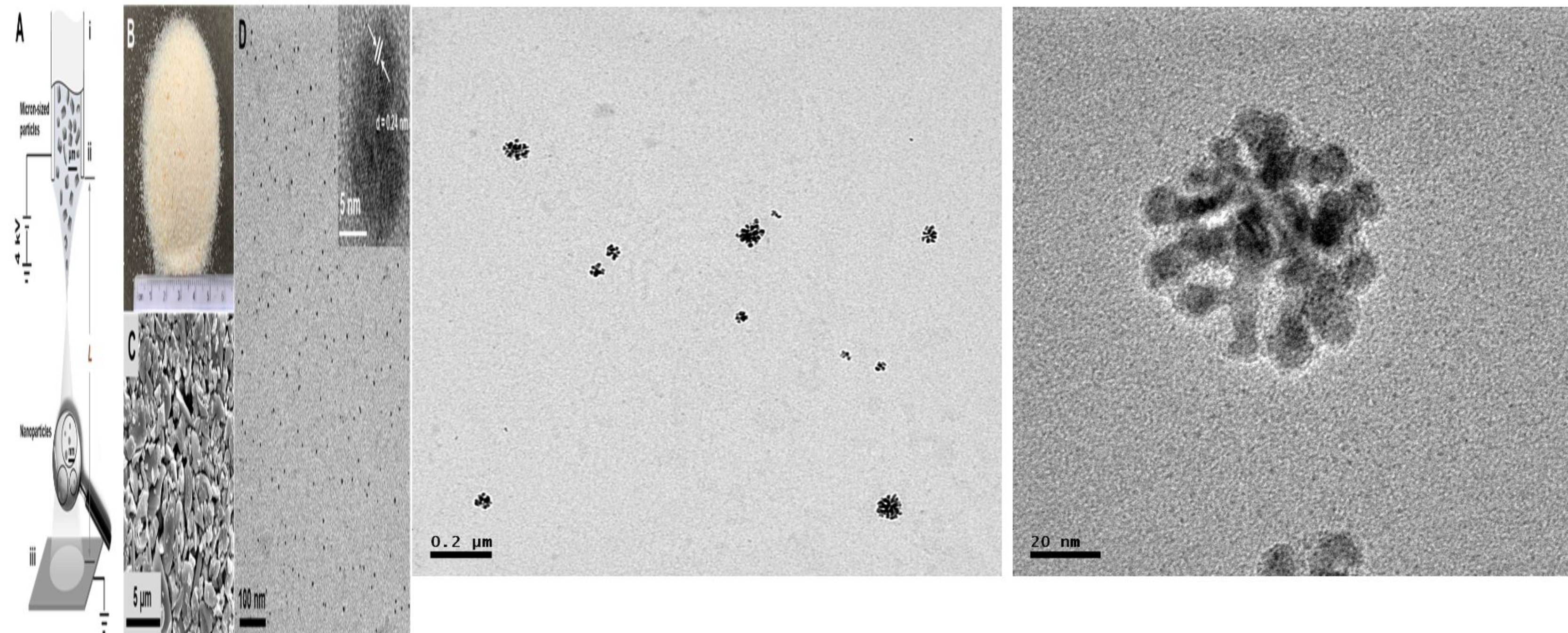
Travel path
h



