Since 1959

Microdroplet Mechanochemistry

Thalappil Pradeep Institute ProfessorIndian Institute of Technology Madras, Chennai 600036Email: pradeep@iitm.ac.in | Web: https://pradeepresearch.org

Chemo-Electro-Mechano Unification for Sustainability

INanoEChem-2025, INST Mohali and IIT Ropar, November 18-19, 2025

Weathering the storms with humility

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 Wa
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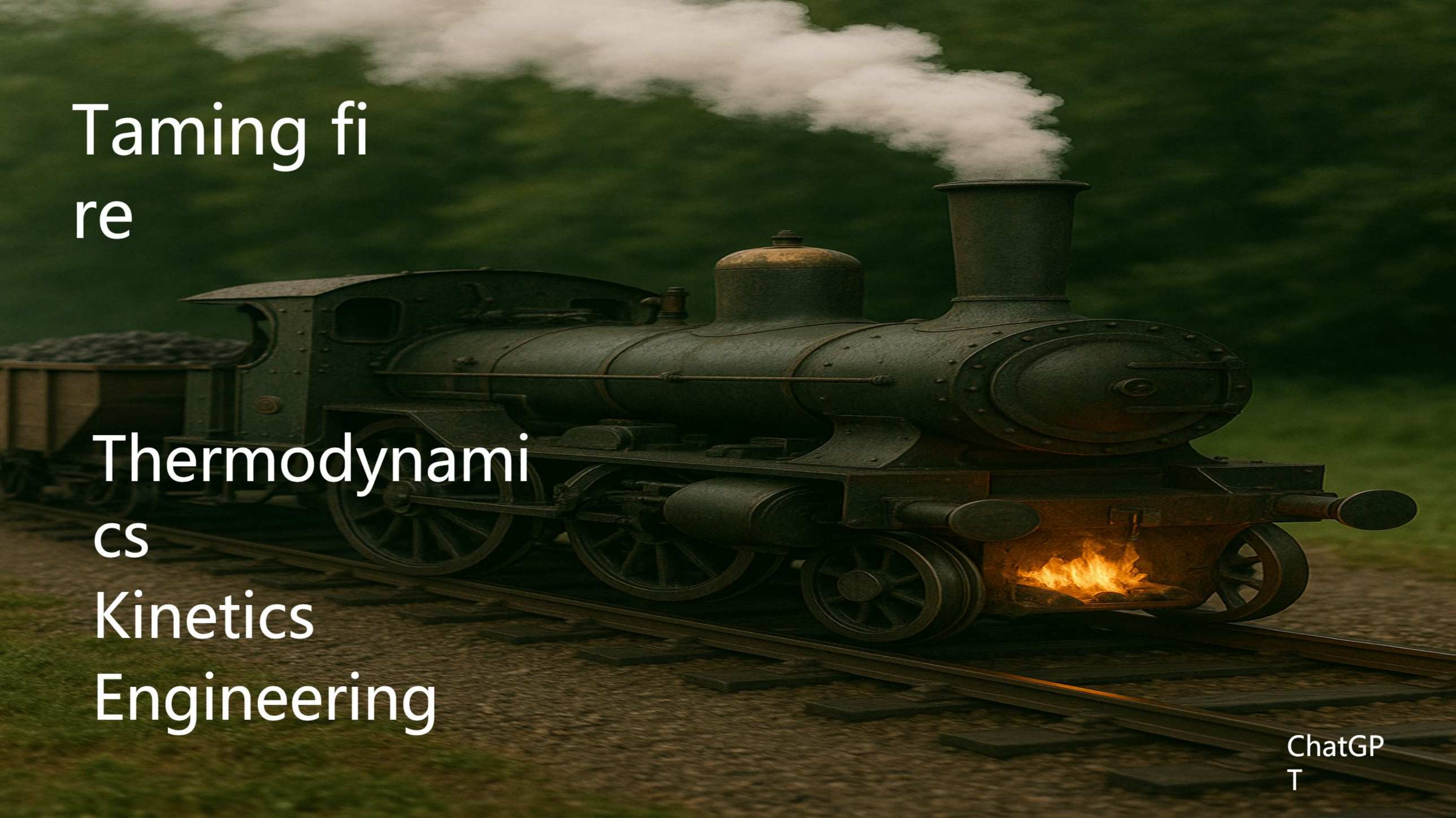
We transform matter with fire
ChatGP
T


Taming fi
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Thermodynami
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Kinetics
Engineering
ChatGP
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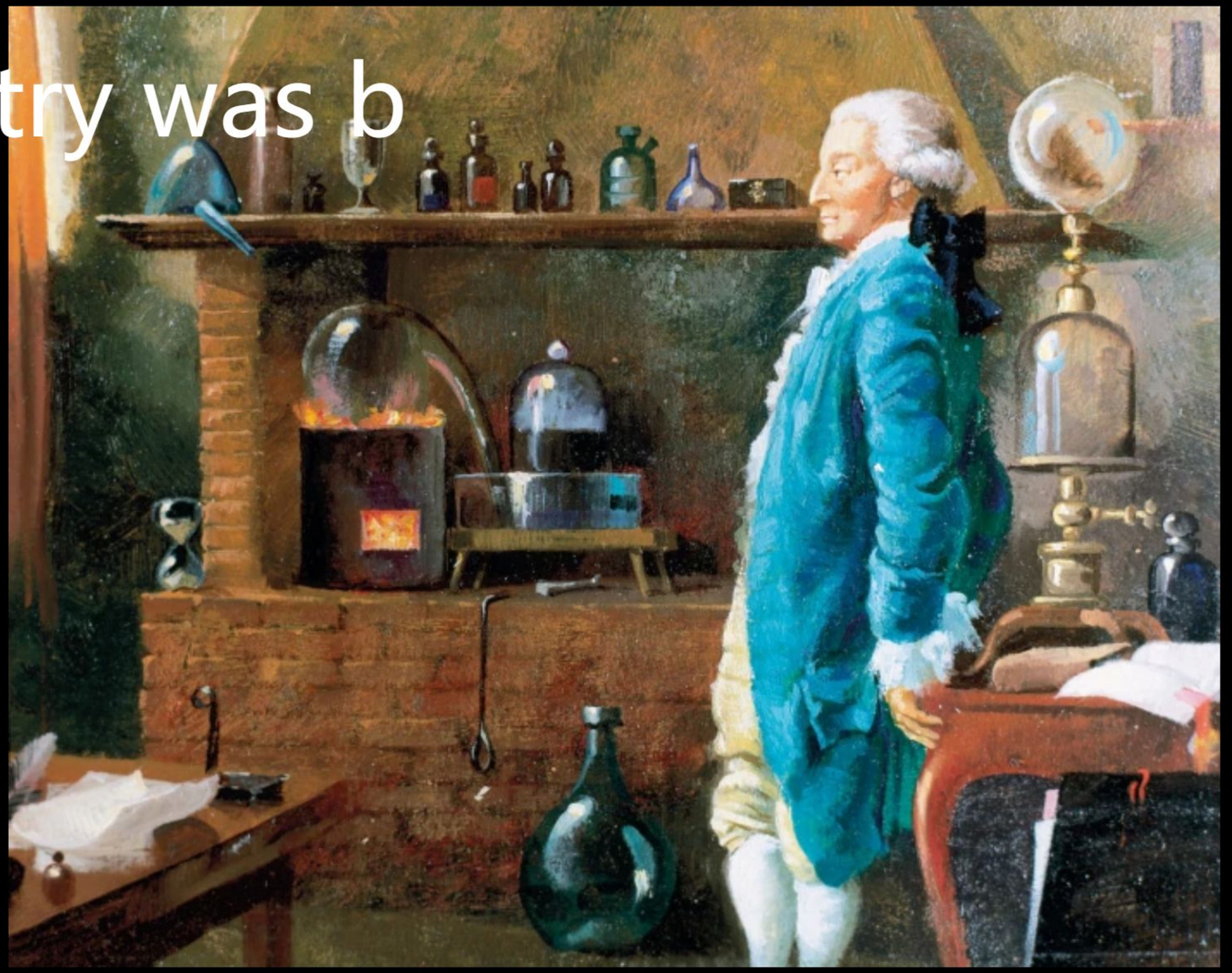
Modern chemistry was b orn



Lowe, D. Laboratory history: The chemistry chronicles. *Nature* **521**, 422 (2015). https://doi.org/10.10 38/521422a

