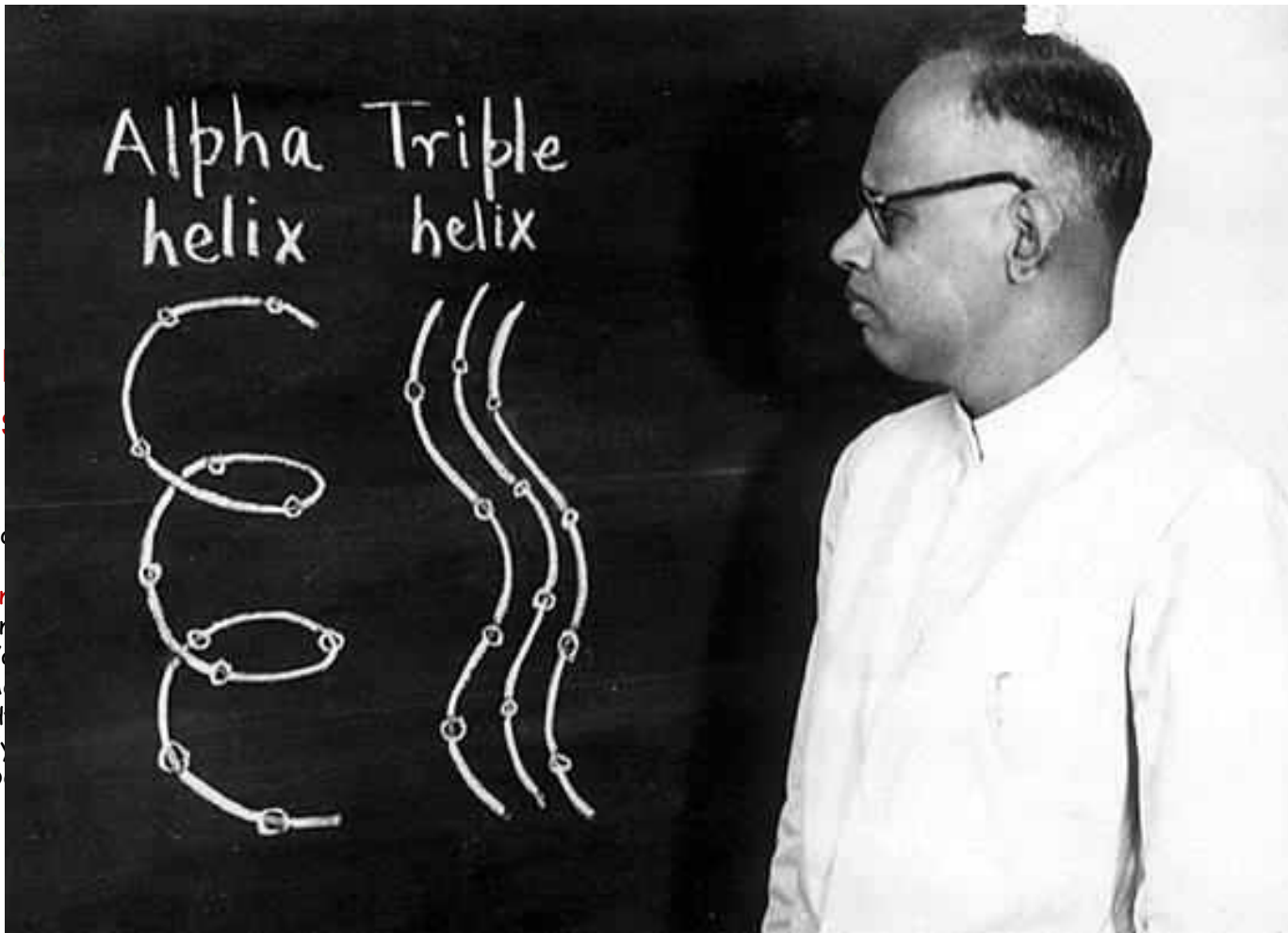




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A scale of 1000

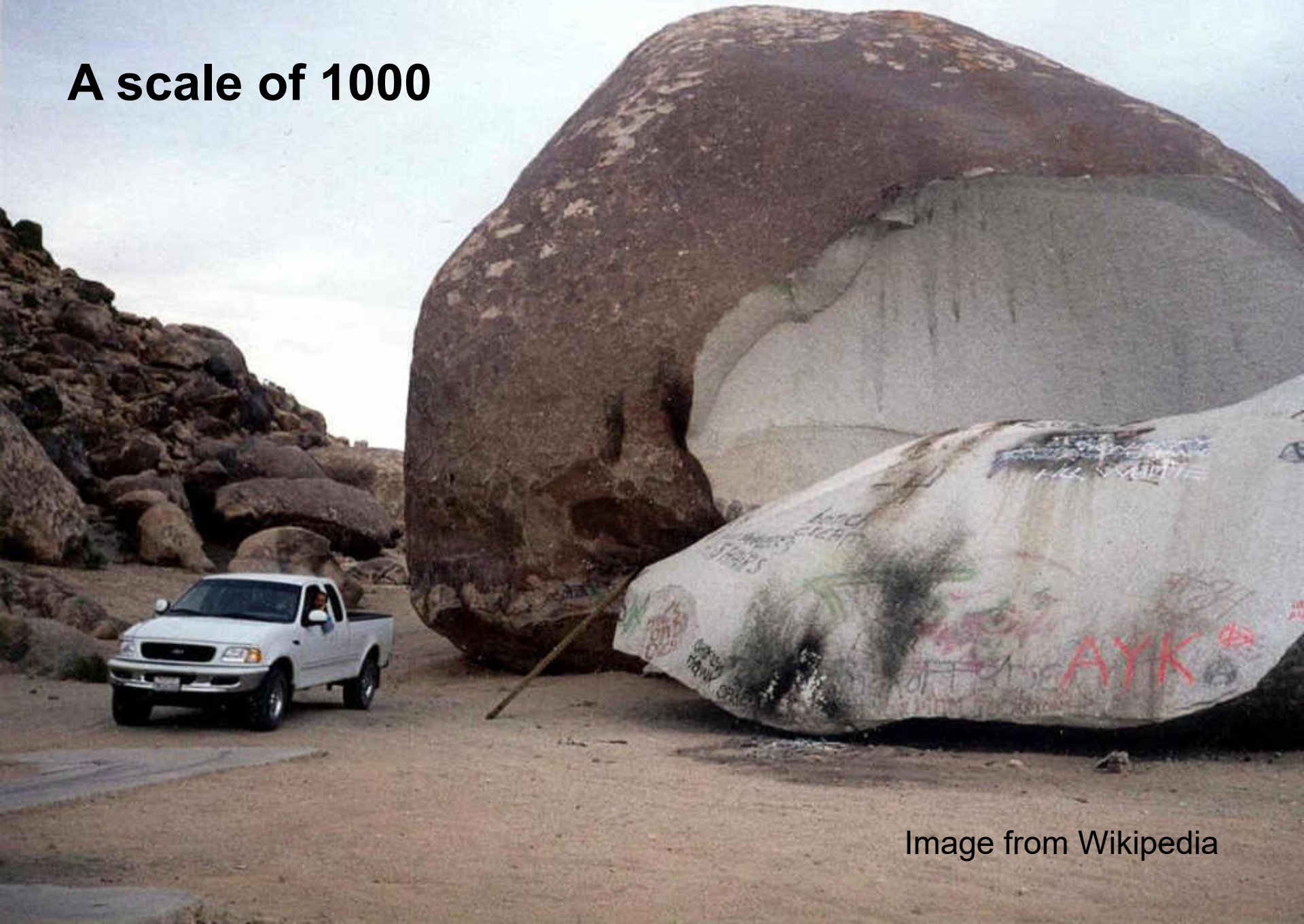


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Science

RESEARCH

NANOPARTICLES

Spontaneous weathering of natural minerals in charged water microdroplets forms nanomaterials

B. K. Spoorthi¹, Kavyashila Debnath², Palash Basu¹, Anil Nagai¹, Umesh V. Vaghmare¹, Thalapatt Pradeep^{1,3*}

In this work, we show that particles of common minerals break down spontaneously to form nanoparticles in charged water microdroplets within milliseconds. We transformed micron-sized natural minerals (like quartz and rutile) into 5- to 10-nanometer particles when integrated into aqueous microdroplets generated via electrospray. We deposited the droplets on a substrate, which allowed nanoparticle characterization. We determined through simulations that quartz undergoes proton-induced etch, especially when reduced in size and exposed to an electric field. This leads to particle scission and the formation of silicate fragments, which we confirmed with mass spectrometry. This rapid weathering process may be important for soil formation, given the prevalence of charged aerosols in the atmosphere.