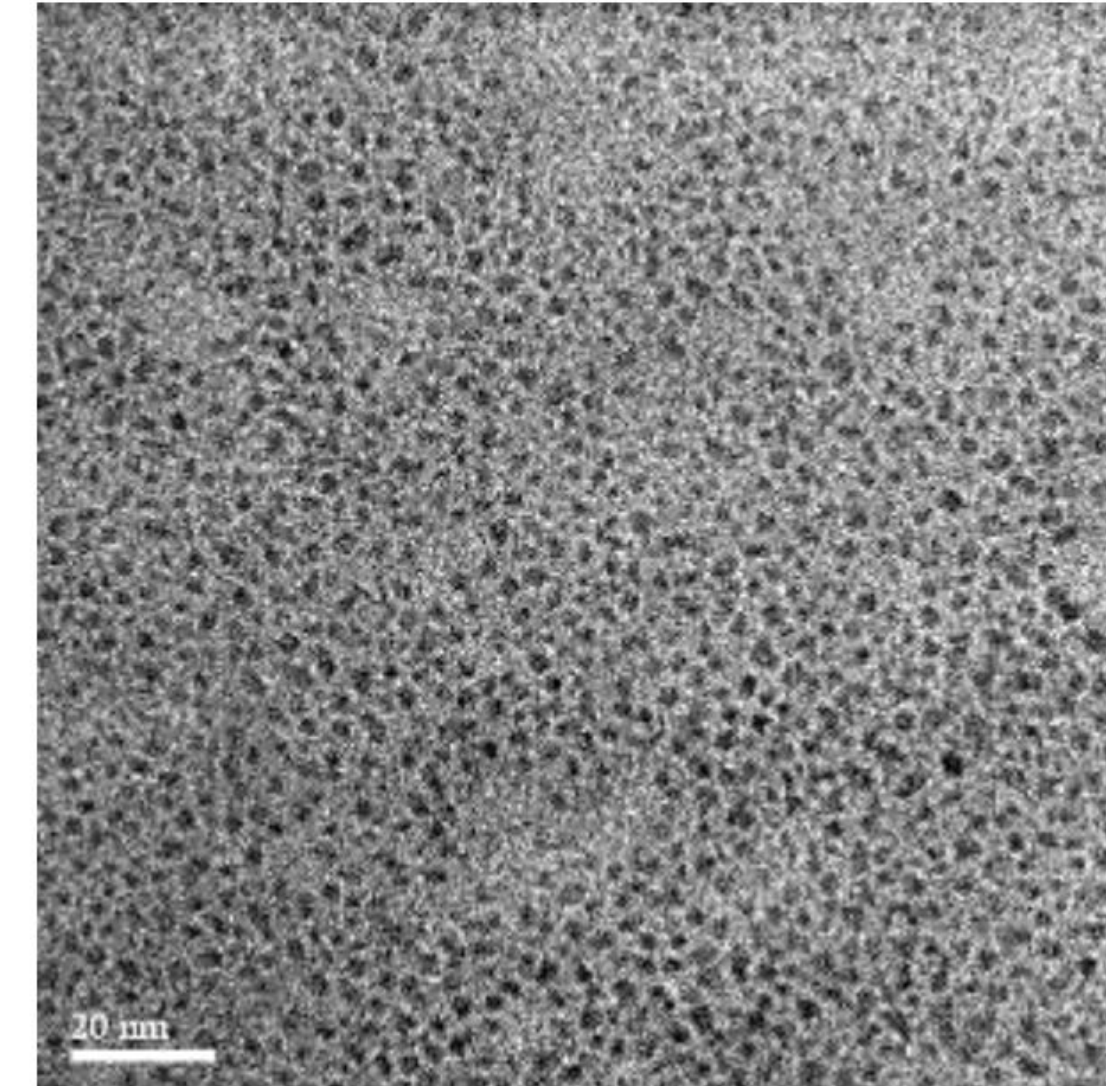
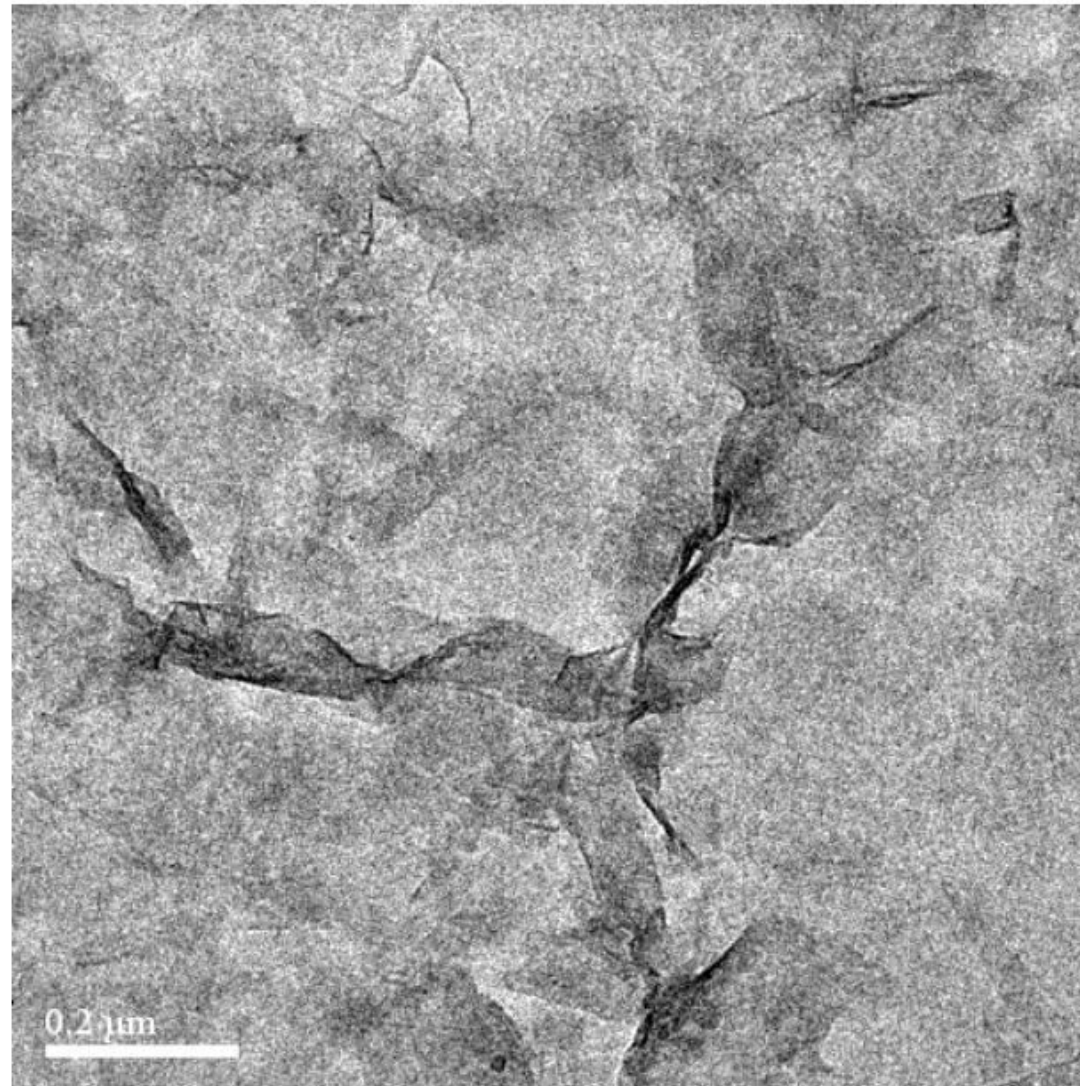