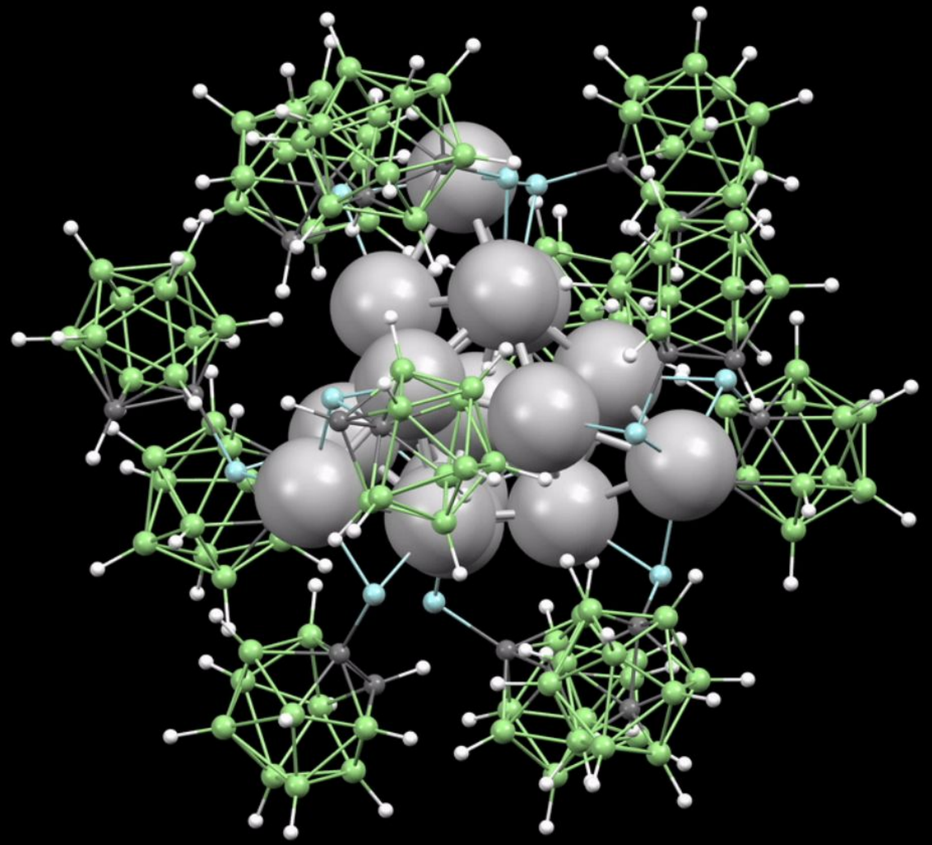

That gave materials and the modern world
And many proble
ms
BASF, Wi
ki


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

Microdroplet Chemistry

Matter in confinement for sustainability

But, matter is becomi
ng
ATOMICALLY PRECISE



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

Organic and inorganic matter too are becoming atomically p
recise

Science

A scale of 10 00

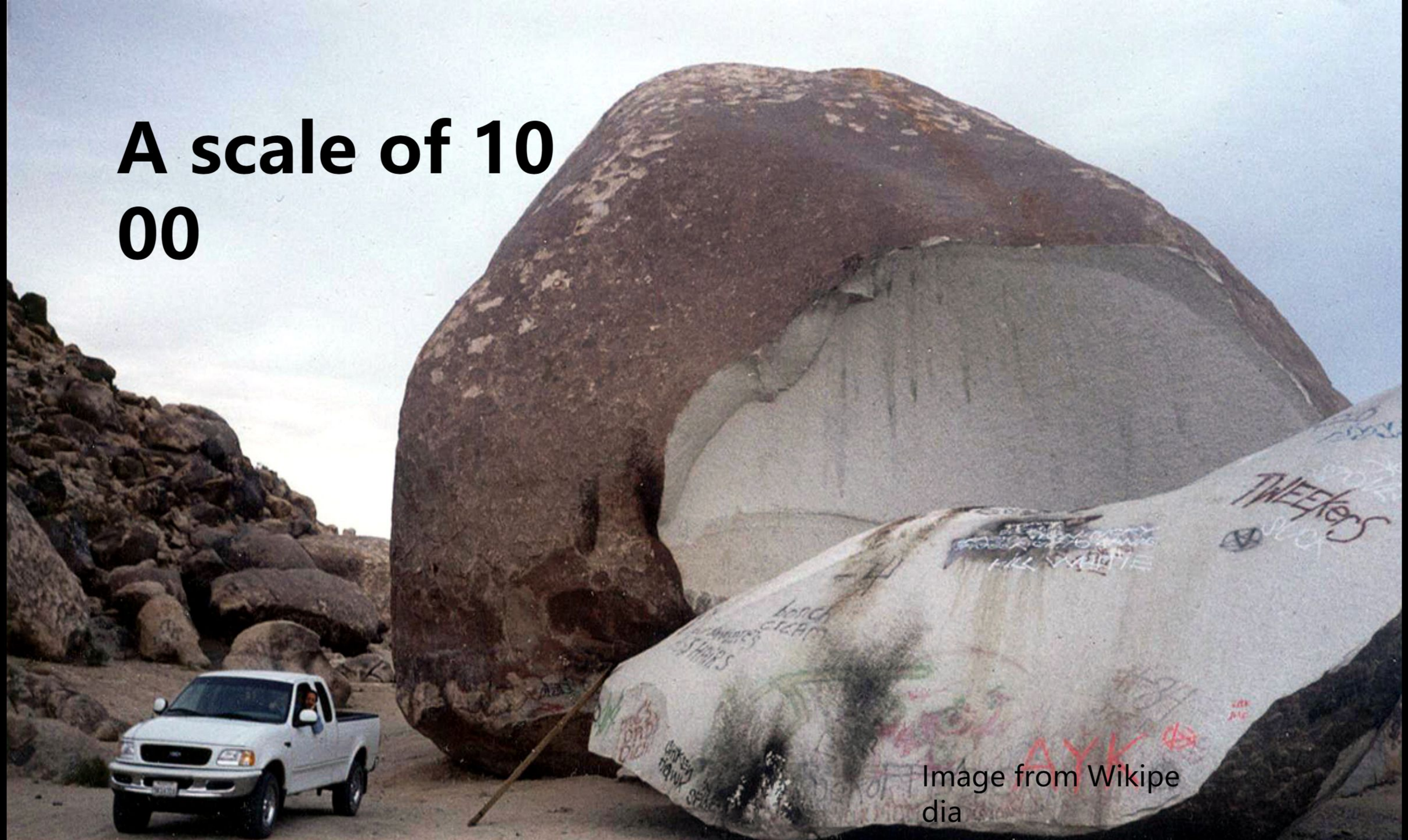
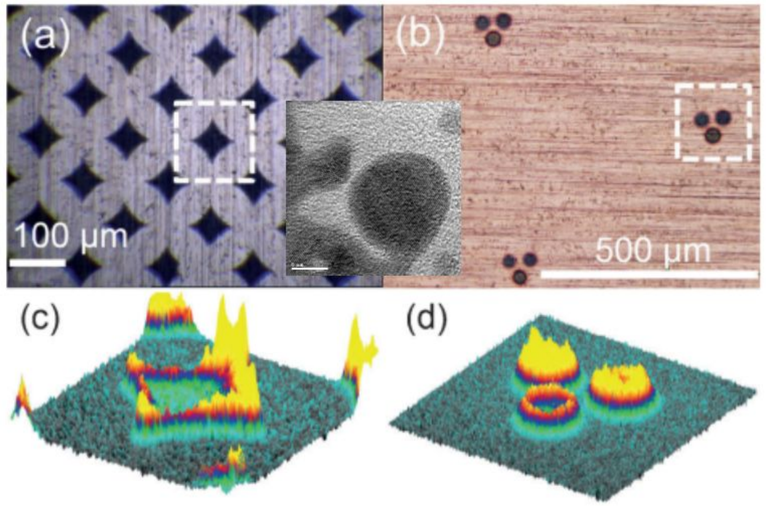


