Since 1959

Research & Impact: My Story

Thalappil Pradeep

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https://pradeepresearch.org

Co-founder

InnoNano Research Pvt. Ltd.
InnoDI Water Technologies Pvt. Ltd.
VayuJAL Technologies Pvt. Ltd.
Aqueasy Innovations Pvt. Ltd.
Hydromaterials Pvt. Ltd.
EyeNetAqua Solutions Pvt. Ltd.
DeepSpectrum Innovations Pvt. Ltd.

Professor-in-charge

International Centre for Clean Water

Associate Editor

ACS Sustainable Chemistry & Engineering

MALAVIYA MISSION TEACHER TRAINING PROGRAMME


Lost in the countryside
Image from Wikipedia

Books and roots

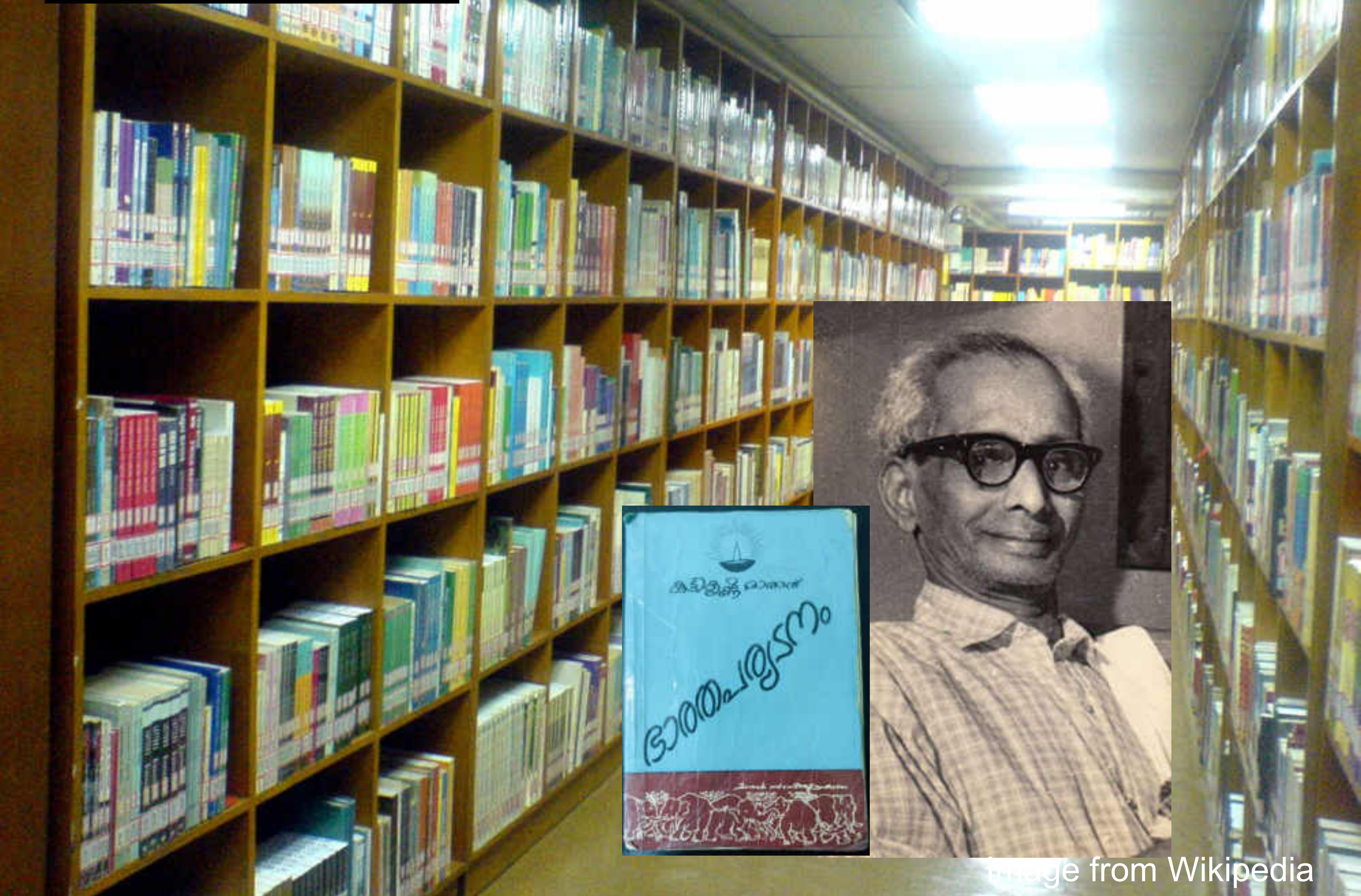
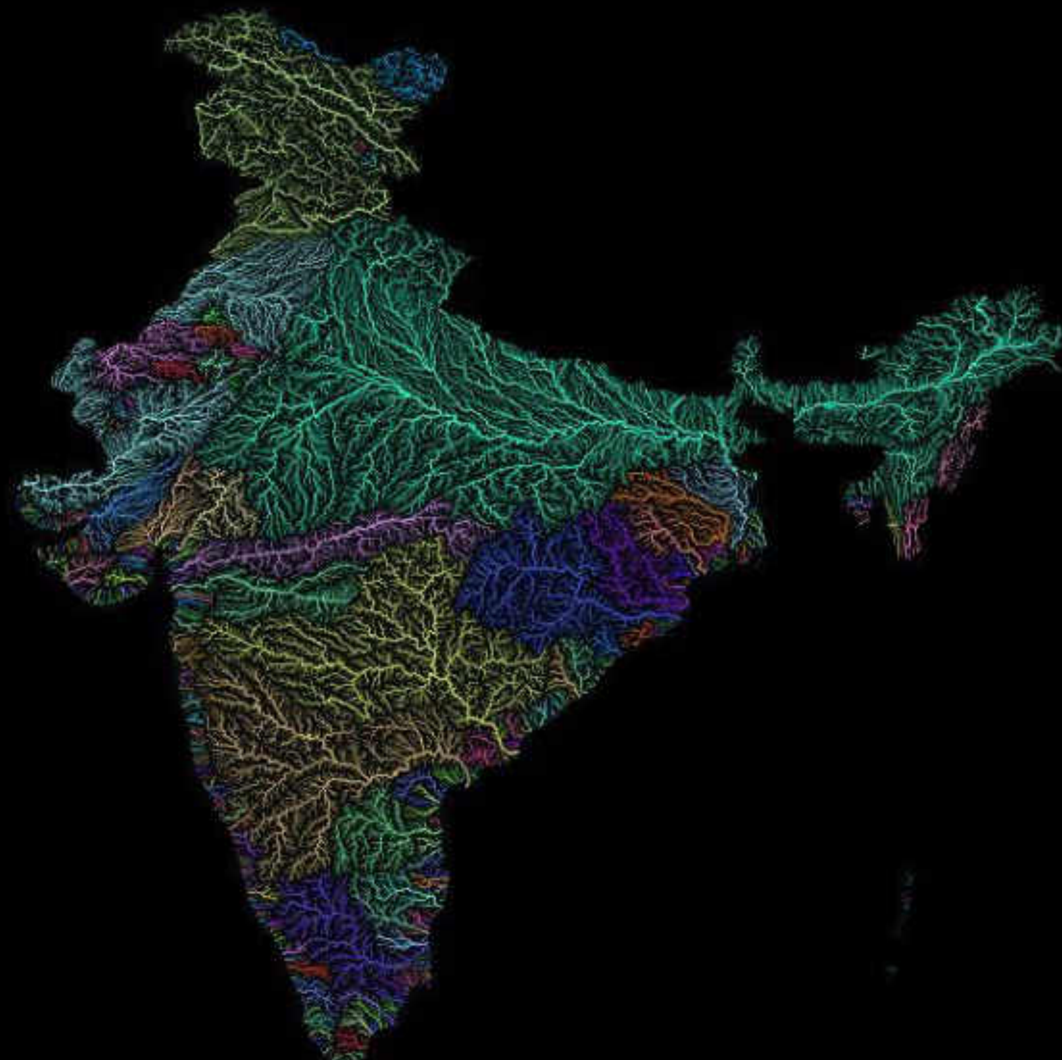