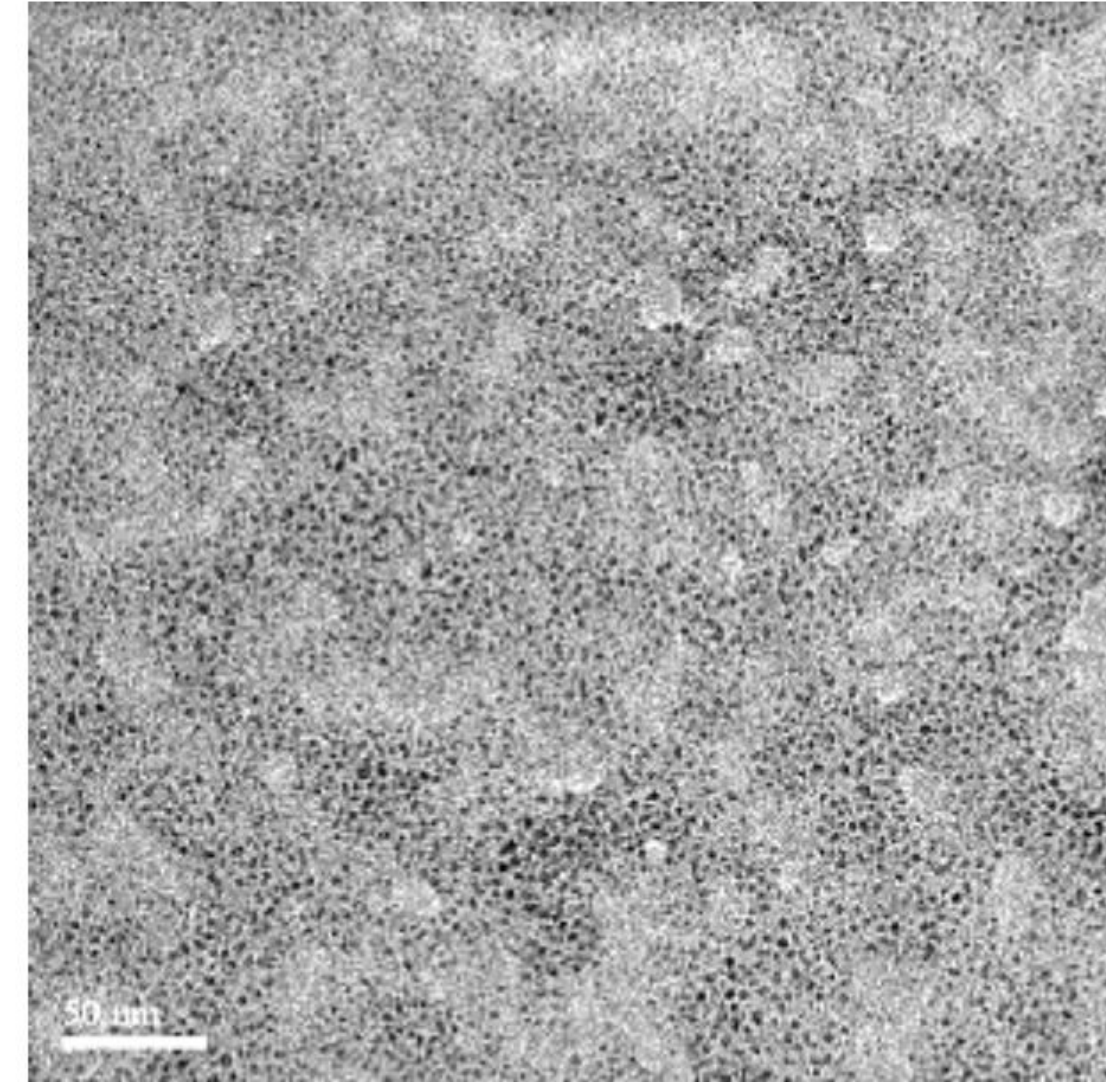