Image from Wikipe dia

Functional Nanomaterials



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

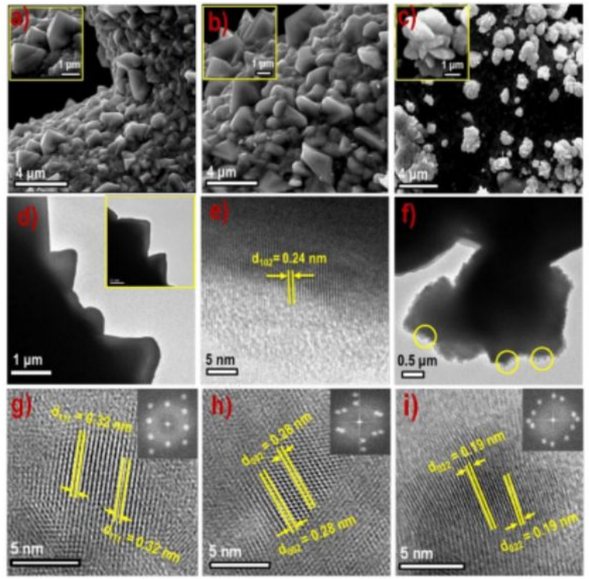
0 D

1 D

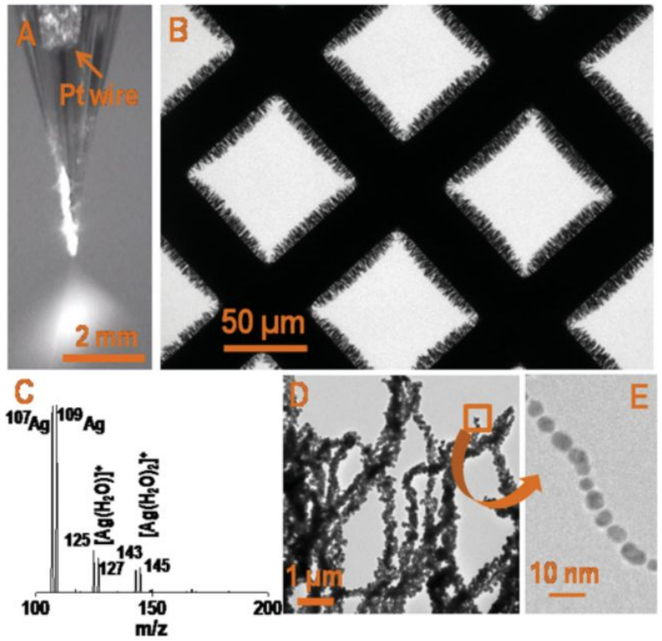
Microdroplets

3 D

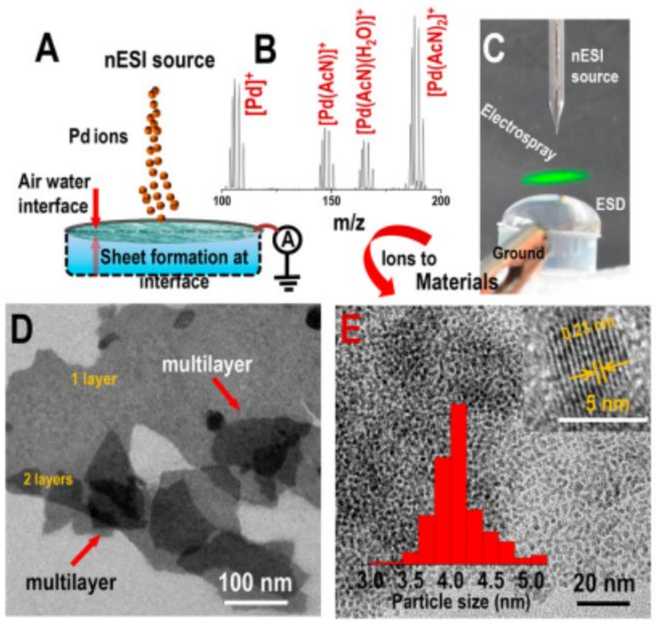
2 D



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



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



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

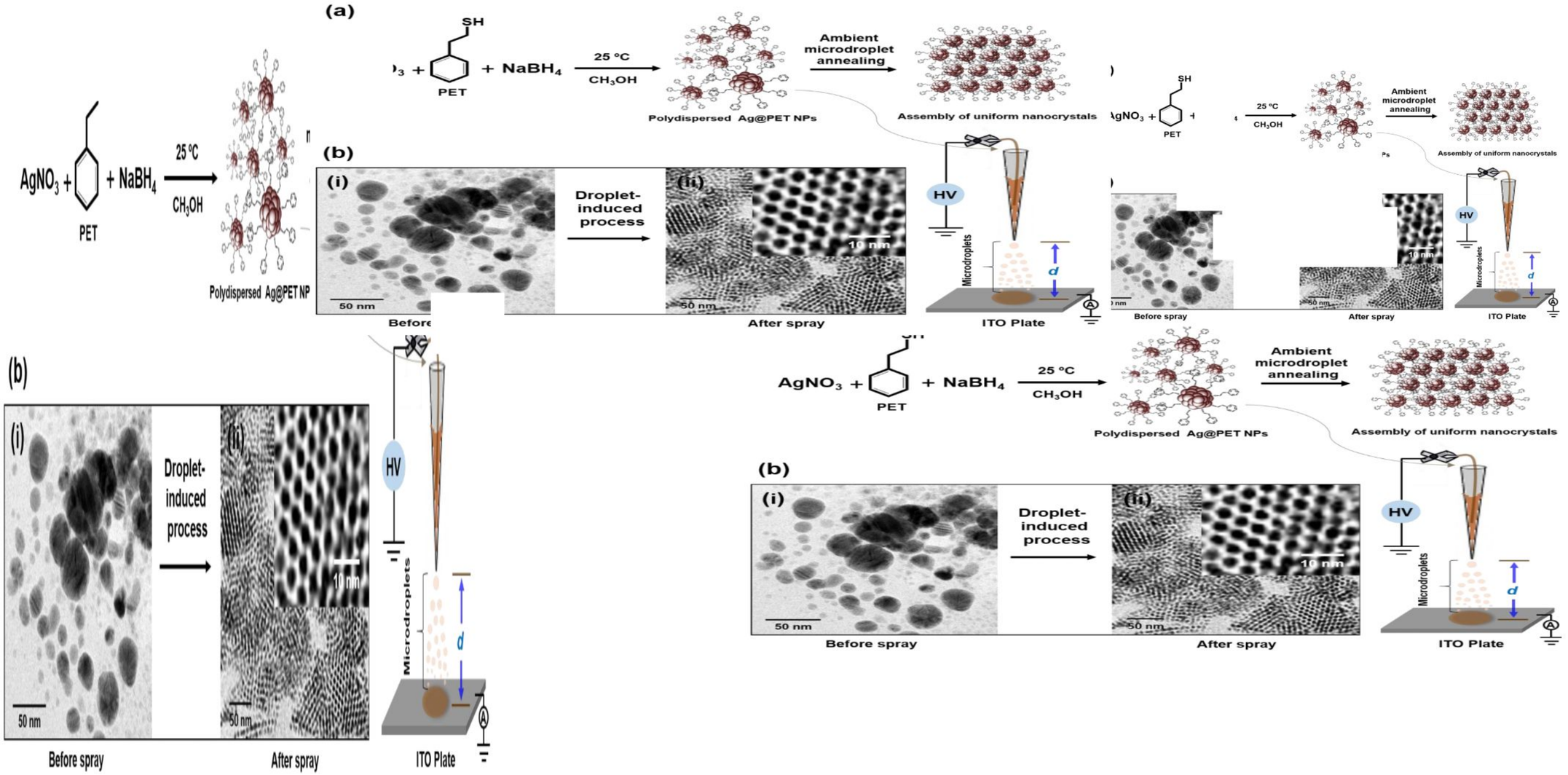
Understanding Microdroplets

Pallab Basuri et. al. *Chem. Sci.,* 2022, 13, 13321–13329.