Nanoparticles of minerals exist naturally in soil, and some of them are essential for life (1). Microscale studies have been a of interest over the past decade, because the confined environment within them is known to cover chemical synthesis at an accelerated rate, as well as other processes such as the formation of nanoparticles (2). We decided to explore whether natural minerals could disintegrate in microdroplets, through a process opposite to chemical synthesis.

For our experiments, we prepared microscale particles of natural quartz (SiO_2) and rutile (TiO_2 -substituted Al_2O_3) for use in an electrospray setup (Fig. 1, A and B). We ground commercial millimeter-sized quartz particles well using a

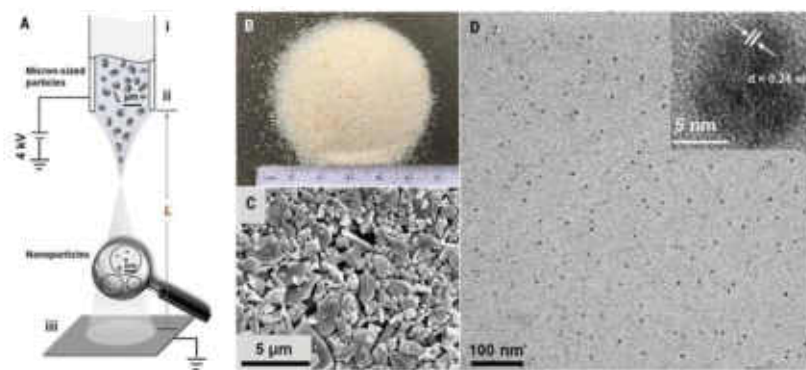
mortar and pestle and used centrifugation to separate the differently sized particles that formed. We carefully excluded all the particles smaller than 1 μm in size and used particles of 5 to 10 μm that were suspended in water for the experiment (Fig. 1C). Even after ultra-sonication to detach any adhered particles, we found some smaller particles attached to a few large ones (Fig. 1C). These adhering particles had dimensions greater than 100 nm (Fig. 1D). We took an optical image of the ground quartz powder and an optical microscopic image of the separated particles that we used for electrospray (Fig. 1E). We electrosprayed a suspension of about 6 mg/ml of the separated quartz particles through a capillary

tube that had an inner diameter of 50 μm , flow rate of 0.5 ml/hour and observed the exiting plume (Fig. 1F). We collected the product of electrospray 15 cm away from the spray tip, which resulted in a flight time on the order of 10 ms, consistent with similar experiments (3, 4). The product that was deposited on a transmission electron microscopy (TEM) grid had only 5- to 10-nm-diameter particles (Fig. 1G) throughout the grid. Under higher magnification, particles of different morphologies were observed. The particles showed the (110) plane of quartz (inset of Fig. 1G). Sonication had no effect on the breaking of silica particles. Experimental methods are presented in the supplementary materials, including a video of the electrospray process (movie S1).

To ensure that our initial observations were truly representative of the process, we performed measurements on larger quantities of samples. We built a multinozzle electrospray unit composed of six nozzles. We electrosprayed 1 liter of the suspension that contained 100 mg of the crushed micron-sized particles discontinuously over a month at the optimized conditions (spray voltage and distance) and a 0.5 ml/hour flow rate, and a deposit