Image from Wikipedia


“Pale blue dot” Voyager 1 Feb. 14, 1990

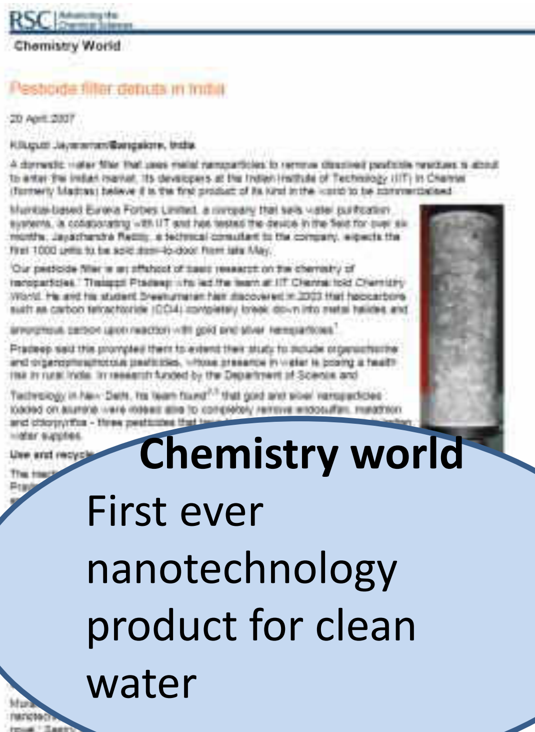
Water is the most important inheritance of our planet



© Robert Szucs/Grasshopper Geography

From S. Vishwanath

World's first nanochemistry-based water purifier


RSC
Chemistry World
Pesticide filter debuts in India
20 April 2007
Killugudi Jayaraman/Bangalore, India

Chemistry world

First ever nanotechnology product for clean water

A plant to make supported nanomaterials for water purification; with capacity of 4.5 tons per month, 2007

1. Patents: A method of preparing purified water from water containing pesticides, **Indian patent 200767**
2. Extraction of malatheon and chlorpiryhphos from drinking water by nanoparticles , **US 7,968,493** A method for decontaminating water containing pesticides, **EP 17,15,947**

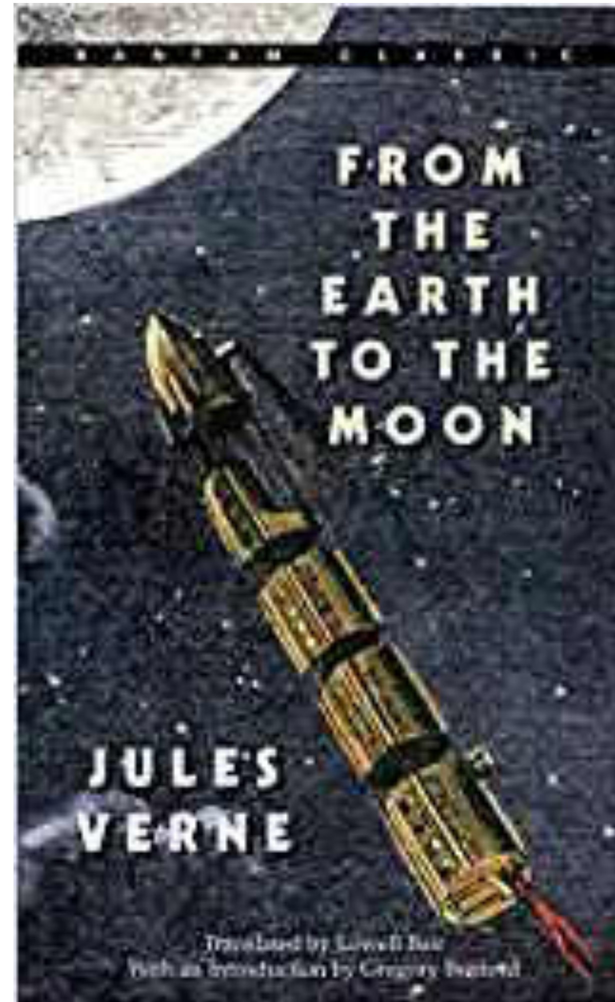
Product is marketed now by a Eureka Forbes Ltd.

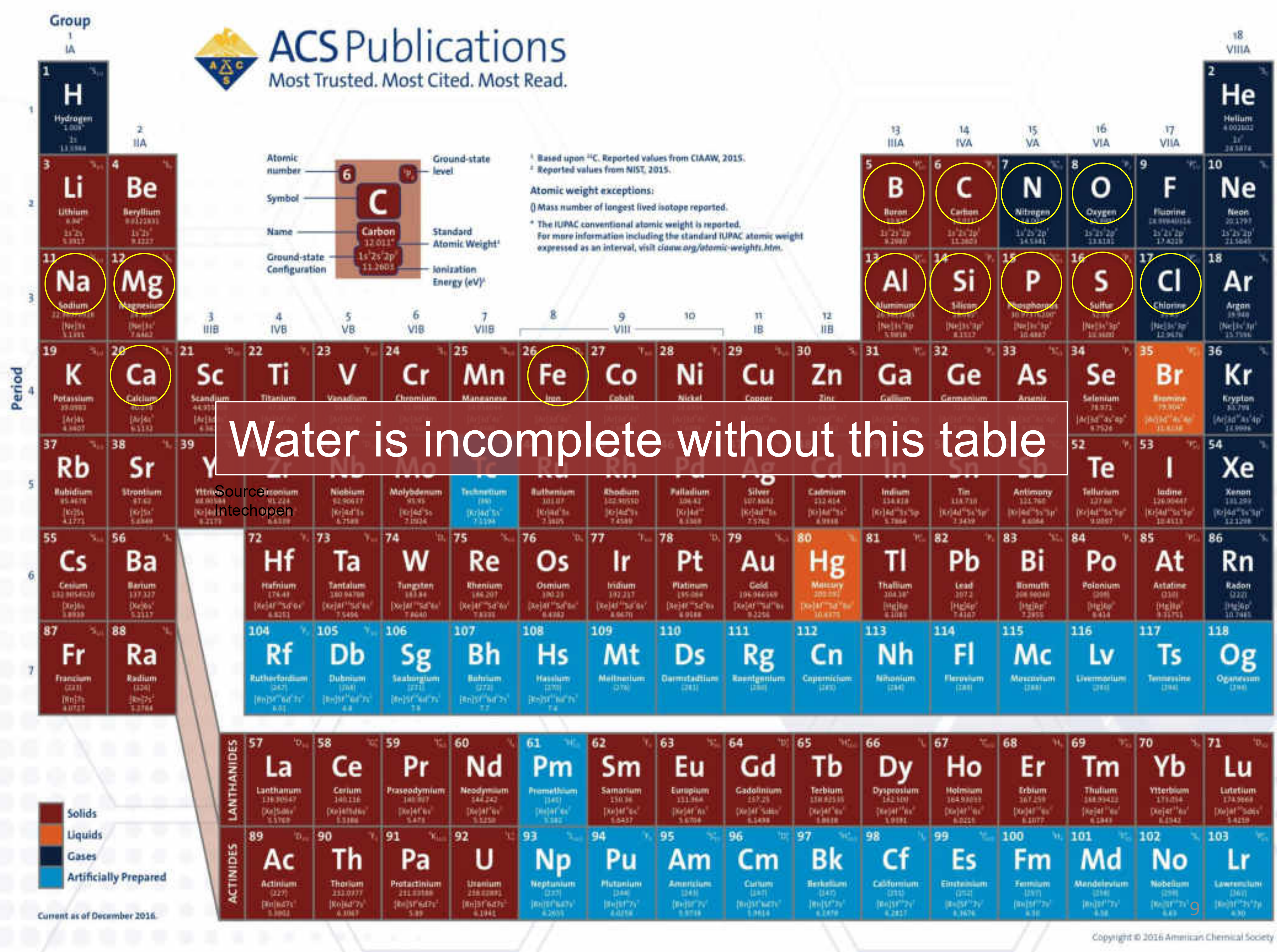
Several new technologies are now available

Water is at the centre of action

There is water in everything we do.

Our dreams become reality with materials





Water is incomplete without this table

Source: Intechopen

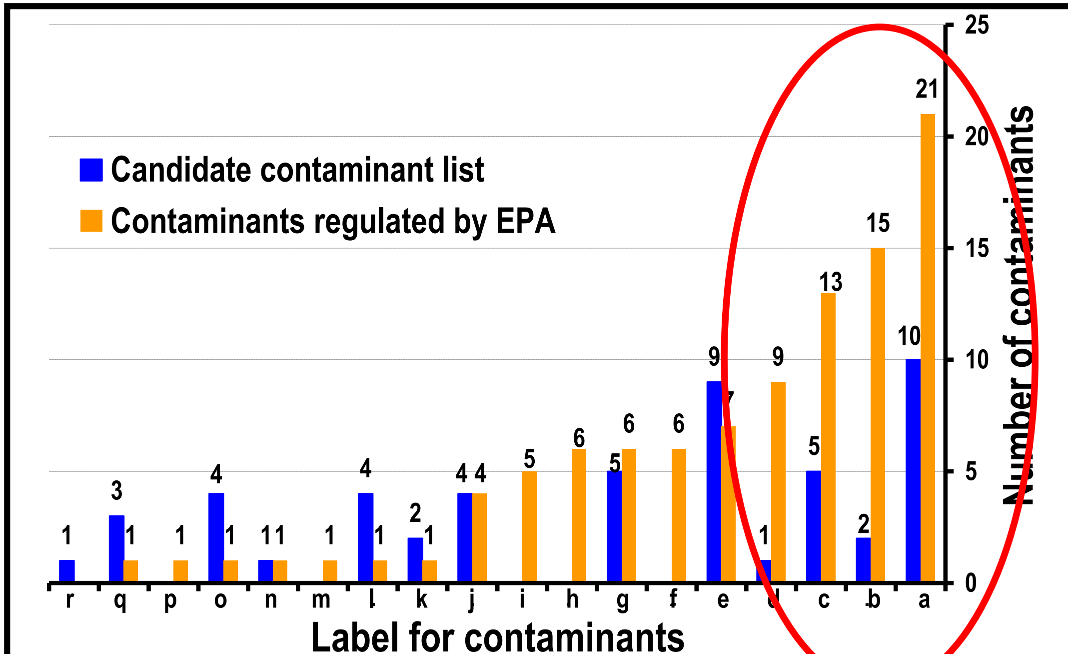
Water purification, history

Important milestones in the history of water purification (1800–2007) from the perspective of noble metal nanoparticles in water treatment (compiled from multiple sources on the World Wide Web).