Transformation of Materials in Microdrop lets

Ambient Microdroplet Annealing of Nanoparticles

Synthesis of polydisperse NPs



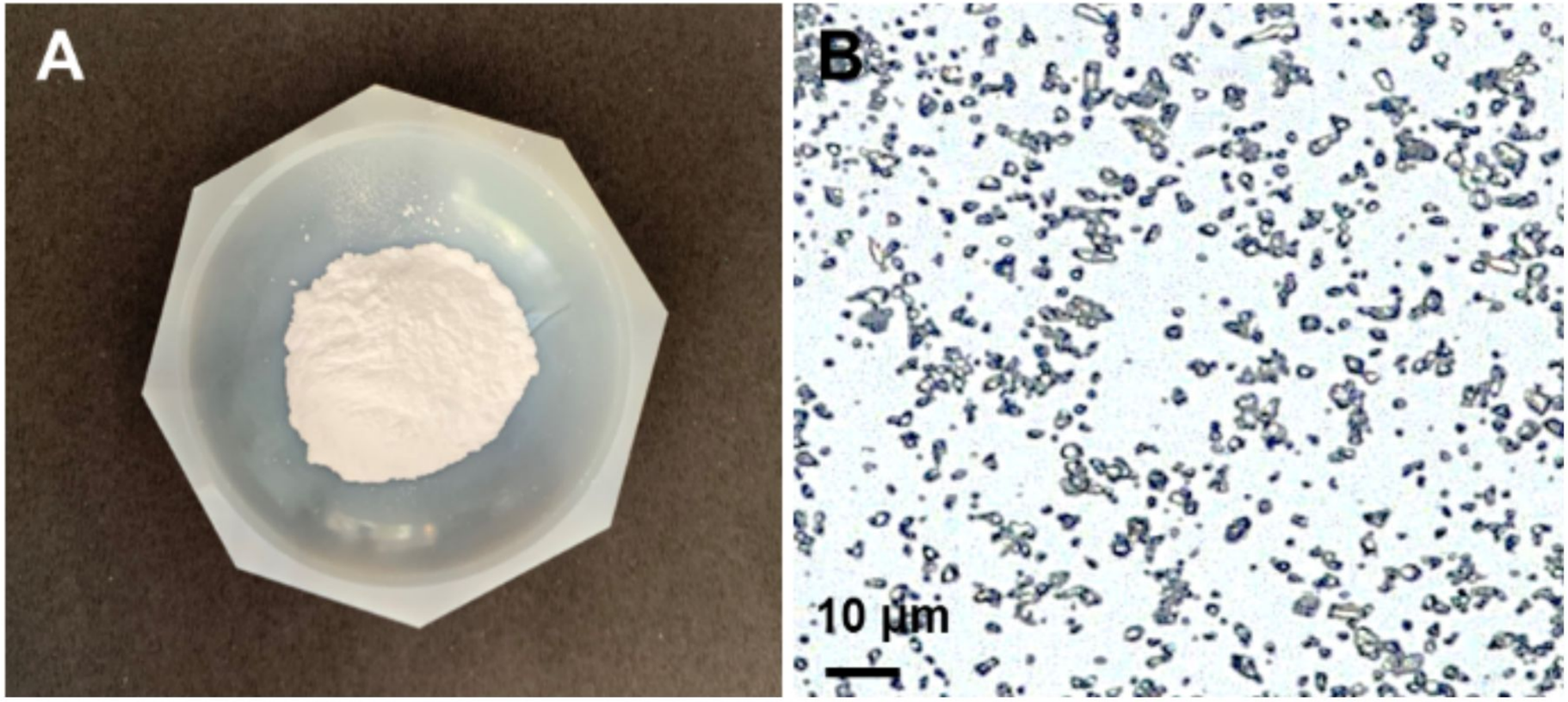
Angshuman Ray Chowdhuri et. al., *Chem. Sci.*, 2021, 12, 6370–6377.