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Weathering in Nature

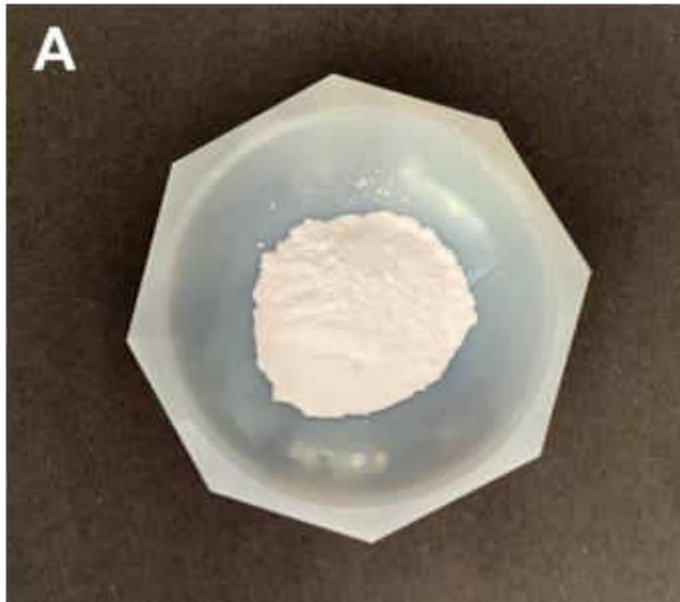


Sand, the Ubiquitous Material

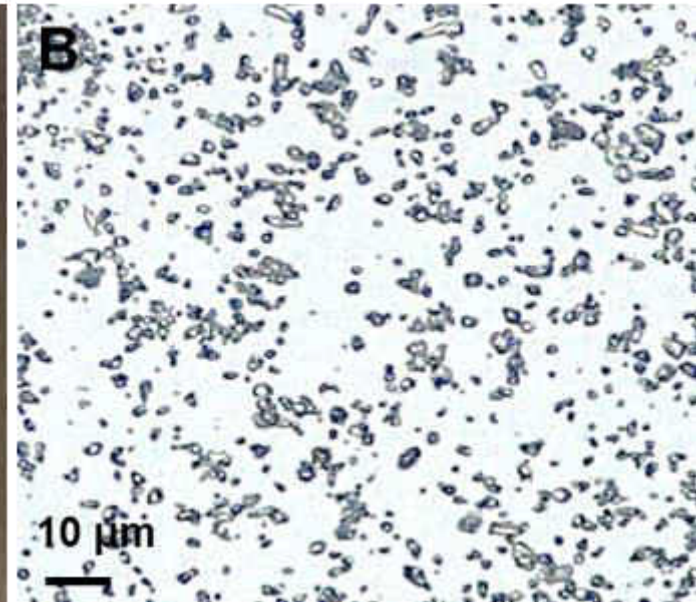


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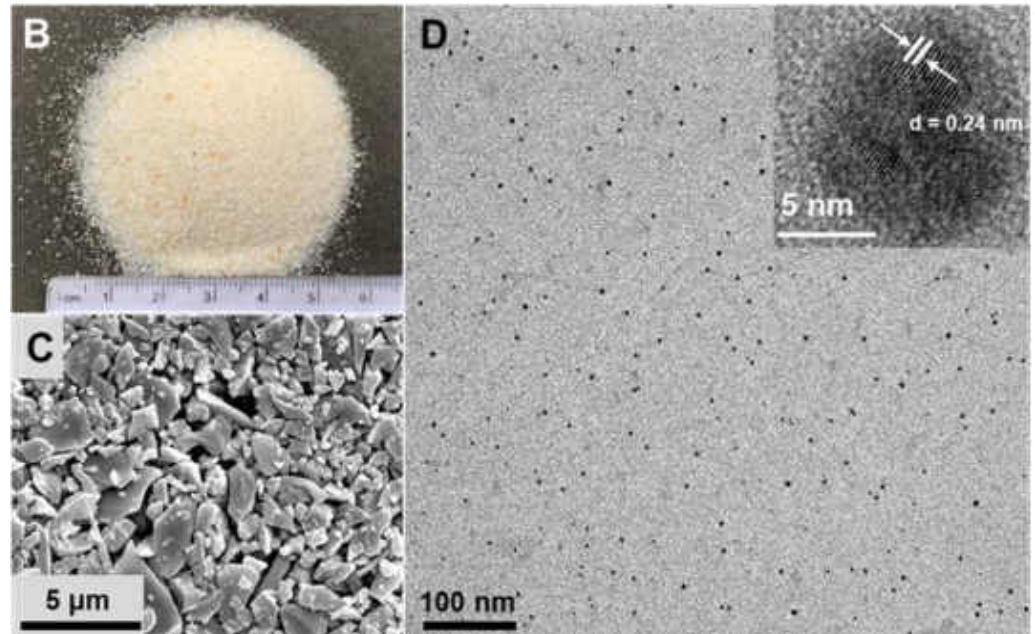
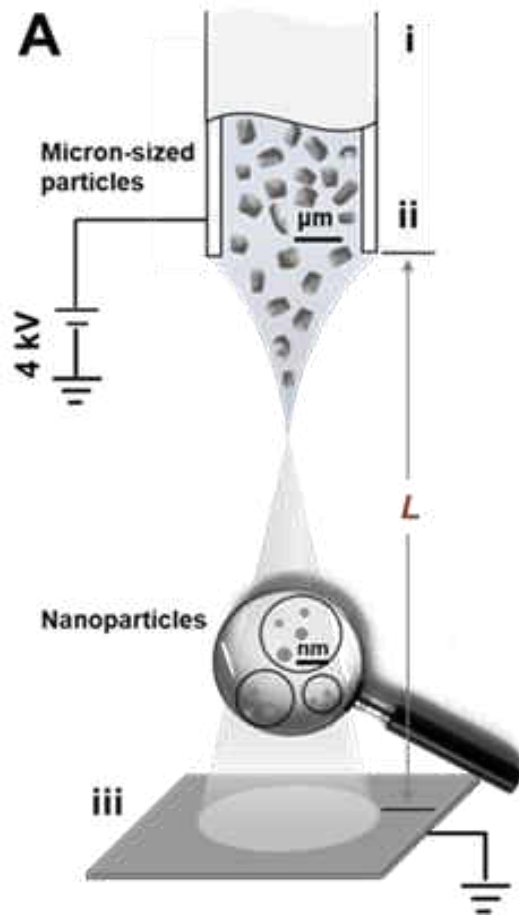