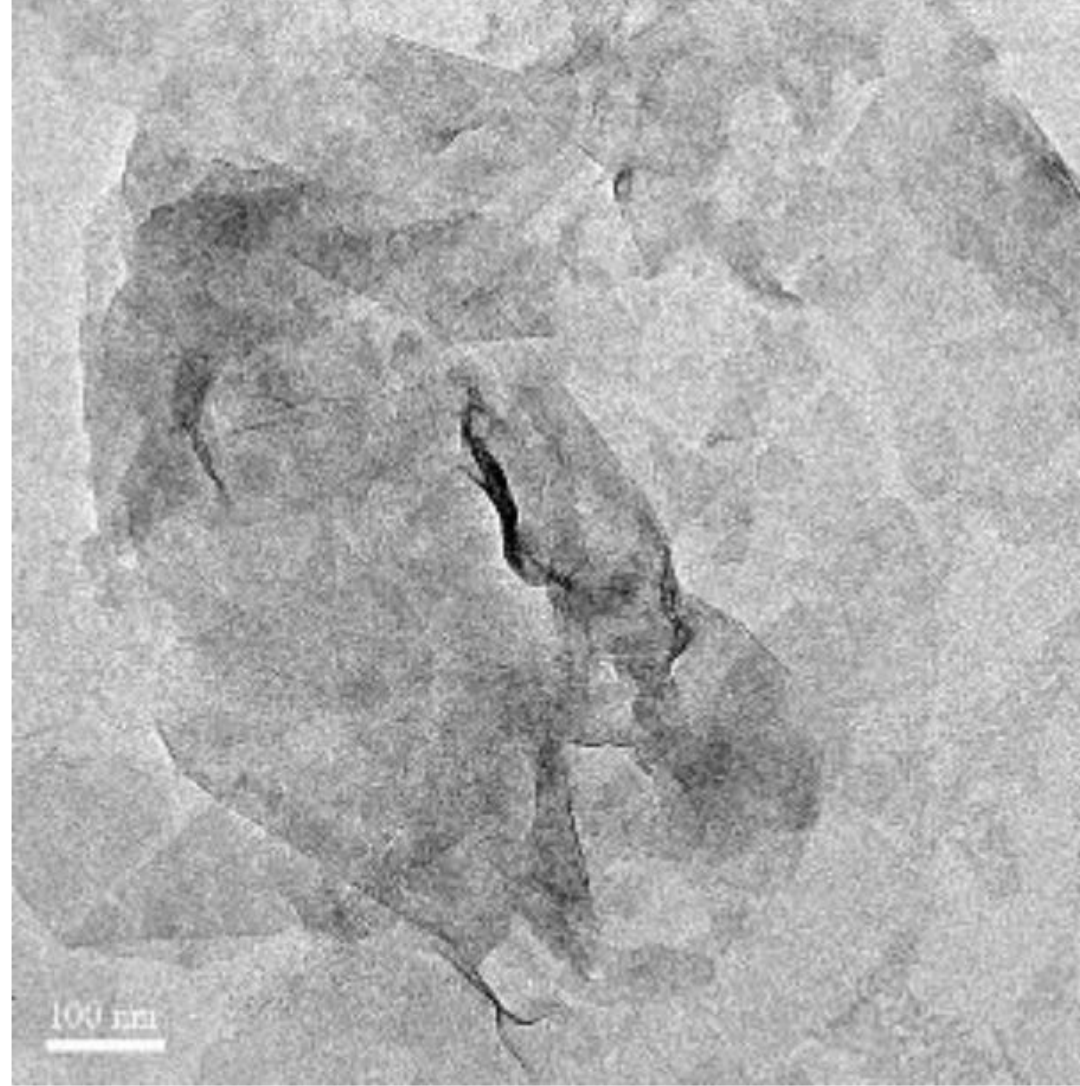
Smaller droplets