Thanks to ChatGP

Weathering in Nature

Sand, the Ubiquitous Material

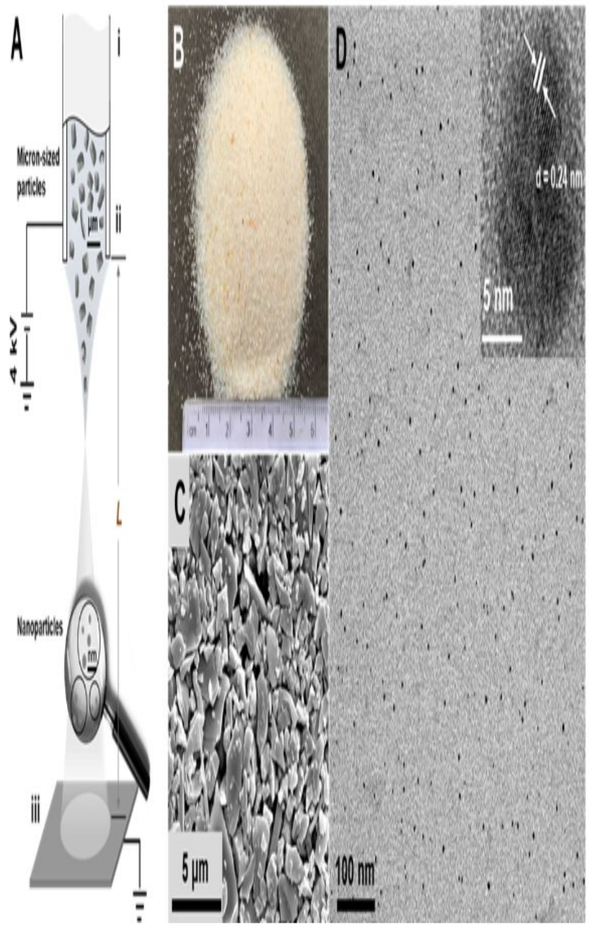
Images from Wikipe
dia

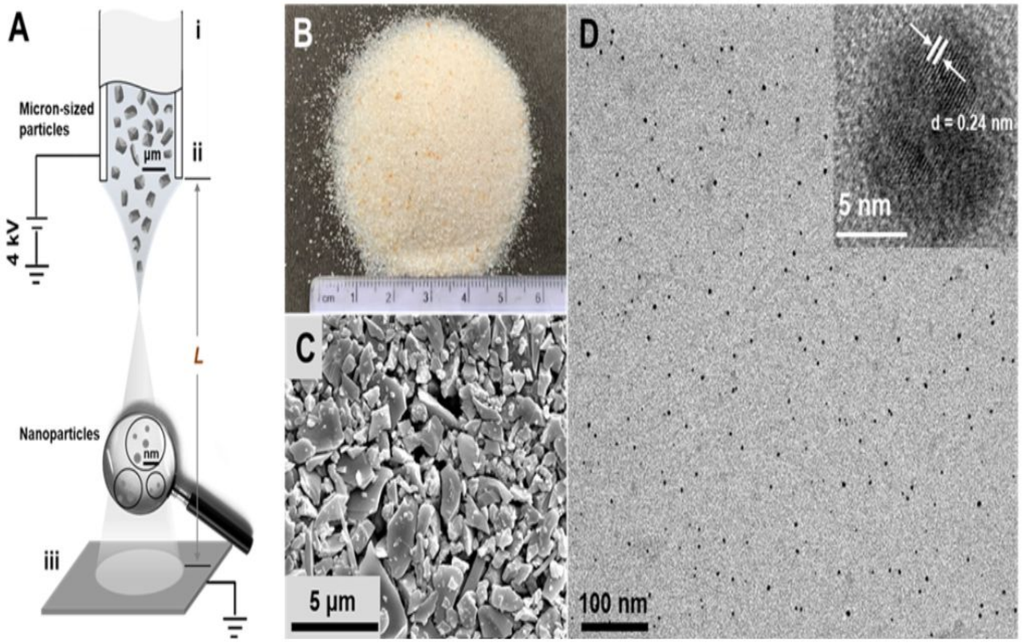


Ground silica

Optical image of silica

Weathering of Minerals in Microdroplets

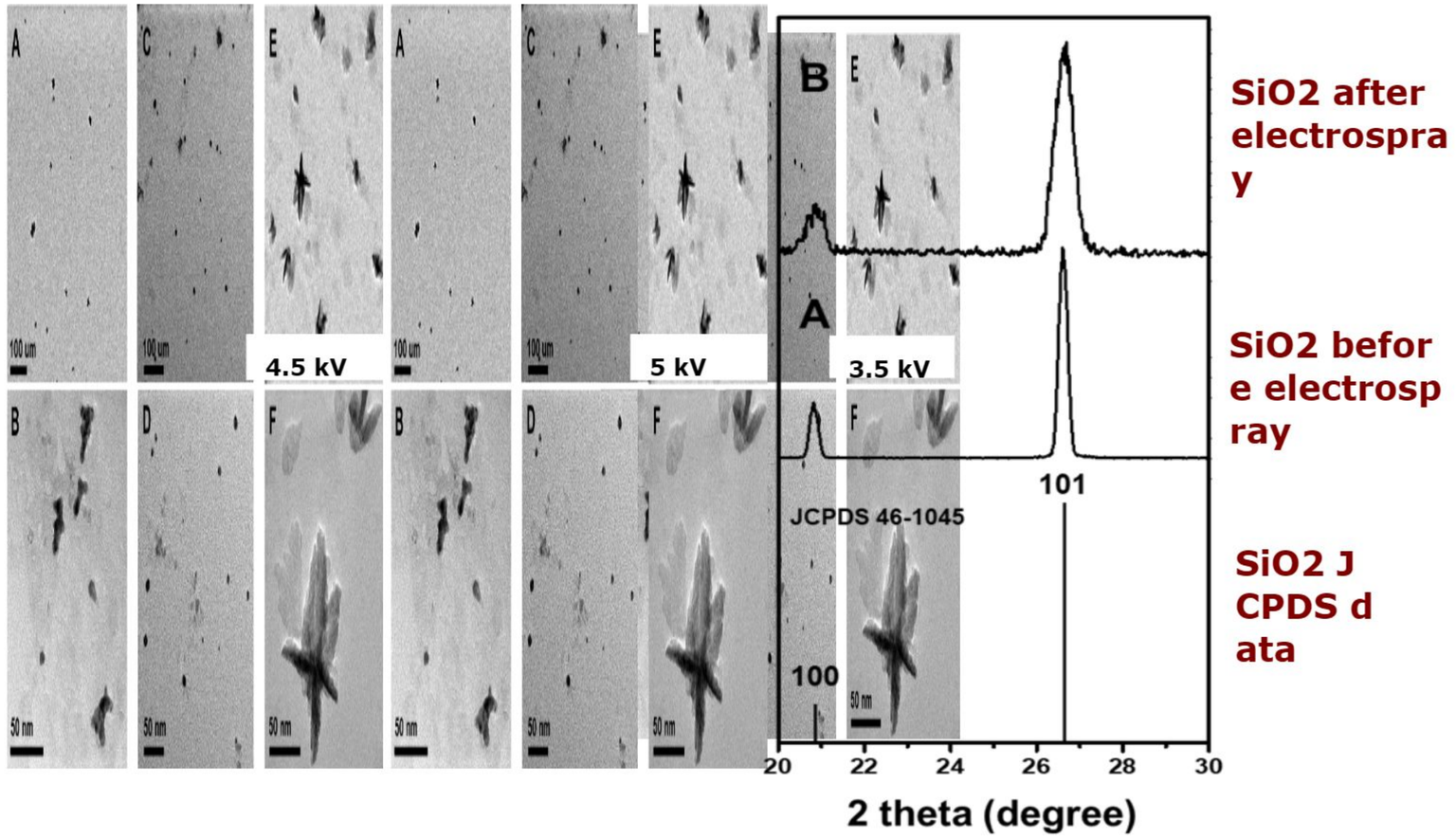




Spoorthi, et. al., *Science*, 2024

Ruby, Fused Alumin
a

Fragmentation of Silica – Varying Conditions



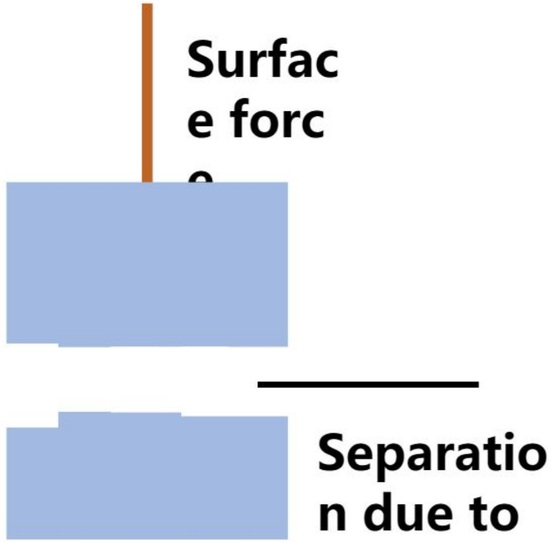