Ground silica

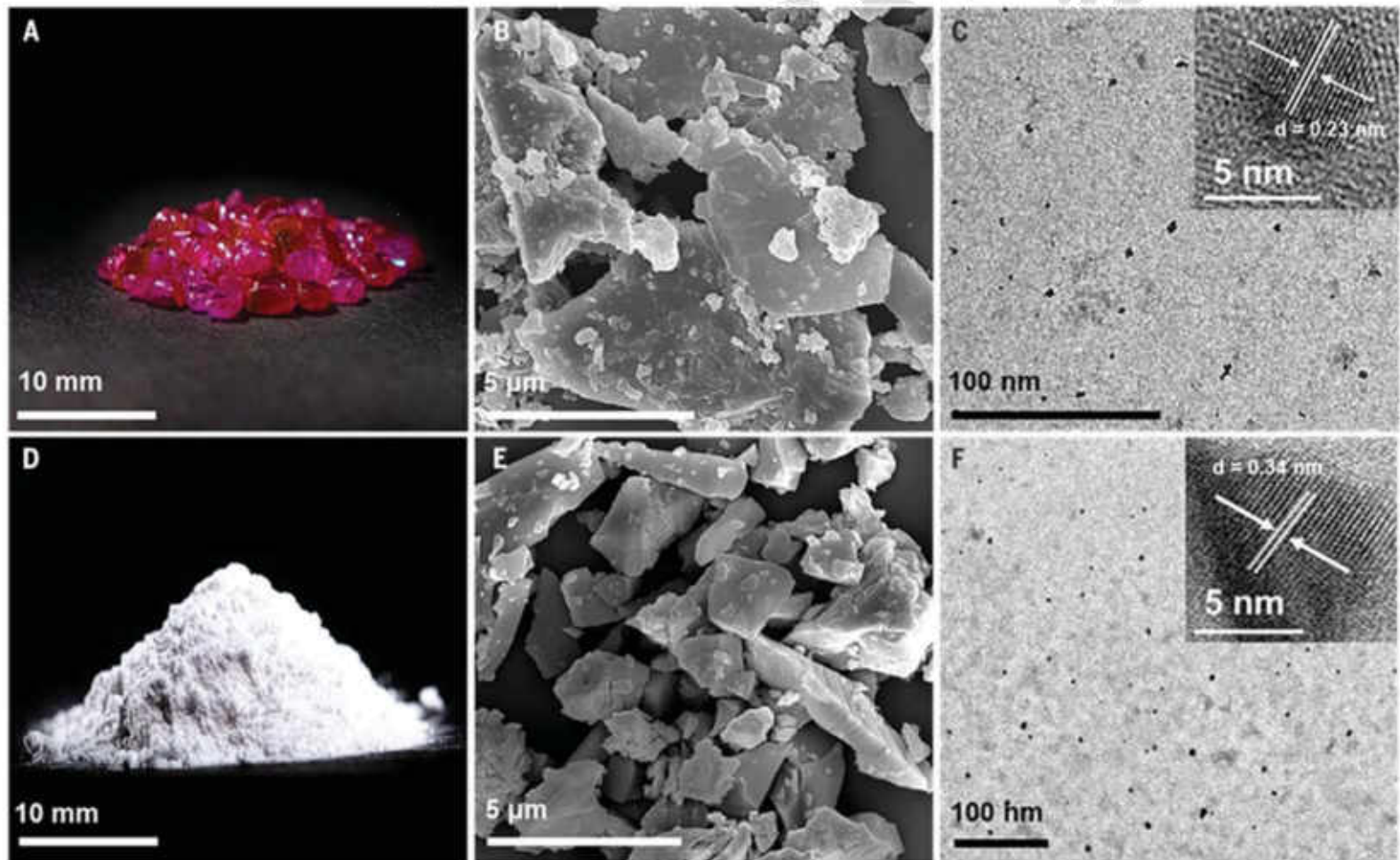


Optical image of silica

Weathering of Minerals in Microdroplets

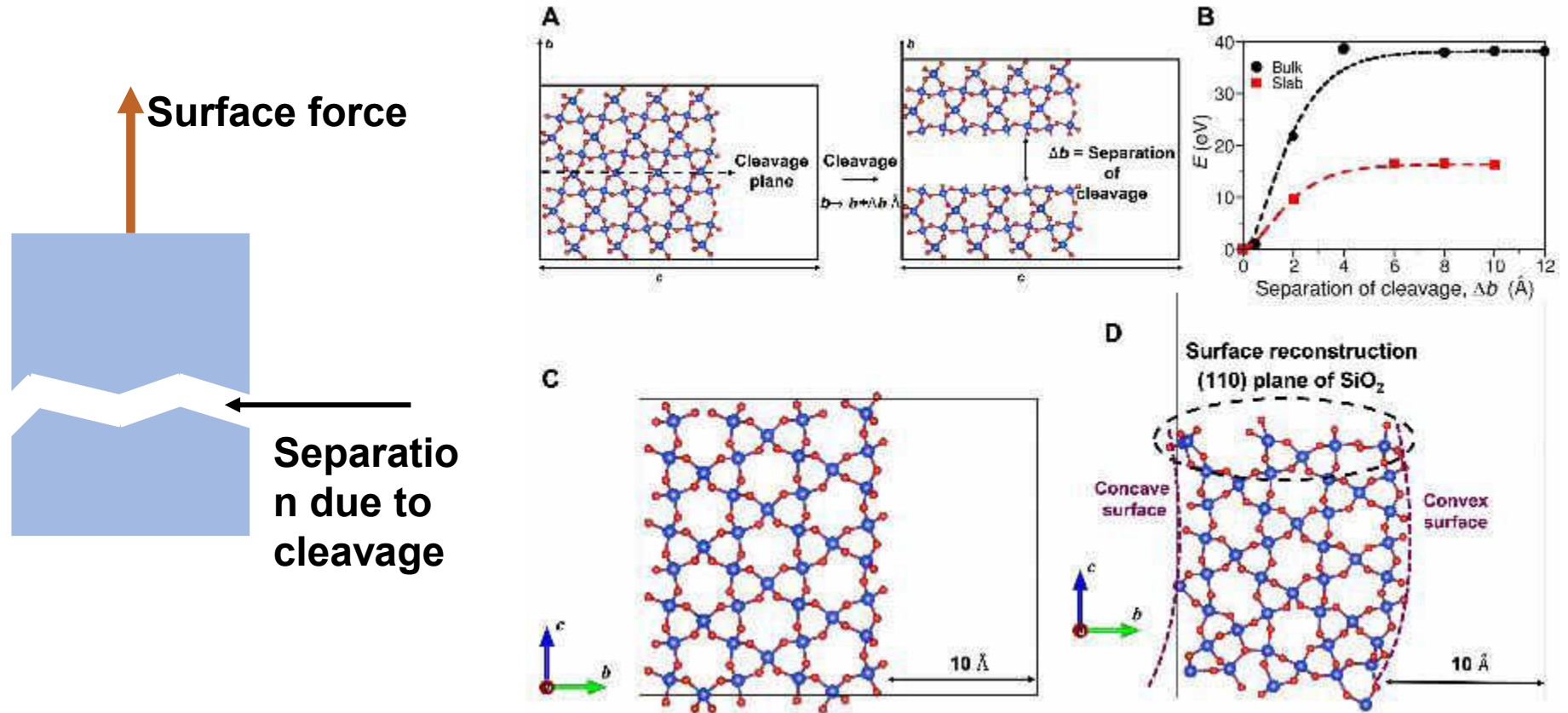


Ruby, Fused Alumina

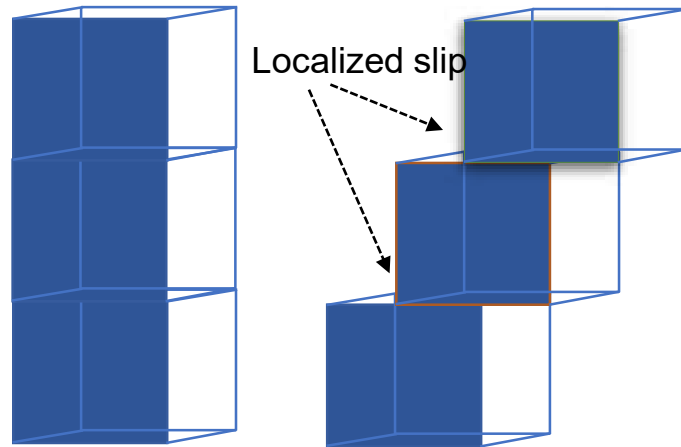


Mechanism: Cleavage

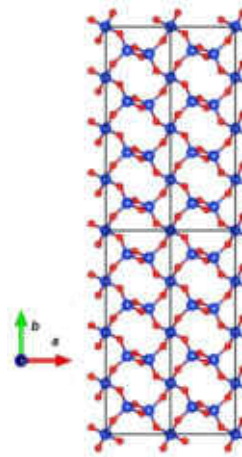
The process of cleavage and surface reconstruction visualized with first-principles simulations



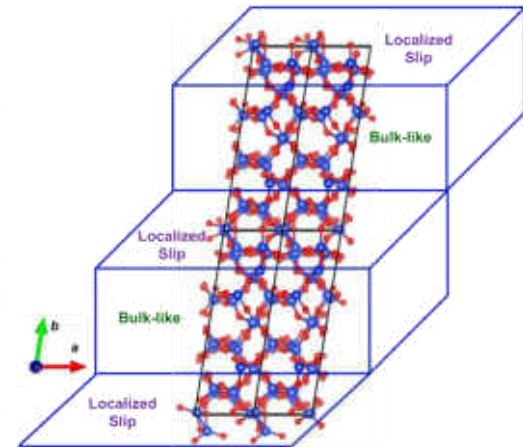
Mechanism: Slip



No slip



Slip



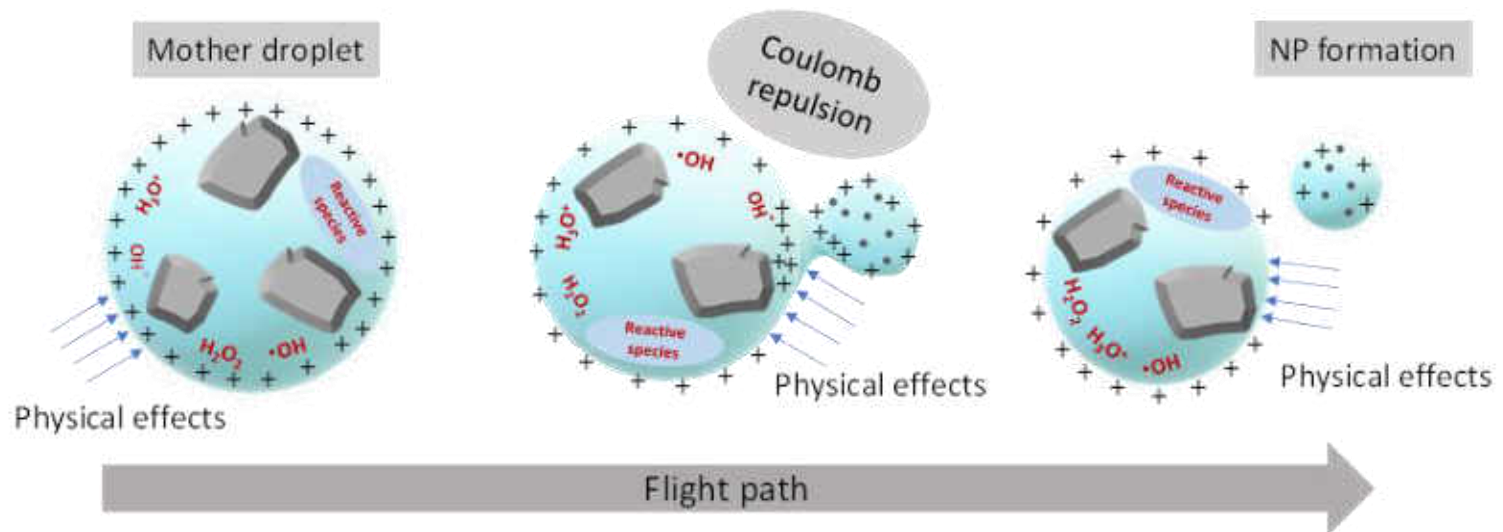
This instability leads to the formation of a stacking fault on the (010) plane, achieved with slip localized at (010) plane