How do they form?



MoS₂ Nanosheets



MoS₂ Nanosheet

MoS₂ Nanoparticles

Unveiling steps in the weathering of minerals

Disintegration of quartz

Salts bring down the potential

Disintegration of quartz particles suspended in NaCl solution. (A to D) TEM images of quartz after electrospray of quartz suspension in varying concentration of NaCl (5 ppm, 0.5 ppm, 0.1 ppm and 0.05 ppm respectively) at an applied potential of 2.0 kV, with a tip-to-substrate distance of 1.5 cm. High-resolution TEM image of a particle shown in the inset. The plane shown is (110), where d is lattice spacing.

Disintegration of quartz particles in HCl and salt solutions. (A-F) TEM images at an applied potential of 2.0 kV, with a tip-to-substrate distance of 1.5 cm and salt concentration of 0.1 ppm. (G-J) TEM images of quartz particles suspended in different sodium halide solutions (NaF, NaCl, NaBr, and NaI, respectively) (2.0 kV, 1.5 cm, 0.1 ppm).

Grand unification of synthesis

Radicals, ions

Transient species

S

S

Electric field

E

Field
s

Pressure fluctuations

ns

M

MV cm
-1

MP
a





ChatGP
T

Vision

Make soil using processed wastewater and make deserts bloom.

Functional nanomaterials!

No solvents

Ambient conditions

Sustainable



Conclusions

Natural minerals break spontaneously in charged water microdroplets

It occurs only in water... so far

Studies on a variety of materials

Facile due to proton-induced slip

Detailed investigations are essential to know more

A variety of materials chemistry occurs in microdroplets

Implications to the production of specific nanomaterials and soil in genera

|



Clean water for
all

<https://www.peopleswaterdata.org>



Acknowledgements



Collaborators, DST, ANRF, IIT Madras, Institute of Eminence



Indian Institute of Technology Madras



Bhaskar Ramamurthi/V. Kamakot

Thank you all