SiO2 after electrospray

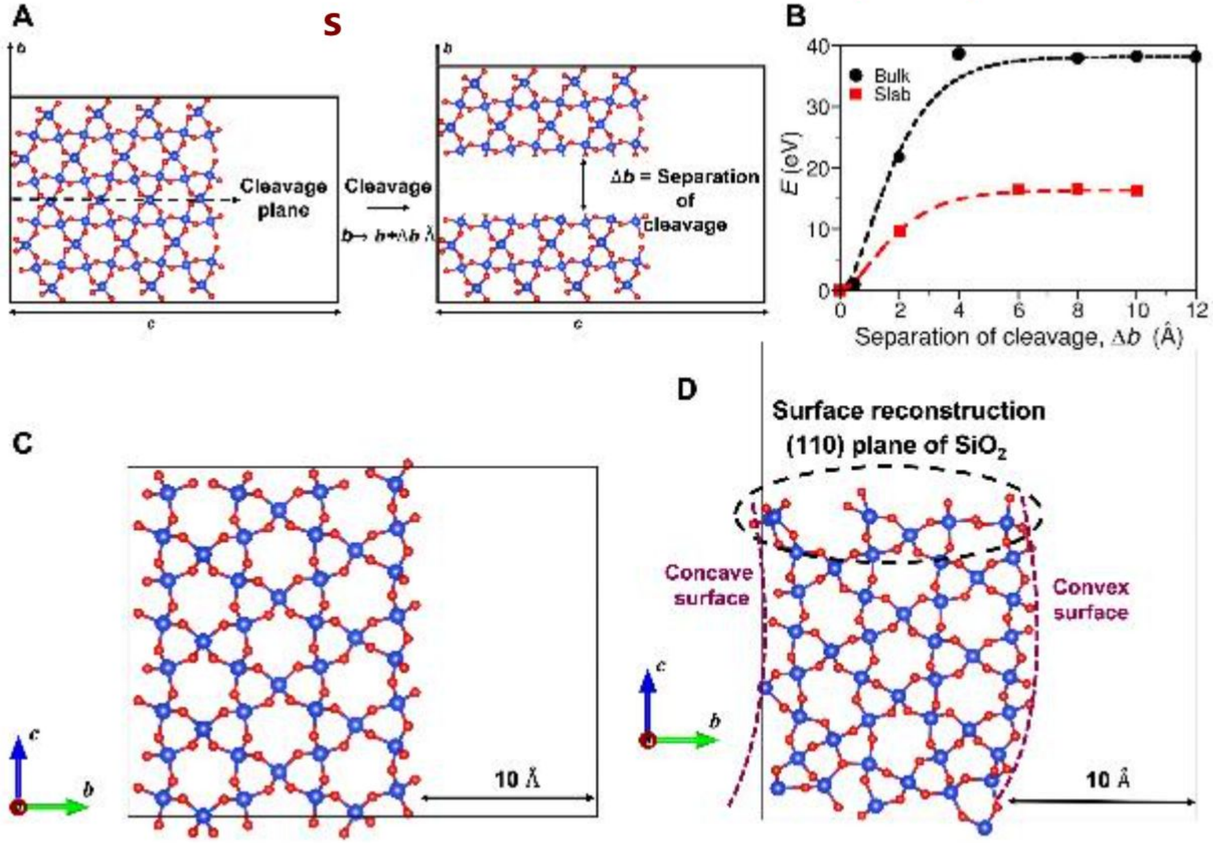
SiO2 before electrospray

SiO2 JCPDS data

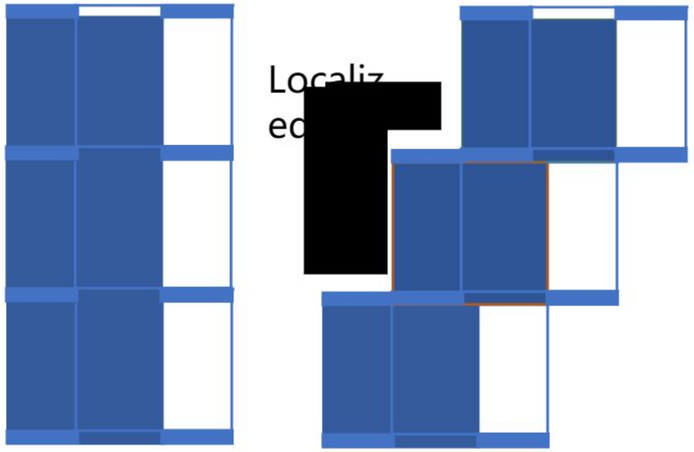
Mechanism: Cleavage

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





Mechanism: Slip



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

Stacking fault

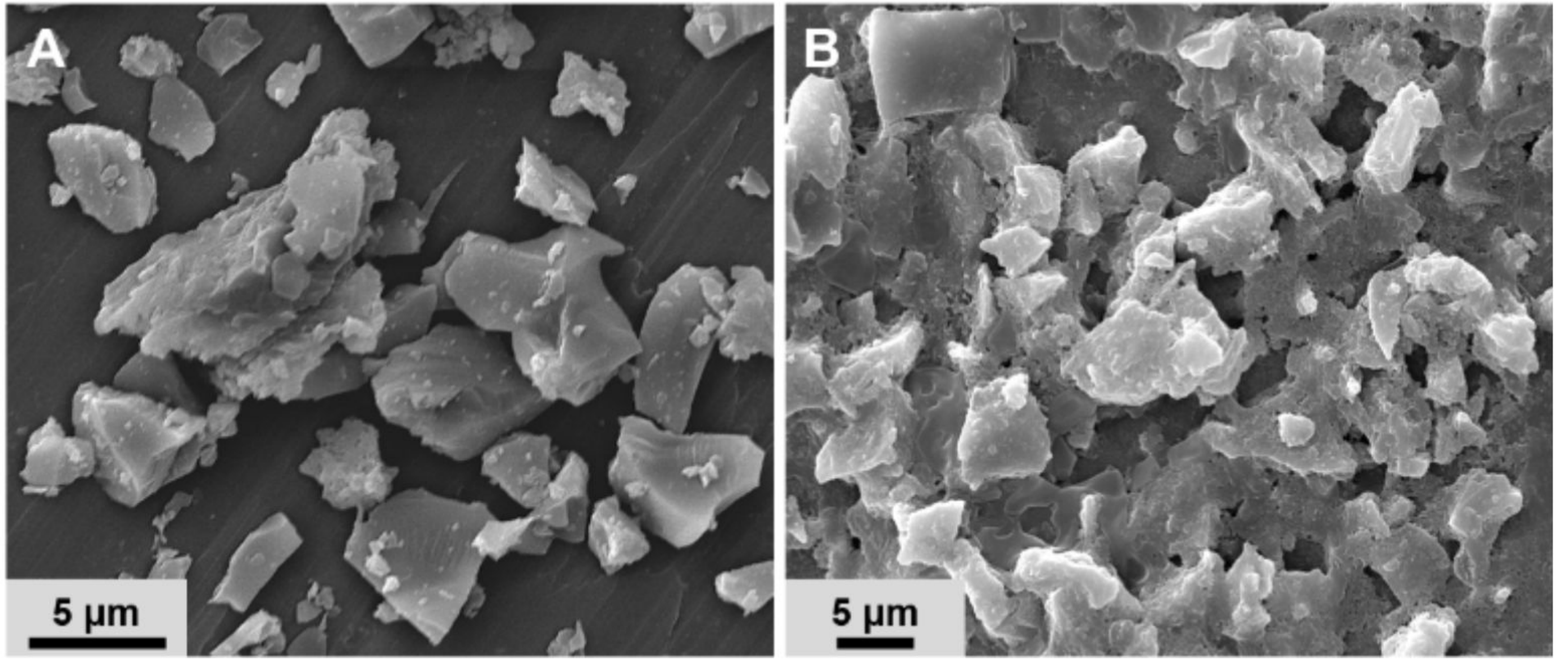
$\vec{b} \rightarrow \overrightarrow{b_0} + (x, 0, z)$;