Year	Milestone
1804	Setup of world's first city-wide municipal water treatment plant (Scotland, sand-filter technology)
1810	Discovery of chlorine as a disinfectant (H. Davy)
1852	Formulation of Metropolis Water Act (England)
1879	Formulation of Germ Theory (L. Pasteur)
1902	Use of chlorine as a disinfectant in drinking water supply (calcium hypochlorite, Belgium)
1906	Use of ozone as a disinfectant (France)
1908	Use of chlorine as a disinfectant in municipal supply, New Jersey
1914	Federal regulation of drinking water quality (USPHS)
1916	Use of UV treatment in municipal supplies
1935	Discovery of synthetic ion exchange resin (B. A. Adams, E. L. Holmes)
1948	Nobel Prize to Paul Hermann Muller (insecticidal properties of DDT)
1959	Discovery of synthetic reverse osmosis membrane (S. Yuster, S. Loeb, S. Sourirajan)
1962	*Silent Spring* published, first report on harmful effects of DDT (R. Carson)
1965	World's first commercial RO plant launched
1974	Reports on carcinogenic by-products of disinfection with chlorine Formulation of Safe Drinking Water Act (USEPA)
1975	Development of carbon block for drinking water purification
1994	Report on use of zerovalent iron for degradation of halogenated organics (R. W. Gillham, S. F. O'Hannesin)
1997	Report on use of zerovalent iron nanoparticles for degradation of halogenated organics (C-B. Wang, W.-X. Zhang)
1998	Drinking Water Directive applied in EU
2000	Adoption of Millennium Declaration during the UN Millennium Summit (UN Millennium Development Goals)
2003	Report on use of noble metal nanoparticles for the degradation of pesticides (A.S. Nair, R. T. Tom, T. Pradeep)
2004	Stockholm Convention, banning the use of persistent organic pollutants
2007	Launch of noble metal nanoparticle-based domestic water purifier (T. Pradeep, A. S. Nair, Eureka Forbes Limited)

T. Pradeep and Anshup, *Thin Solid Films*, 2009

Future of water purification: An enigma with some pointers



(a): Halogenated organic (b): Metal (c): Organochlorine pesticide (d): Inorganic salt (e): Biological contaminant (f): Nuclear (g): Benzo derivative (h): Carbamate pesticide (i): Pesticides (others) (j): Unclassified (k): Triazine derivative pesticide (l): Organophosphorus pesticide (m): Organobromine pesticide (n): Non-metal (o): Nitrophenol derivative, (p): Dioxin, (q): Benzo and halogenated organic (r): Organometallics

Category-wise distribution of contaminants regulated by USEPA and future contaminants

Noble metal nanoparticles for water purification: A critical review, T. Pradeep and Anshup, Invited critical review, Thin Solid Films, 517 (2009) 6441-6478 (DOI: 10.1016/j.tsf.2009.03.195).