Stacking fault

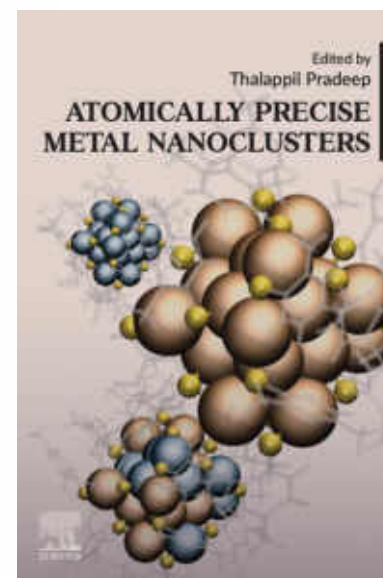
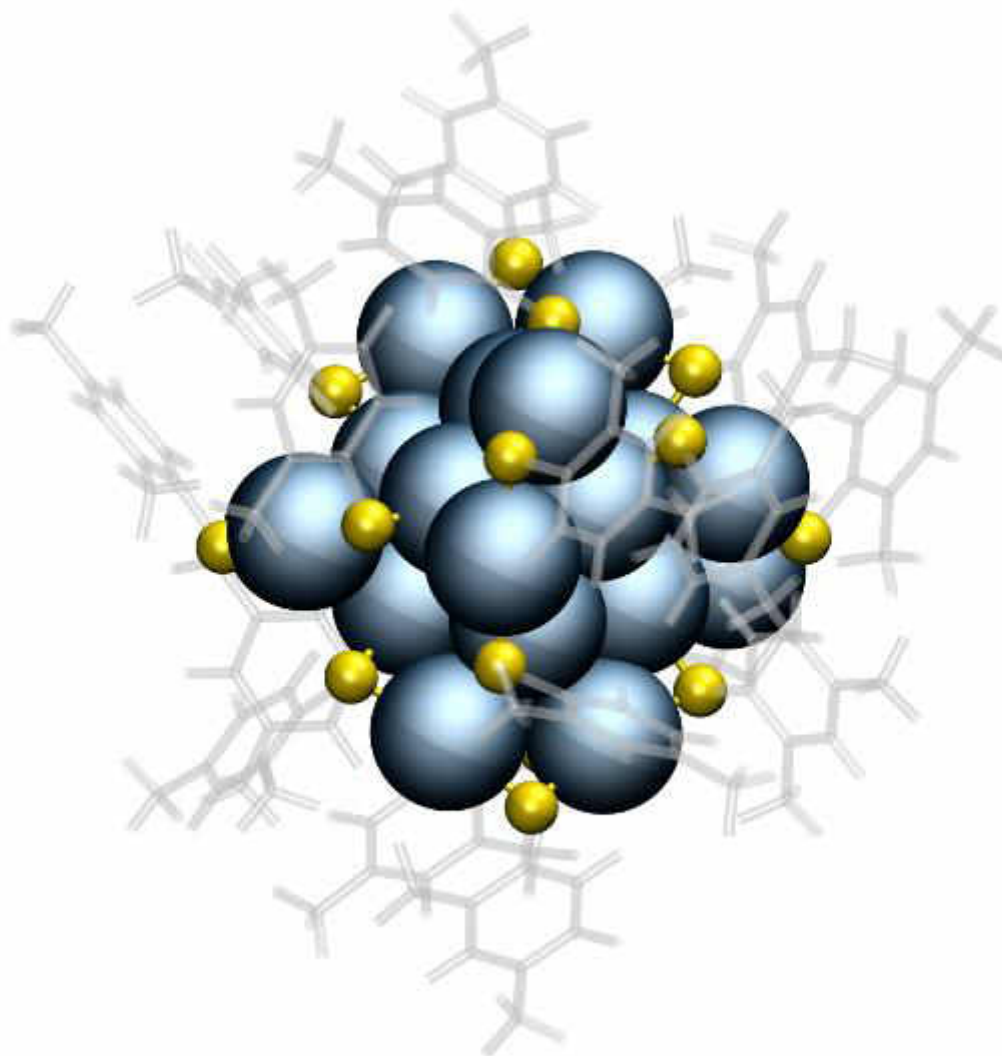
$$\vec{b} \rightarrow \vec{b}_0 + (x, 0, z).$$

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

Mechanism of nanoparticle formation



New molecules



Au_{25} , Ag_{25} , Ag_{29}

Biopolymer-reinforced synthetic granular nanocomposites for affordable point-of-use water purification

Mohan Udhaya Sankar¹, Sahaja Aigal¹, Shihabudheen M. Maliyekkal¹, Amrita Chaudhary, Anshup, Avula Anil Kumar, Kamalesh Chaudhari, and Thalappil Pradeep²

¹Unit of Nanoscience and Thematic Unit of Ex

Edited by Eric Hoek, University of California,

Creation of affordable materials for cons water is one of the most promising way drinking water for all. Combining the composites to scavenge toxic species other contaminants along with the ab affordable, all-inclusive drinking water without electricity. The critical proble synthesis of stable materials that can uously in the presence of complex s drinking water that deposit and caus surfaces. Here we show that such can be synthesized in a simple and effective out the use of electrical power. The na sand-like properties, such as higher shea forms. These materials have been used water purifier to deliver clean drinking ility. The ability to prepare nanostructu ambient temperature has wide releva water purification.