(��, ⬚ ∈ [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

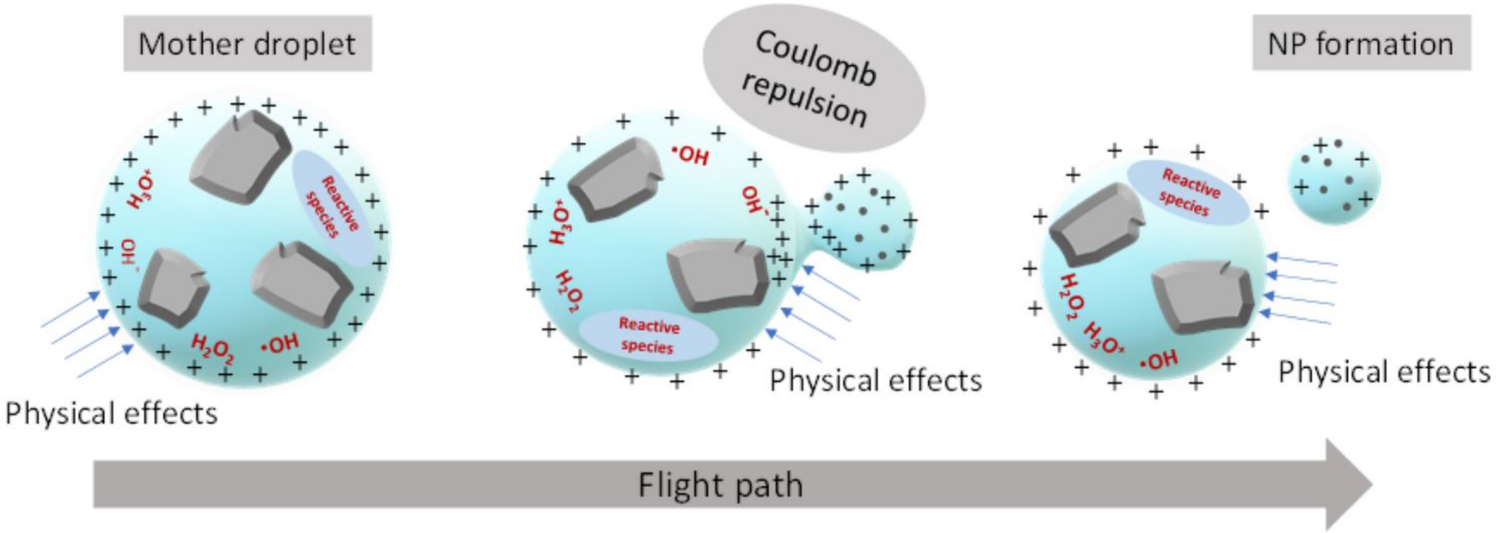
Mass Spectrometry of the Fragments

Effect of charged microdroplets on quartz

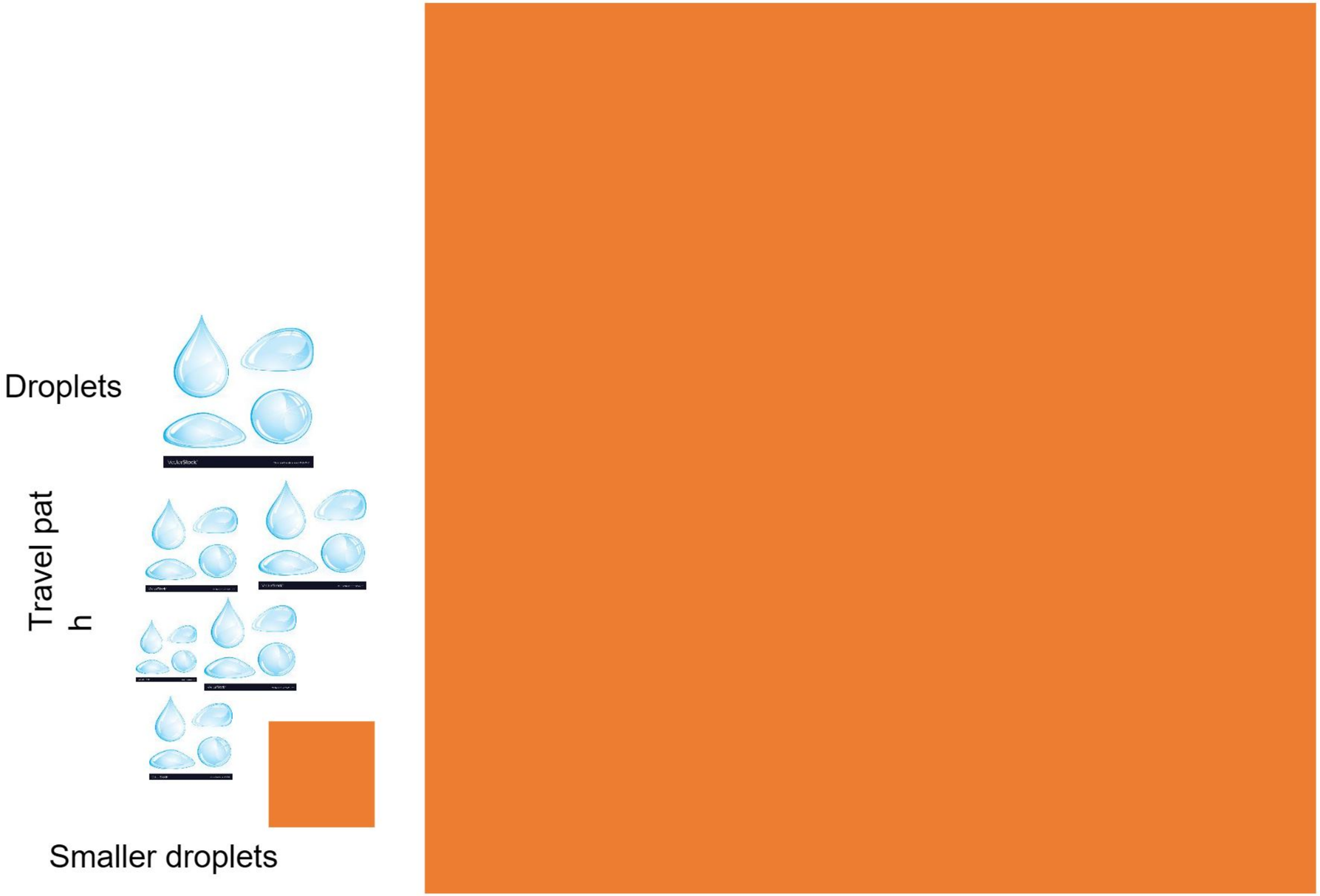


Increased surface roughness after the spray

Mechanism of nanoparticle formation

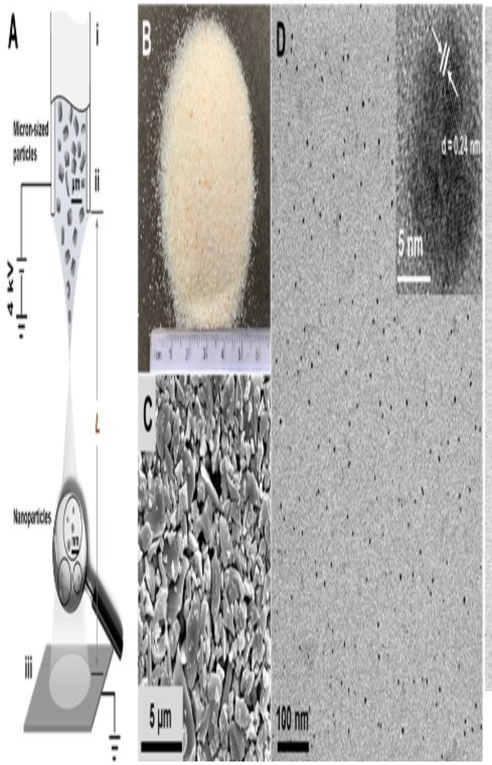


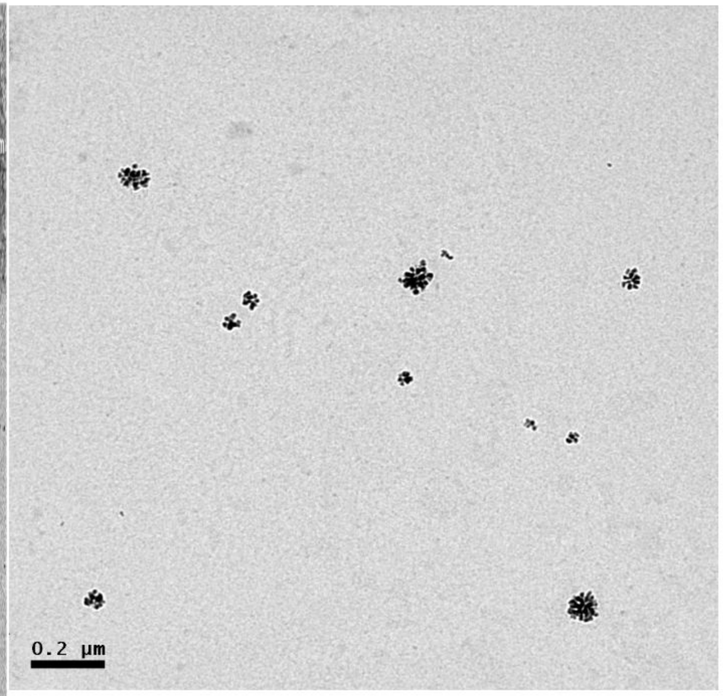
Understanding Microdroplets

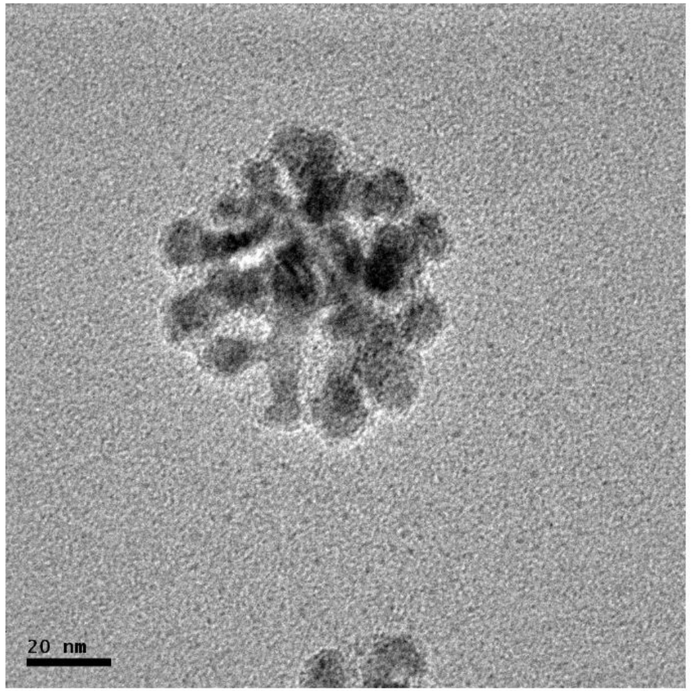


Grazia Rovelli, et. al. *Chem. Sci.*, 2020, 11, 13026–13043.

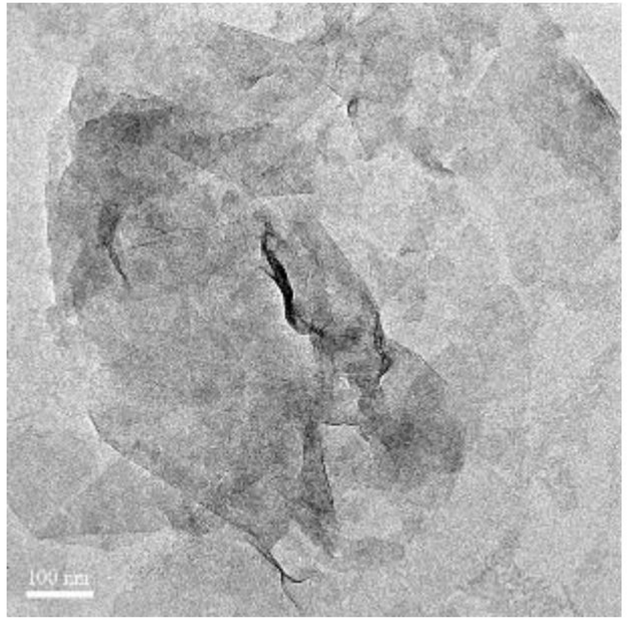
How do they for m?