Affordable clean water is a problem of advanced materials

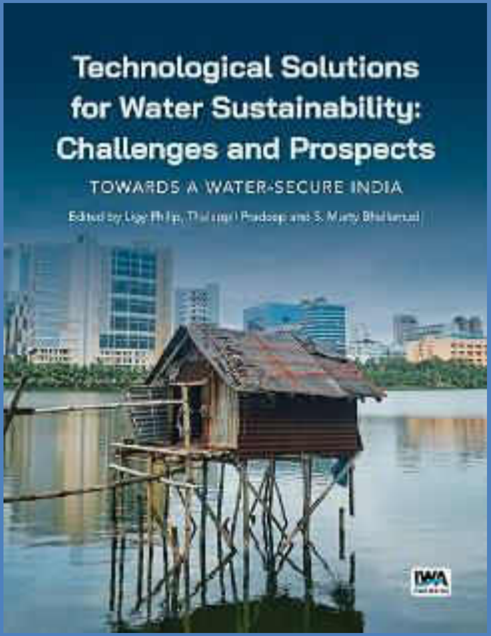
New adsorbents

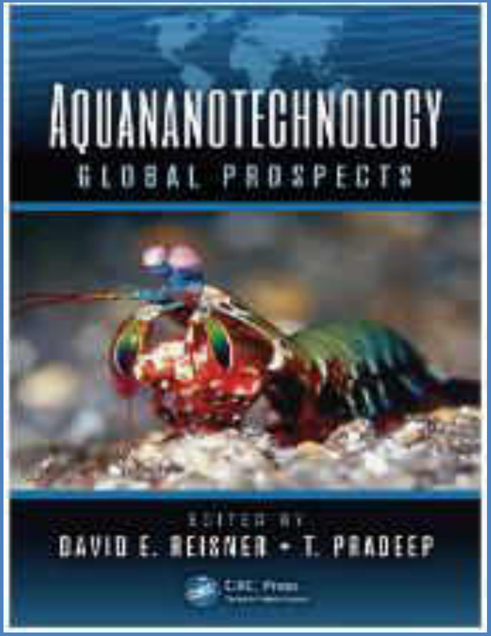
New sensors

New catalysts

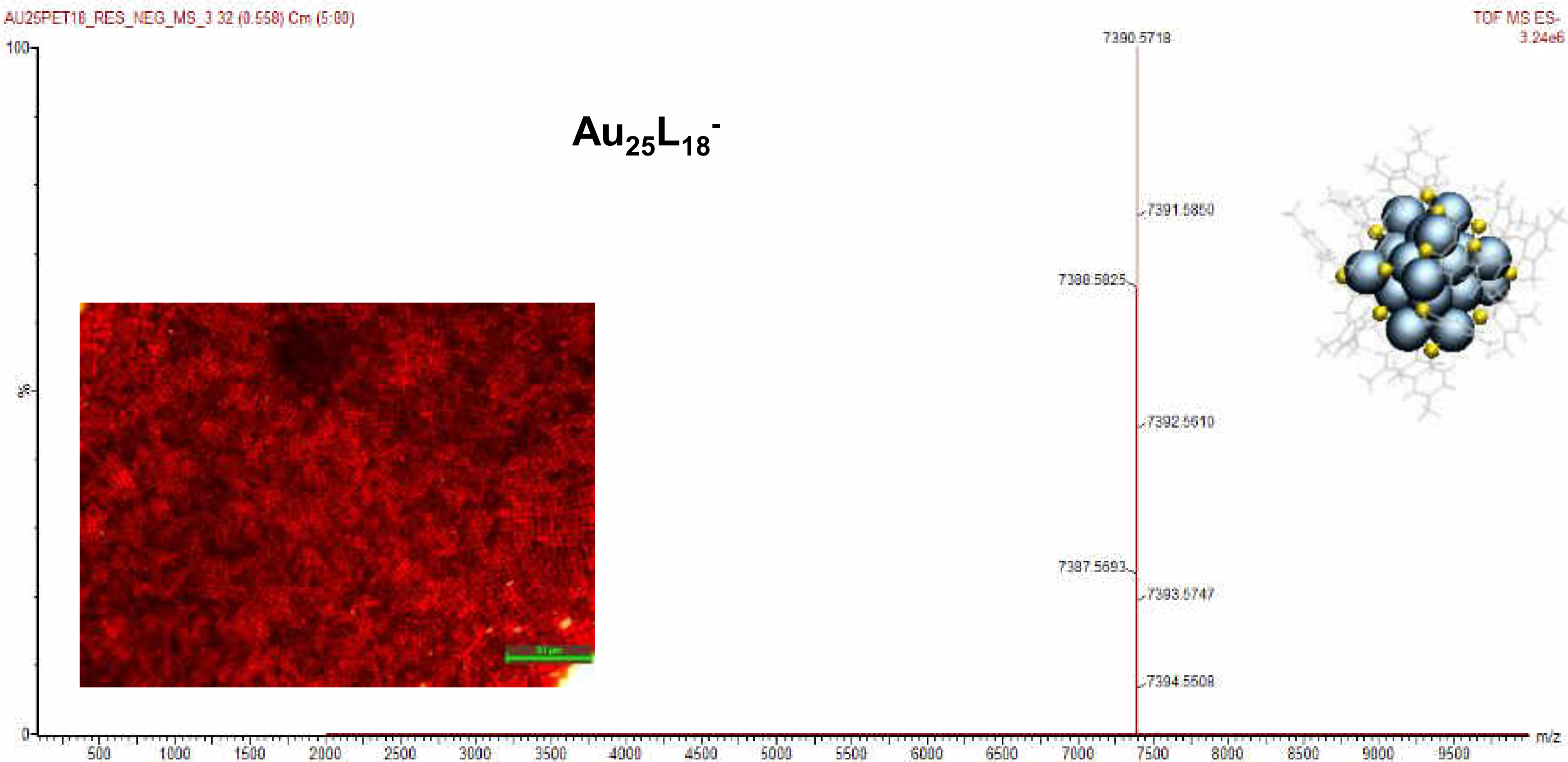
Novel phenomena

New devices





Nanomaterials are now atomically precise

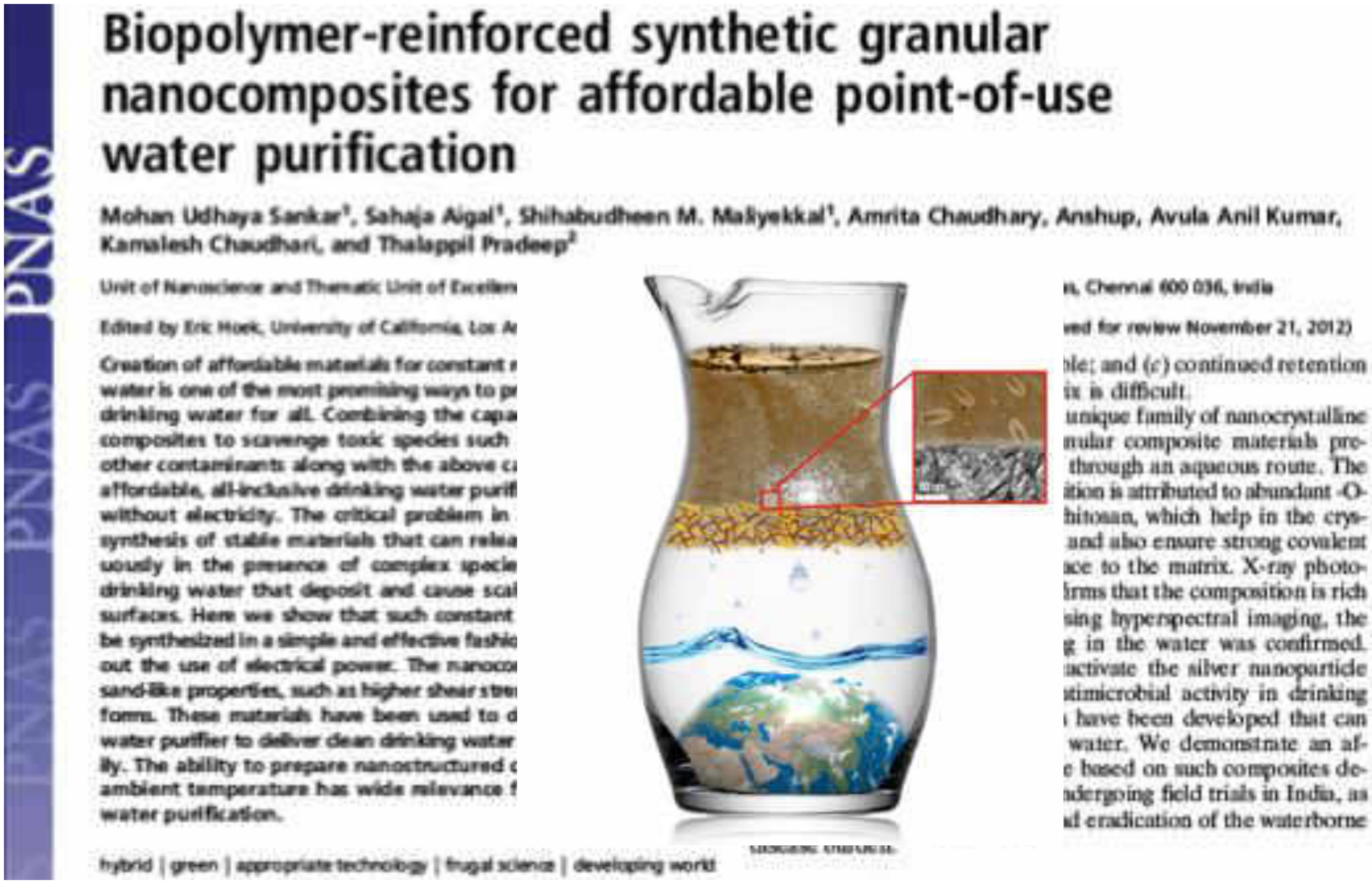


T. Pradeep et. al. *Acc. Chem. Res.* 2018; 2019.

Clean water for everyone

ACS Sustainable Chemistry & Engineering Editorial, December 2016

Water positive materials



PNAS

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

Mohan Udhaya Sankar[1], Sahaja Aigal[1], Shihabudheen M. Maliyekkal[1], Amrita Chaudhary, Anshup, Avula Anil Kumar, Kamalesh Chaudhari, and Thalappil Pradeep[2]

Unit of Nanoscience and Thematic Unit of Excellen … s, Chennai 600 036, India

Edited by Eric Hoek, University of California, Los A … ved for review November 21, 2012)

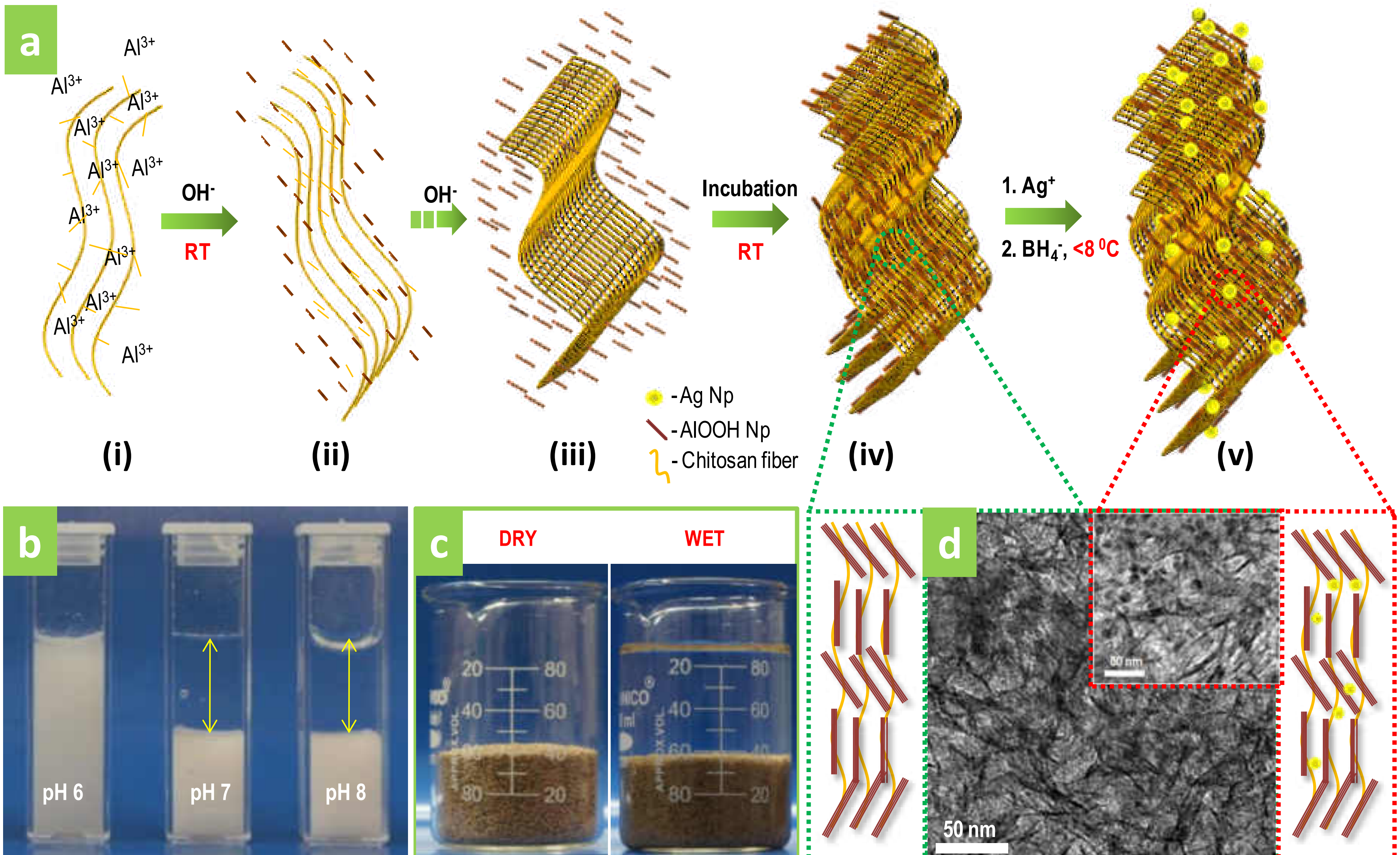
Creation of affordable materials for constant r
water is one of the most promising ways to pr
drinking water for all. Combining the capa
composites to scavenge toxic species such
other contaminants along with the above ca
affordable, all-inclusive drinking water purif
without electricity. The critical problem in
synthesis of stable materials that can relea
uously in the presence of complex specie
drinking water that deposit and cause scal
surfaces. Here we show that such constant
be synthesized in a simple and effective fashio
out the use of electrical power. The nanocom
sand-like properties, such as higher shear stre
forms. These materials have been used to d
water purifier to deliver clean drinking water
ily. The ability to prepare nanostructured c
ambient temperature has wide relevance f
water purification.