hybrid | green | appropriate technology | frugal science | developing world

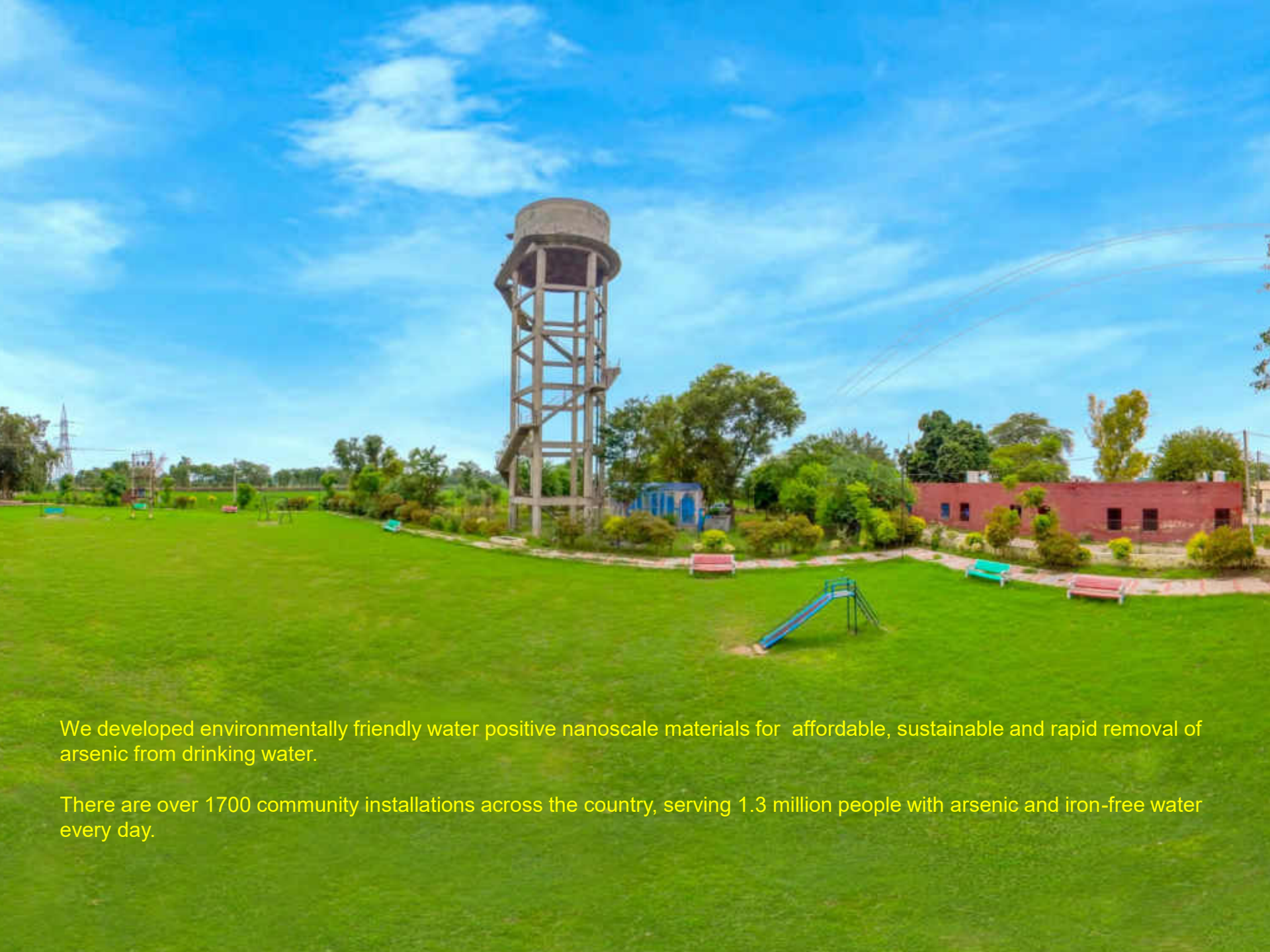


Madras, Chennai 600 036, India

(received for review November 21, 2012)

available; and (c) continued retention matrix is difficult. ate a unique family of nanocrystalline n granular composite materials pre- ature through an aqueous route. The mposition is attributed to abundant -O on chitosan, which help in the crys- oxide and also ensure strong covalent : surface to the matrix. X-ray photo-) confirms that the composition is rich ps. Using hyperspectral imaging, the aching in the water was confirmed. to reactivate the silver nanoparticle ial antimicrobial activity in drinking osites have been developed that can its in water. We demonstrate an af- device based on such composites de- und undergoing field trials in India, as :spread eradication of the waterborne

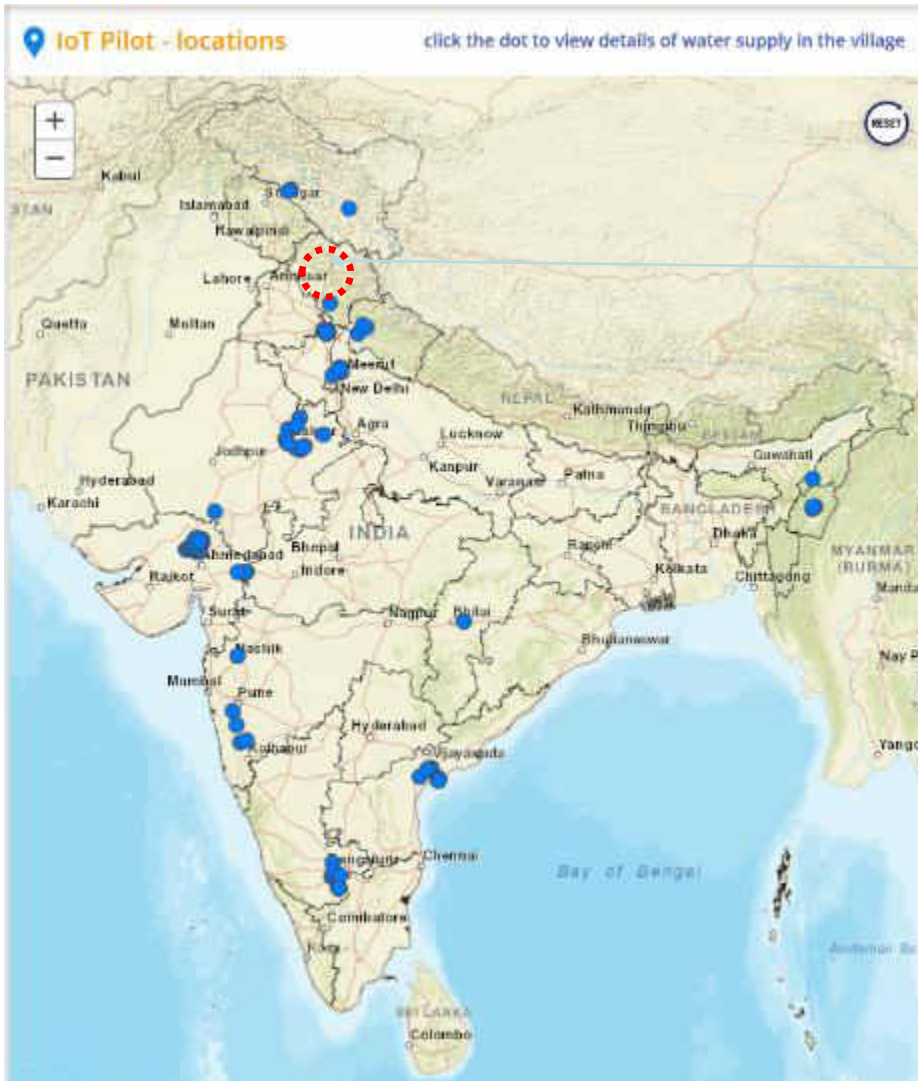
RESULTS AND DISCUSSION



We developed environmentally friendly water positive nanoscale materials for affordable, sustainable and rapid removal of arsenic from drinking water.

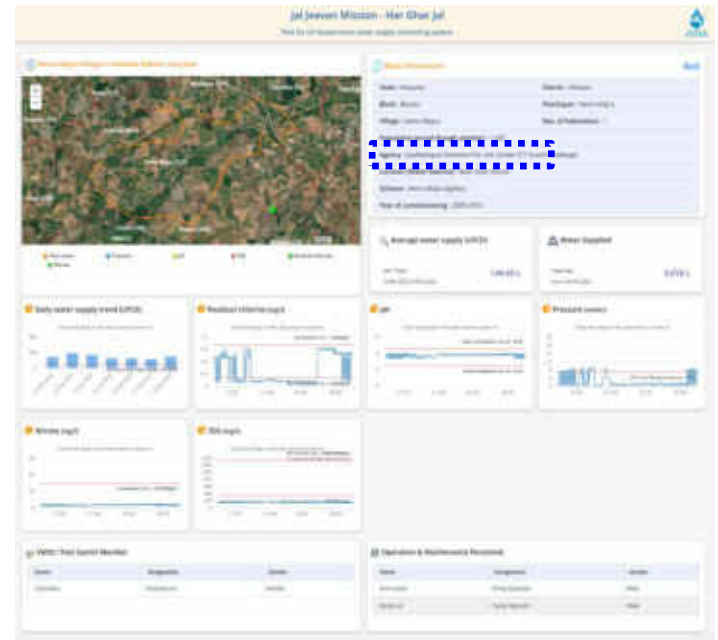
There are over 1700 community installations across the country, serving 1.3 million people with arsenic and iron-free water every day.