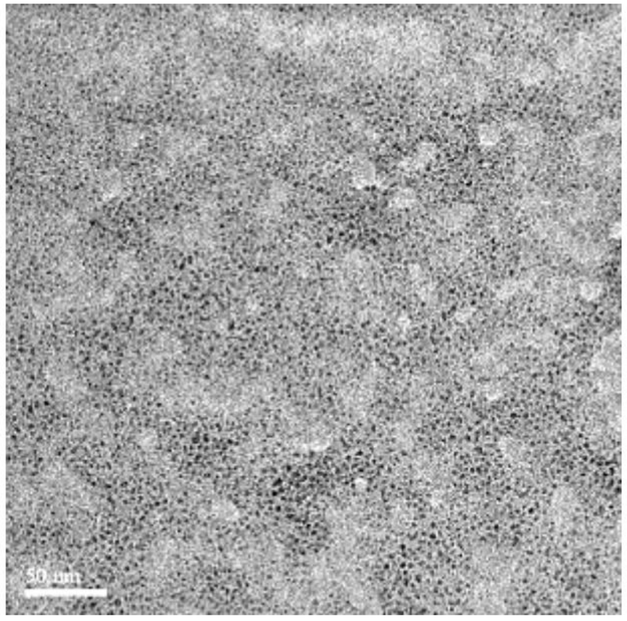


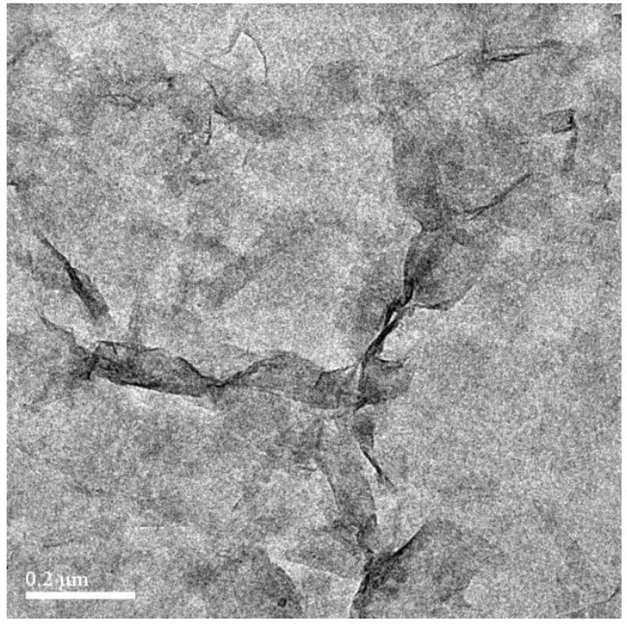


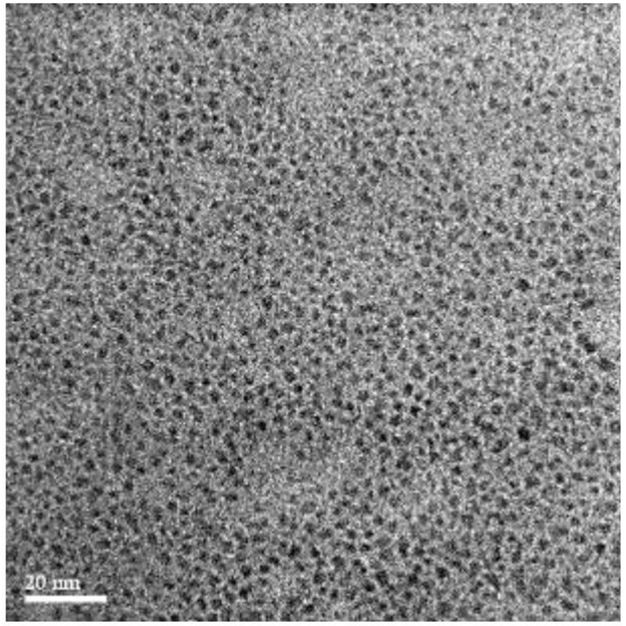


MoS2 Nanosheets









MoS2 Nanosheet

MoS2 Nanoparticles

Unveiling steps in the weathering of miner als

Anubhav Mahapatra et al, Chem. Comm. 2
025

Disintegration of quar
tz

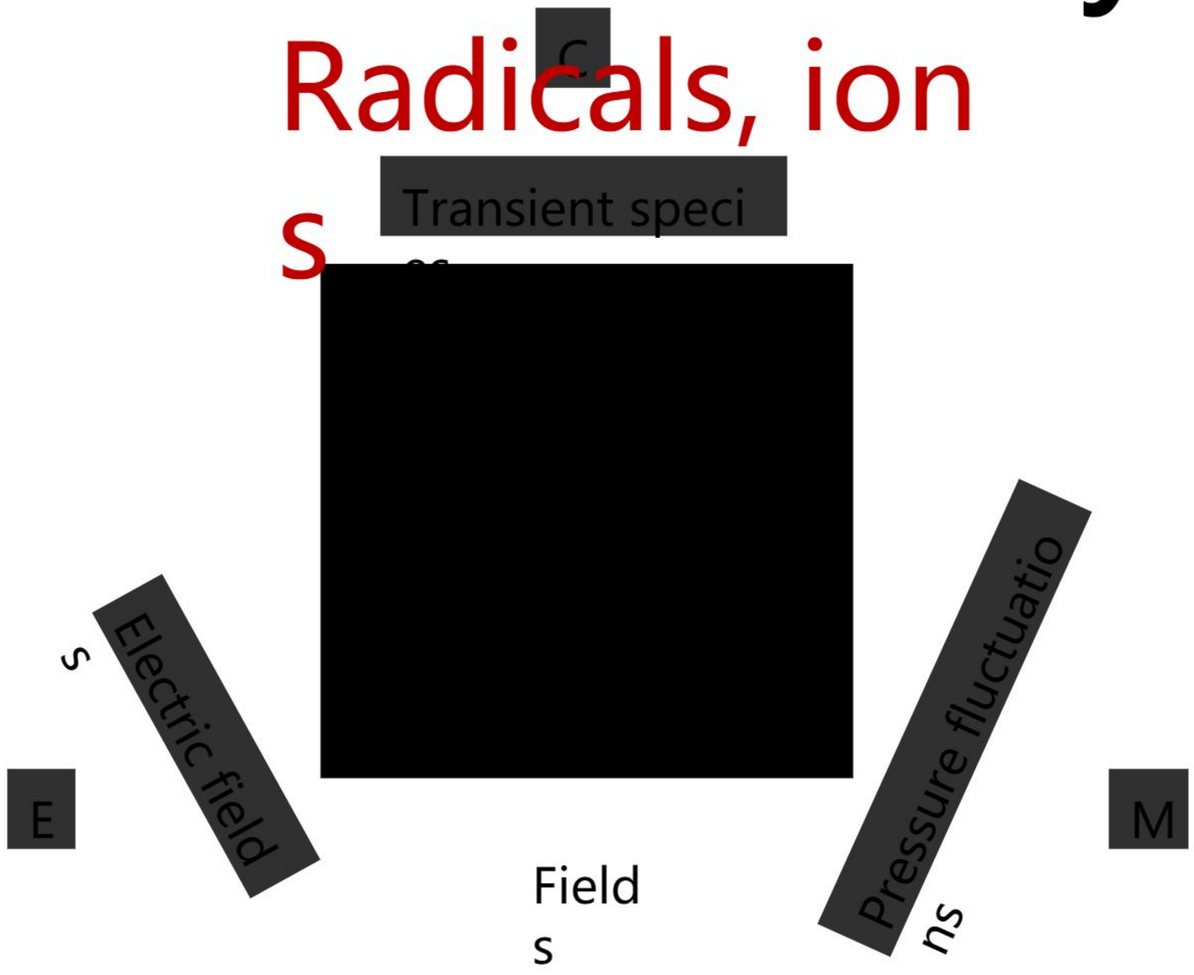
Salts bring down the potential

Jamshia Sulthana et al., Patent filed, unpublished

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

MV cm-1

MPa

ChatGP
T


ChatGP
T

Vision

Make soil using proce ssed wastewater and make deserts bloom.

Functional nanomateri als!

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
l

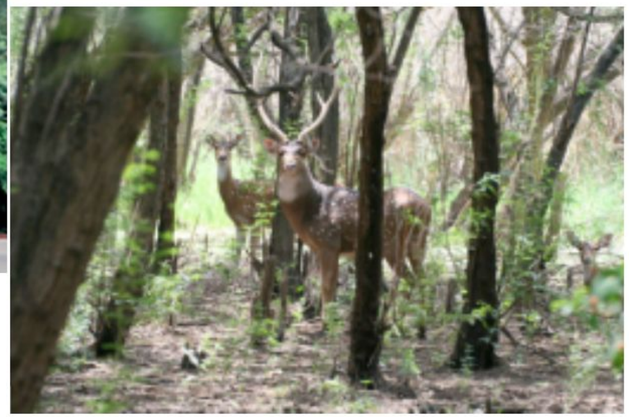
Clean water for all

https://www.peopleswaterdata.org

Acknowledgements

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

Indian Institute of Technology Madras



Bhaskar Ramamurthi/V. Kamakot

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Thank you all