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

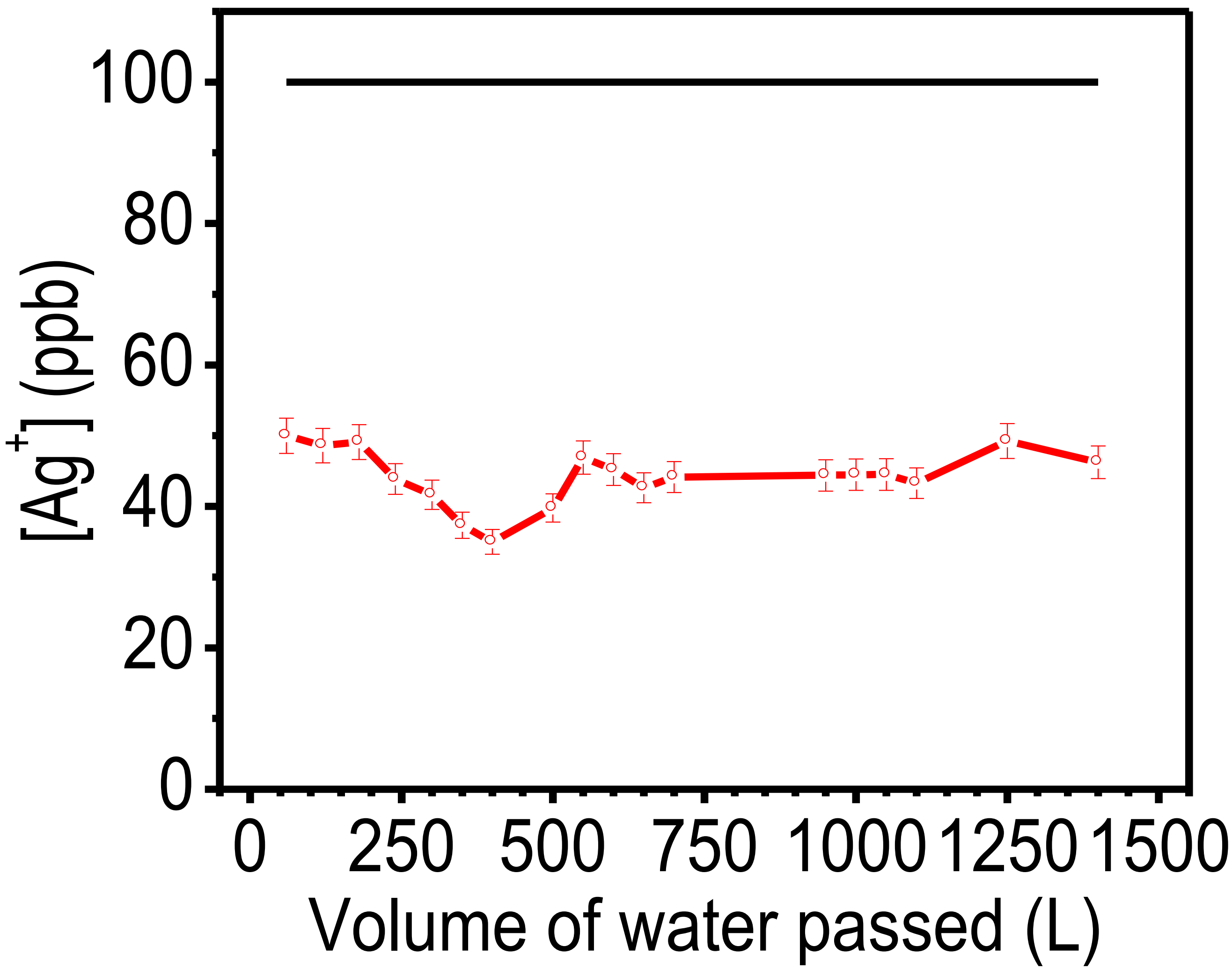
ble; and (c) continued retention
ix is difficult.
unique family of nanocrystalline
nular composite materials pre-
through an aqueous route. The
ition is attributed to abundant -O-
hitosan, which help in the crys-
and also ensure strong covalent
ace to the matrix. X-ray photo-
irms that the composition is rich
sing hyperspectral imaging, the
g in the water was confirmed.
activate the silver nanoparticle
ntimicrobial activity in drinking
h have been developed that can
water. We demonstrate an af-
e based on such composites de-
ndergoing field trials in India, as
d eradication of the waterborne
disease burden.

M. Udhaya Sankar, et. al. *Proc. Natl. Acad. Sci.,* 110 (2013) 8459-8464.

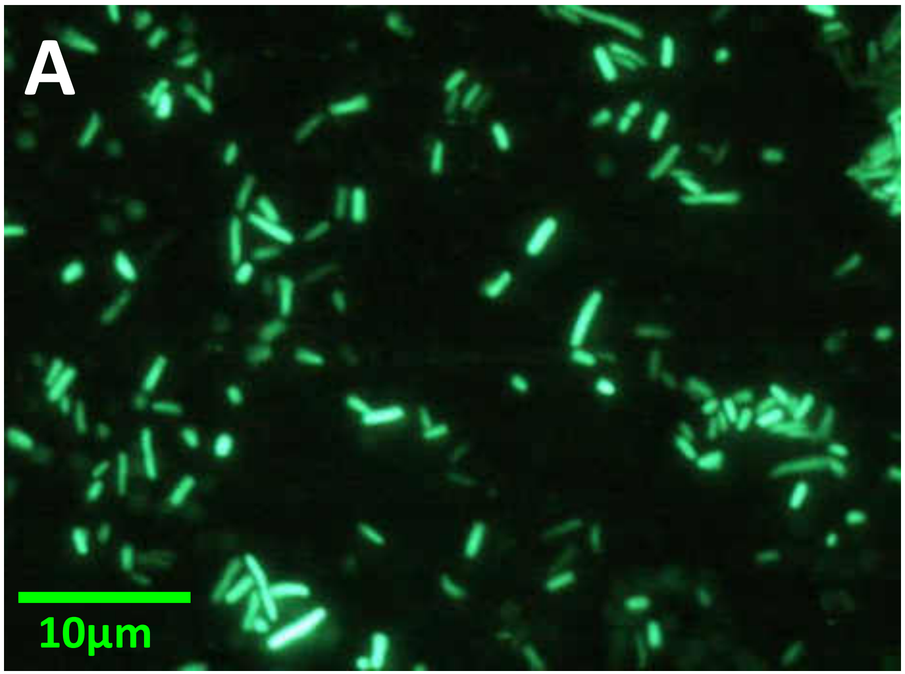
How to make?

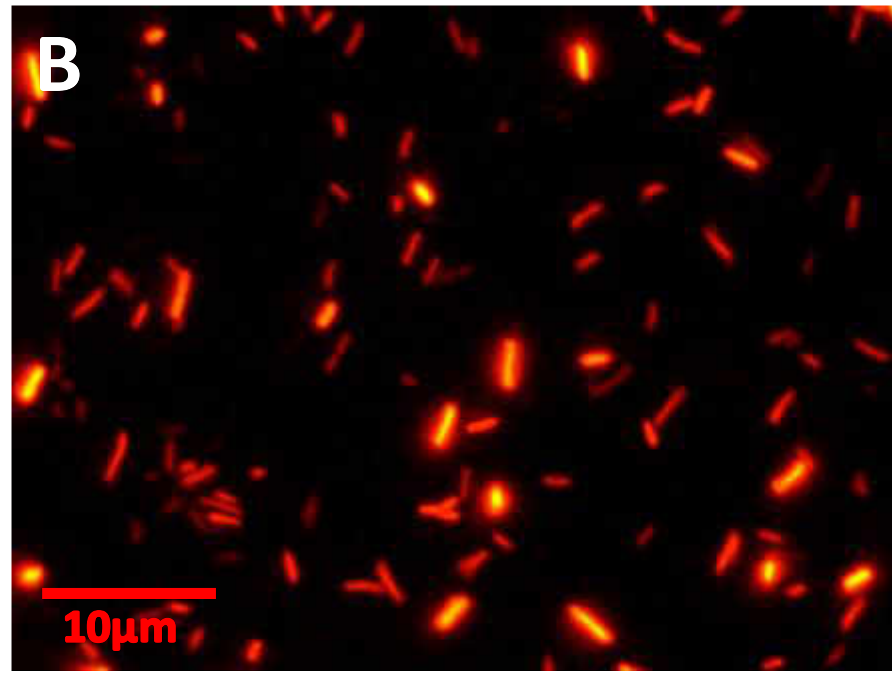

a
Al3+
OH-
RT
OH-
Incubation
RT
1. Ag+
2. BH4-, <8 0C
-Ag Np
-AlOOH Np
-Chitosan fiber
(i)
(ii)
(iii)
(iv)
(v)
b
pH 6
pH 7
pH 8
c
DRY
WET
d
50 nm

What is special?