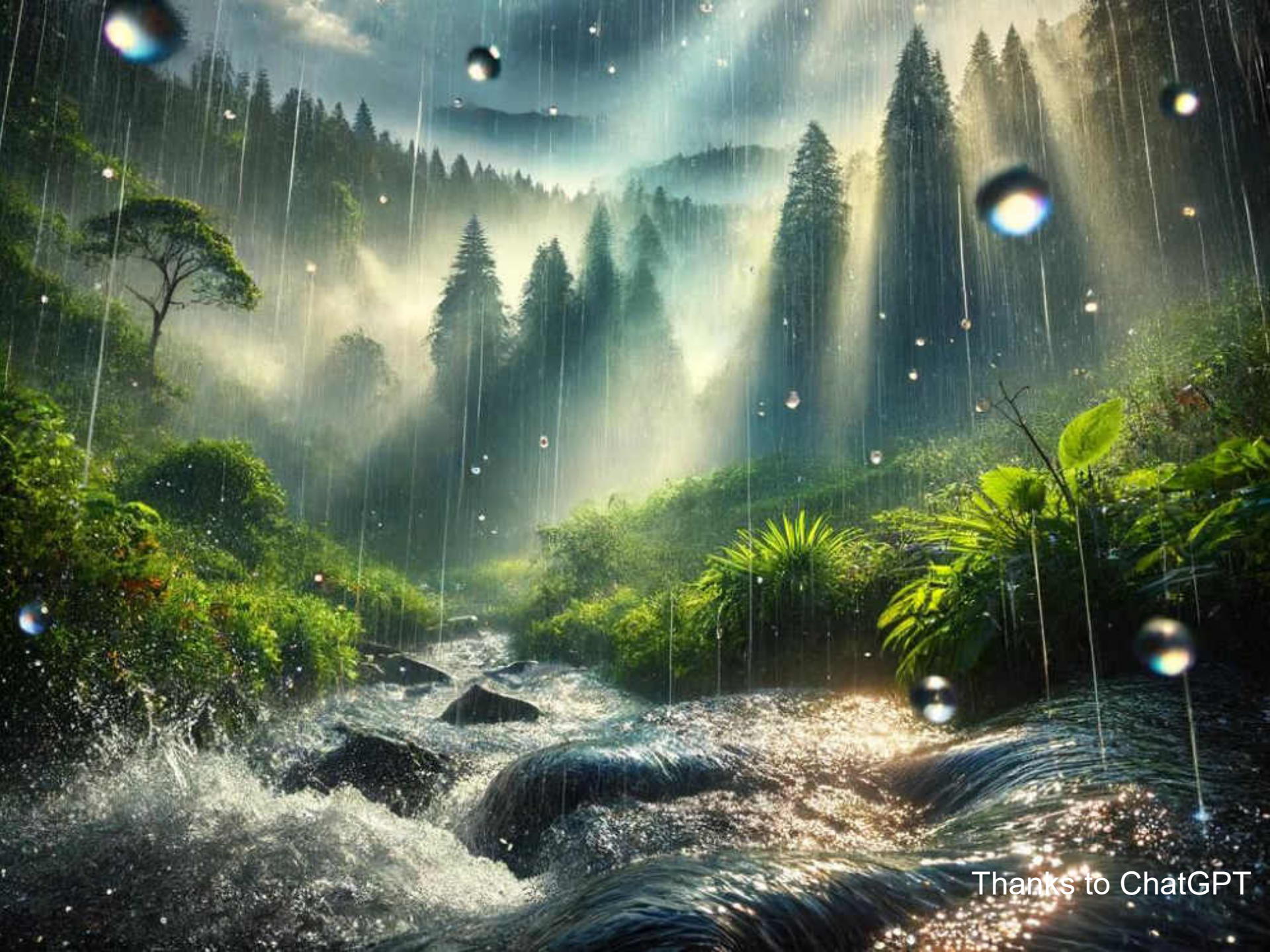
India's water is being monitored



IITM/IISc

Installations made by four companies





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Vision

Make soil using
processed wastewater
and make deserts
bloom.