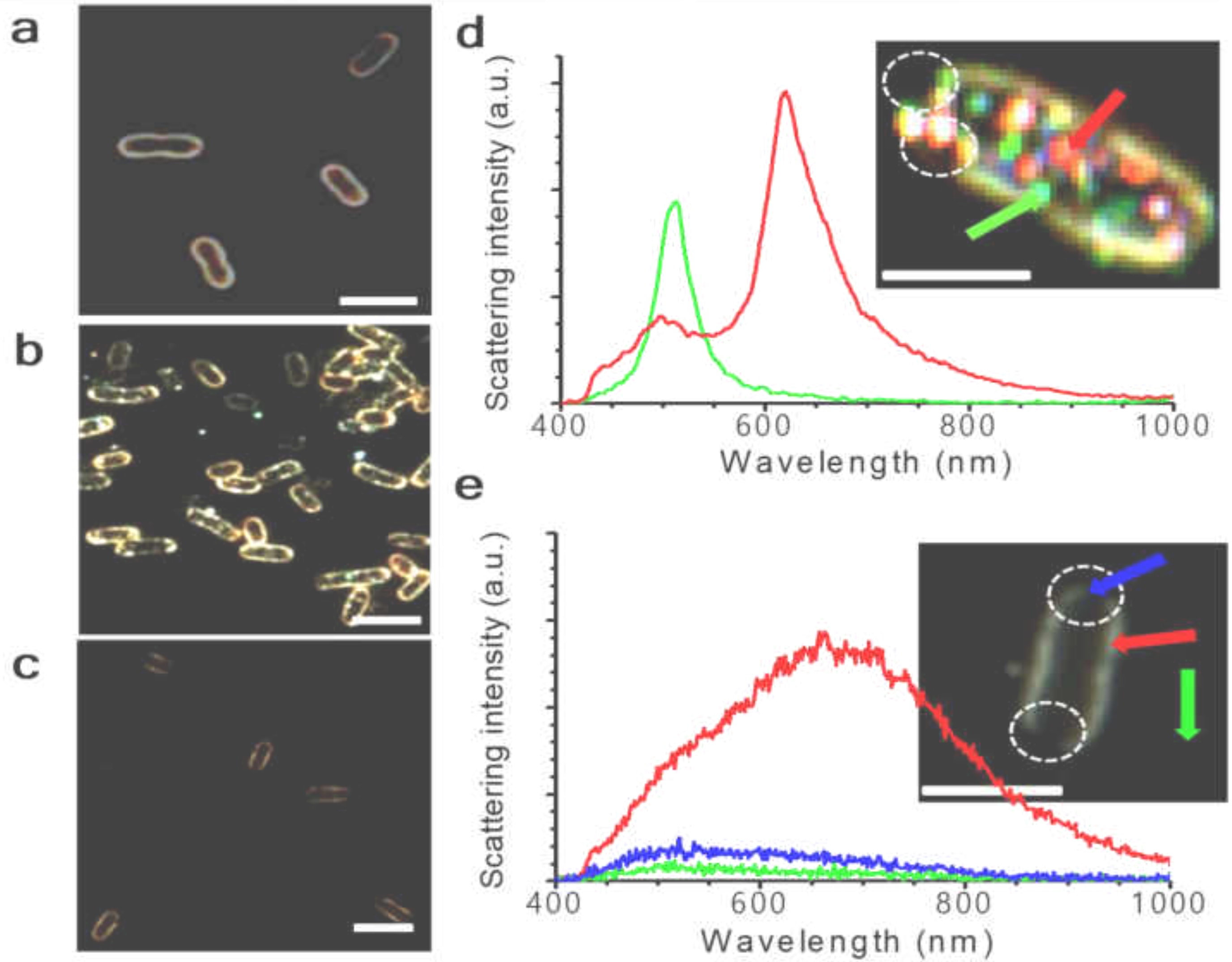


Live/dead staining experiments

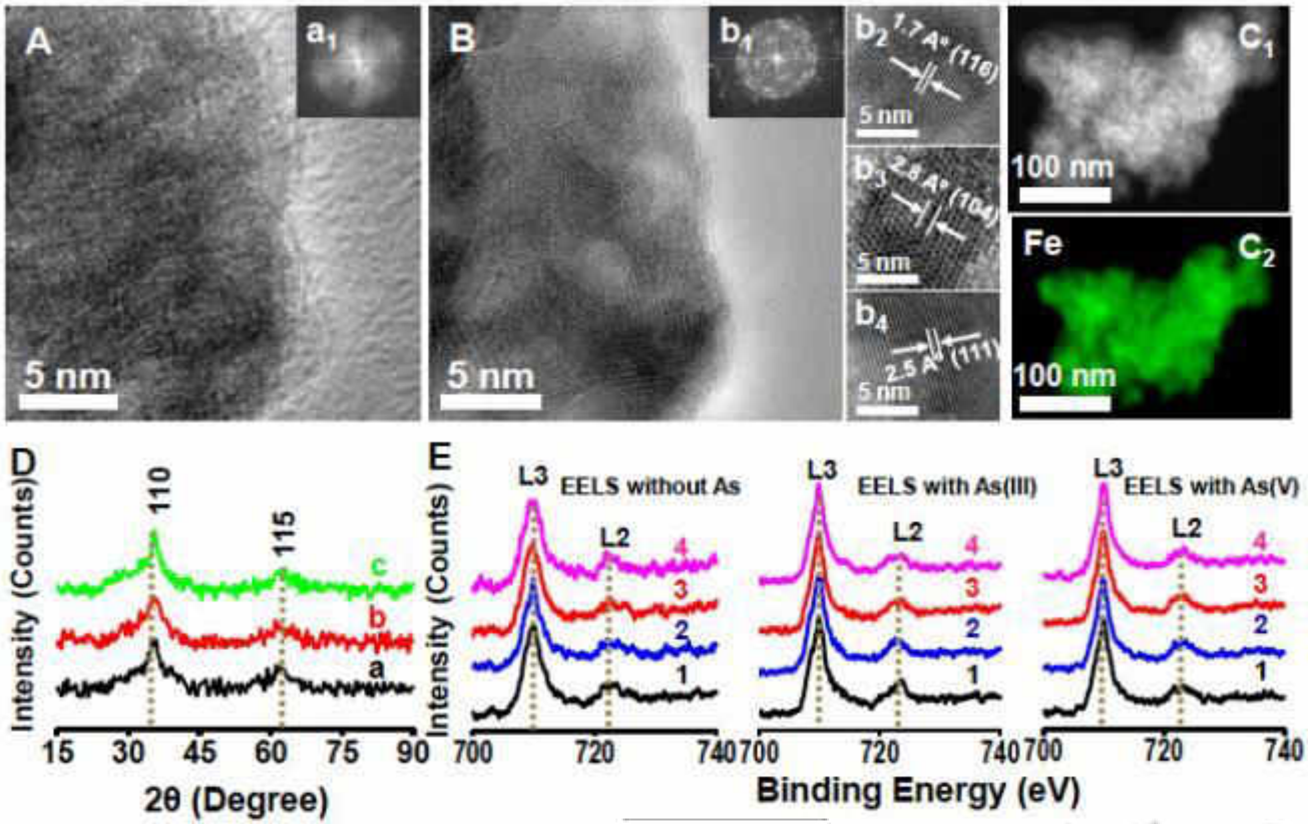


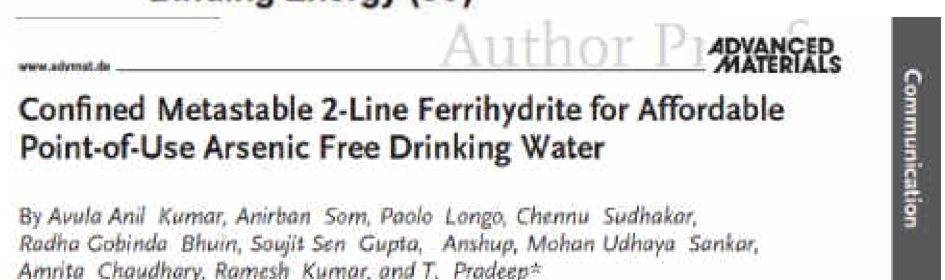


No nanotoxicity



Variety of materials



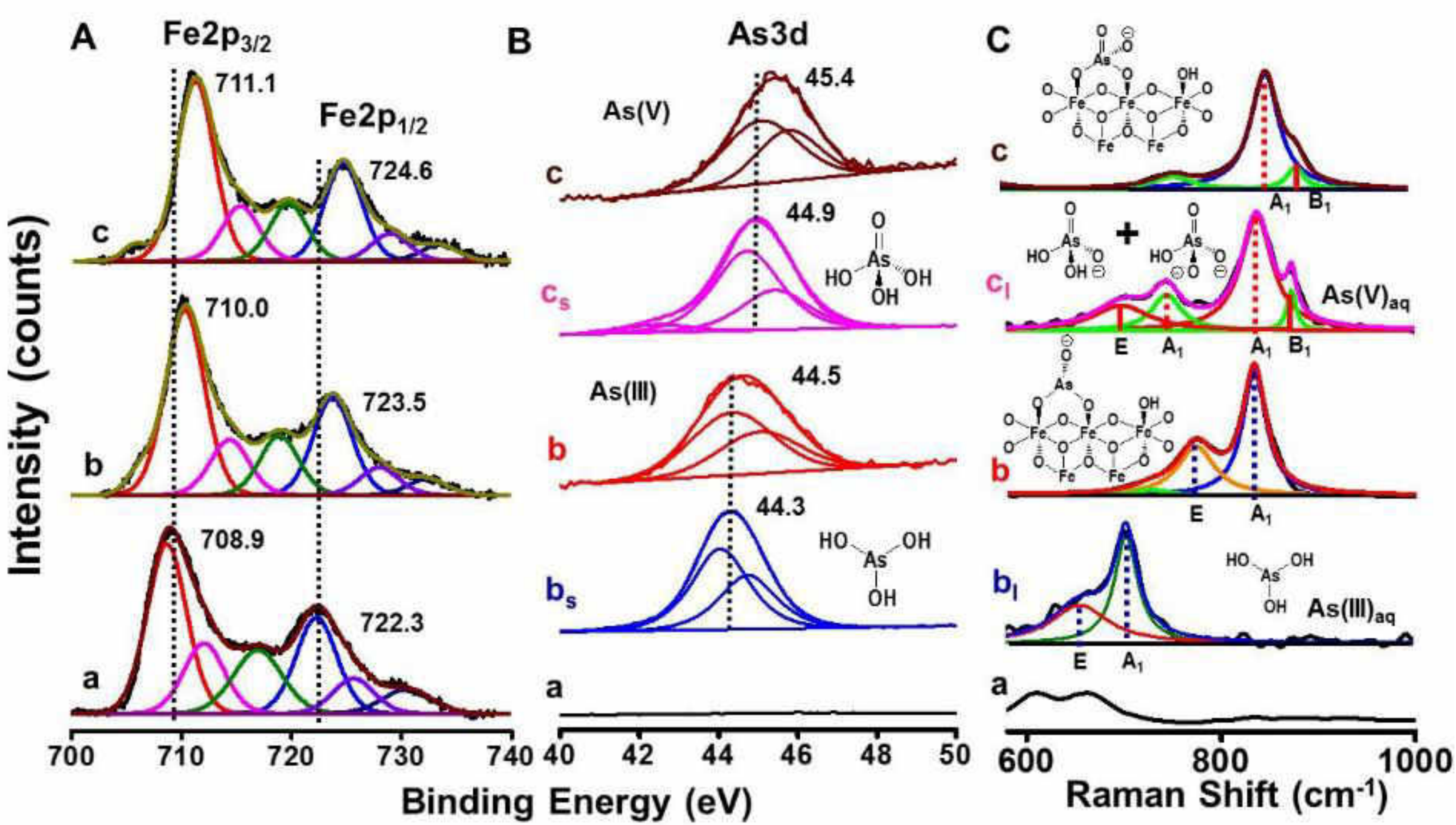

Author Proof
ADVANCED MATERIALS
www.advmat.de
Communication

Confined Metastable 2-Line Ferrihydrite for Affordable Point-of-Use Arsenic Free Drinking Water

By Avula Anil Kumar, Anirban Som, Paolo Longo, Chennu Sudhakar, Radha Gobinda Bhuin, Soujit Sen Gupta, Anshup, Mohan Udhaya Sankar, Amrita Chaudhary, Ramesh Kumar, and T. Pradeep*

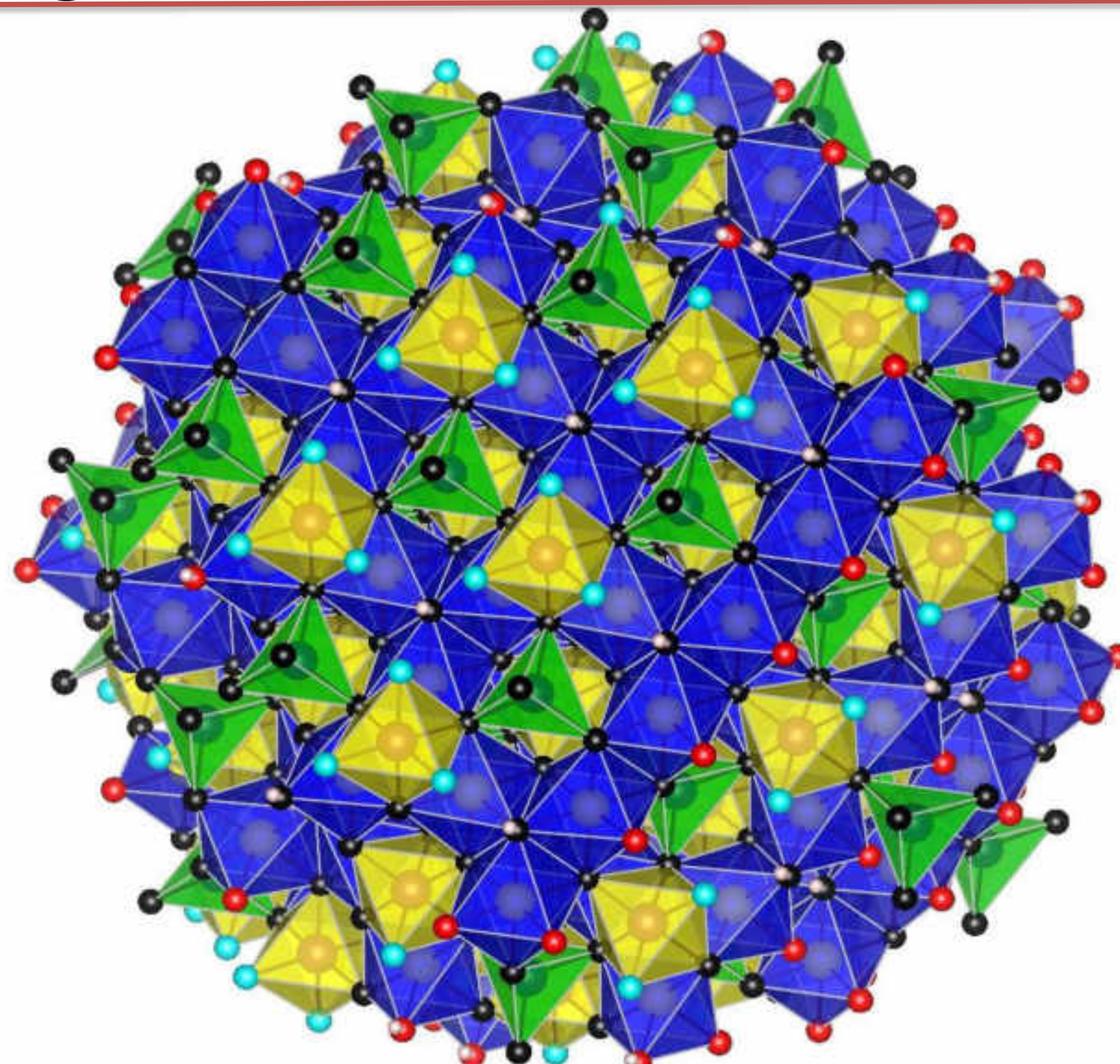
A. Anil Kumar, et. al. *Adv. Mater.*, 29 (2016) 1604260.