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Conclusions

Natural minerals break spontaneously in charged water microdroplets

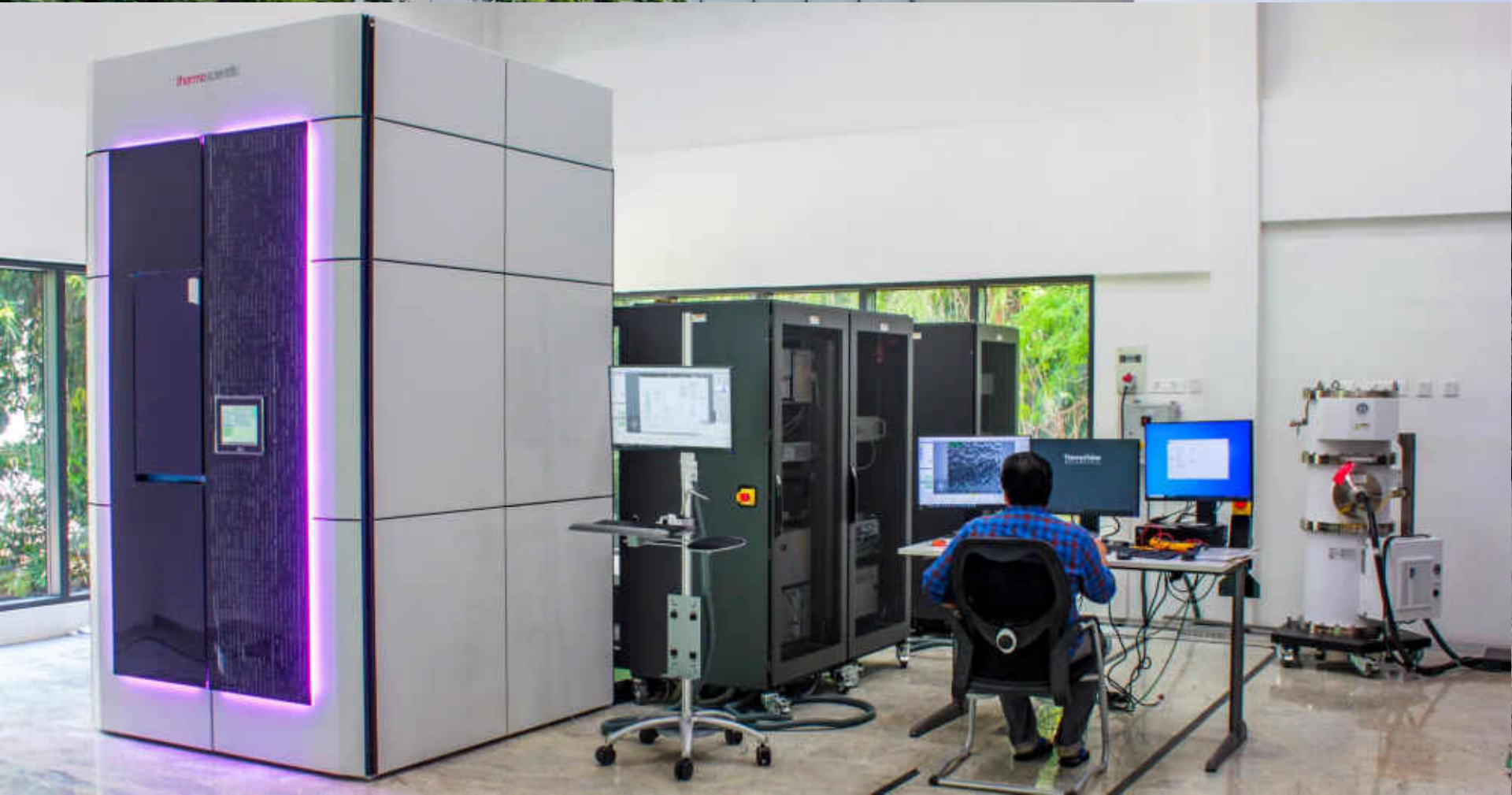
It occurs only in water... so far

Studies on a variety of materials

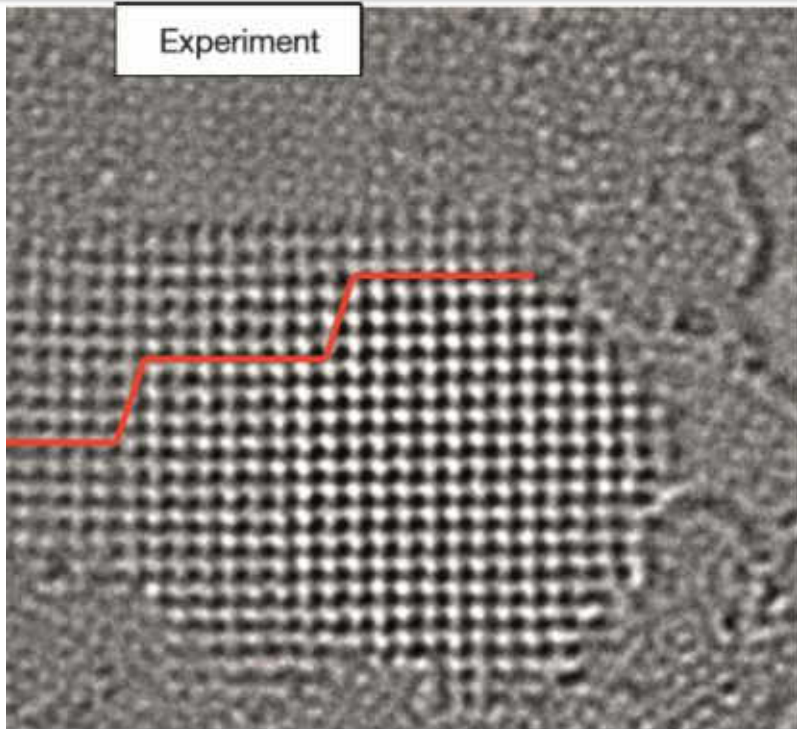
Facile due to proton-induced slip

Detailed investigations are essential to know more

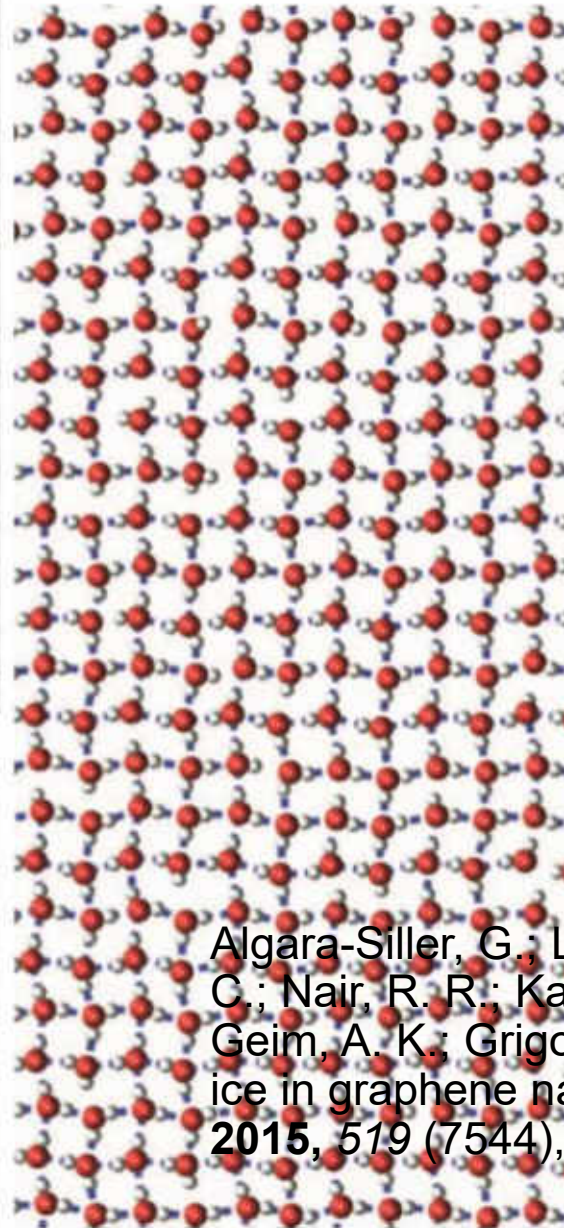
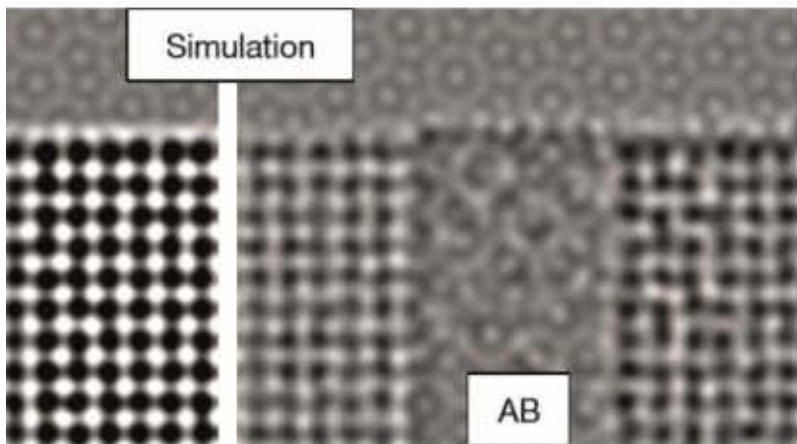
Implications to the production of specific nanomaterials and soil in general



Observing water



c



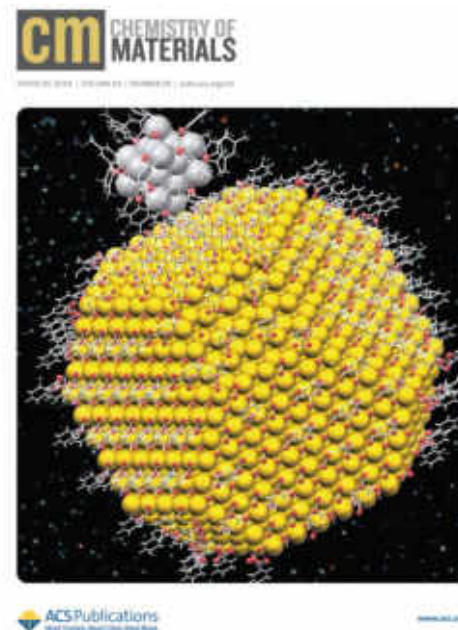
Algara-Siller, G.; Lehtinen, O.; Wang, F. C.; Nair, R. R.; Kaiser, U.; Wu, H. A.; Geim, A. K.; Grigorieva, I. V., Square ice in graphene nanocapillaries. *Nature* **2015**, 519 (7544), 443-445.







Department of Science and Technology
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Bhaskar Ramamurthi/V. Kamakoti

Thank you all