Mechanism



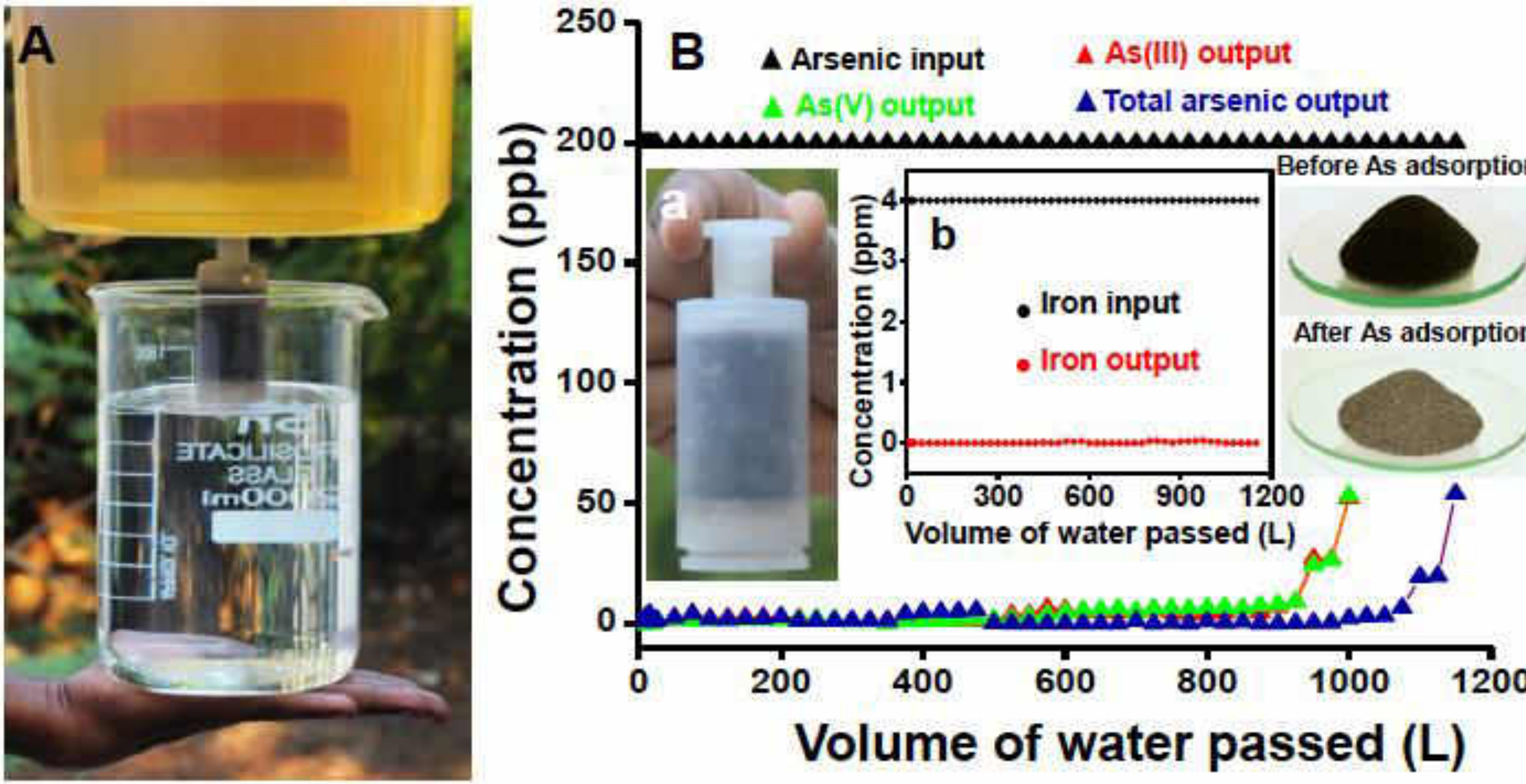
A
Fe2p3/2
711.1
Fe2p1/2
724.6
710.0
723.5
708.9
722.3
c
b
a
Intensity (counts)
700
710
720
730
740
B
As3d
As(V)
45.4
c
44.9
cs
As(III)
44.5
b
44.3
bs
a
40
42
44
46
48
50
Binding Energy (eV)
C
c
A1
B1
cl
As(V)aq
E
b
bl
As(III)aq
a
600
800
1000
Raman Shift (cm-1)

Modeling surfaces



Chennu Sudhakar, et al. *ACS Sustainable Chemistry & Engineering*, 6 (2018) 9990-10000.

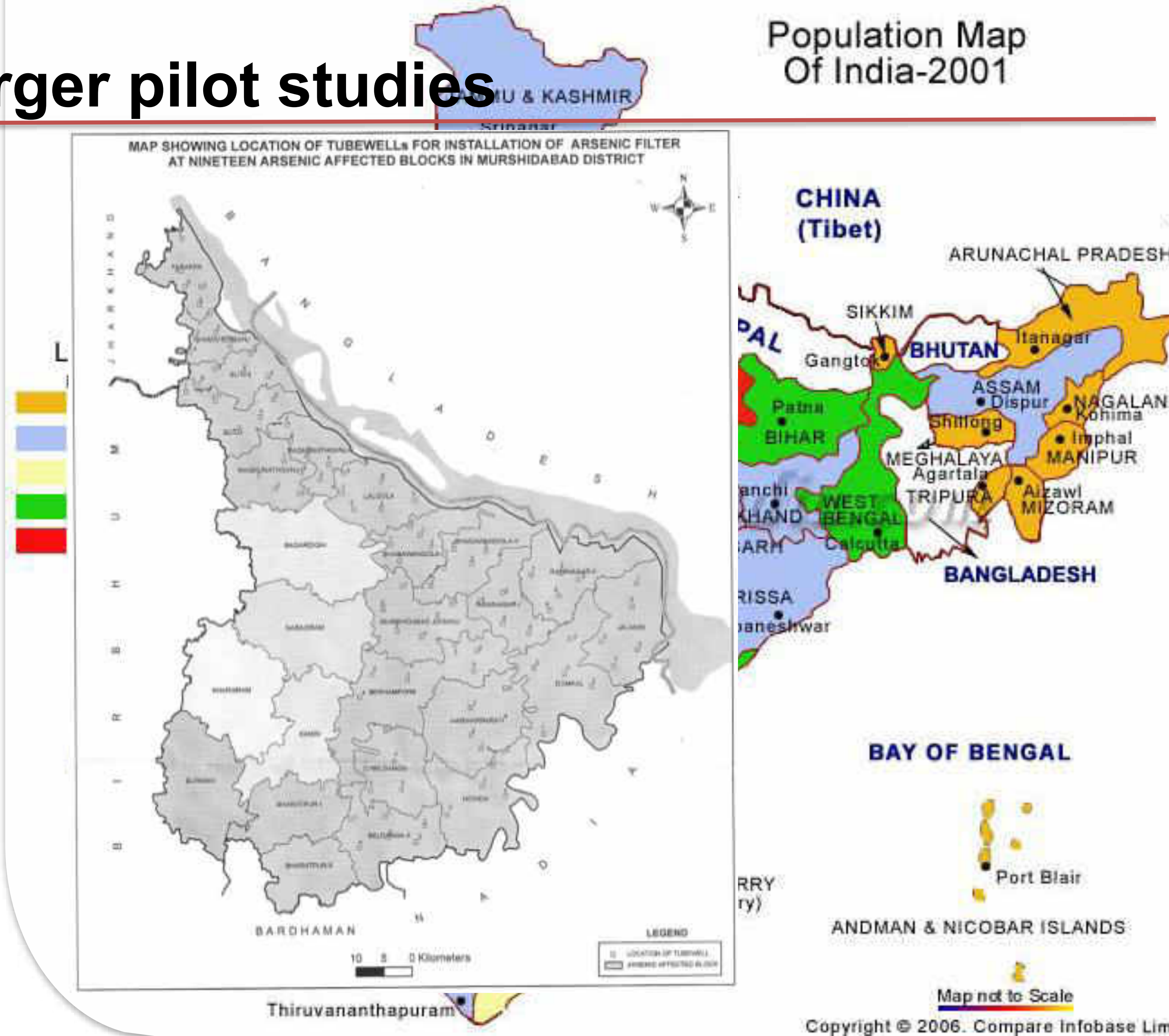
Lab studies



A. Anil Kumar, et. al. *Adv. Mater.*, 29 (2016) 1604260.

Initial pilot studies

Larger pilot studies



Changing the dynamics in the field

- Existing unit for iron and arsenic removal – 20 m^3/h
- Uses activated alumina and iron oxide (old generation of adsorbents)

- Existing unit for iron and arsenic removal – 18 m^3/h
- Uses iron oxyhydroxide (new generation of adsorbents)
- Input arsenic concentration: 168 ppb
- Output arsenic concentration: 2 ppb

Completed 3 years maintenance (stipulated: 2 years) for 330 bamboo unit project in Nadia, WB

Minimum uptime: 91%, Maximum: 98%
Only 4/330 have reported arsenic above 10 ppb
Benefiting over 100,000 children and villagers

Glimpse of Installed units (330 nos)

Implementation - From 25 KLD to 1 MLD

Large water supply schemes
Capacity: above 1 MLD

5 schemes in use across India

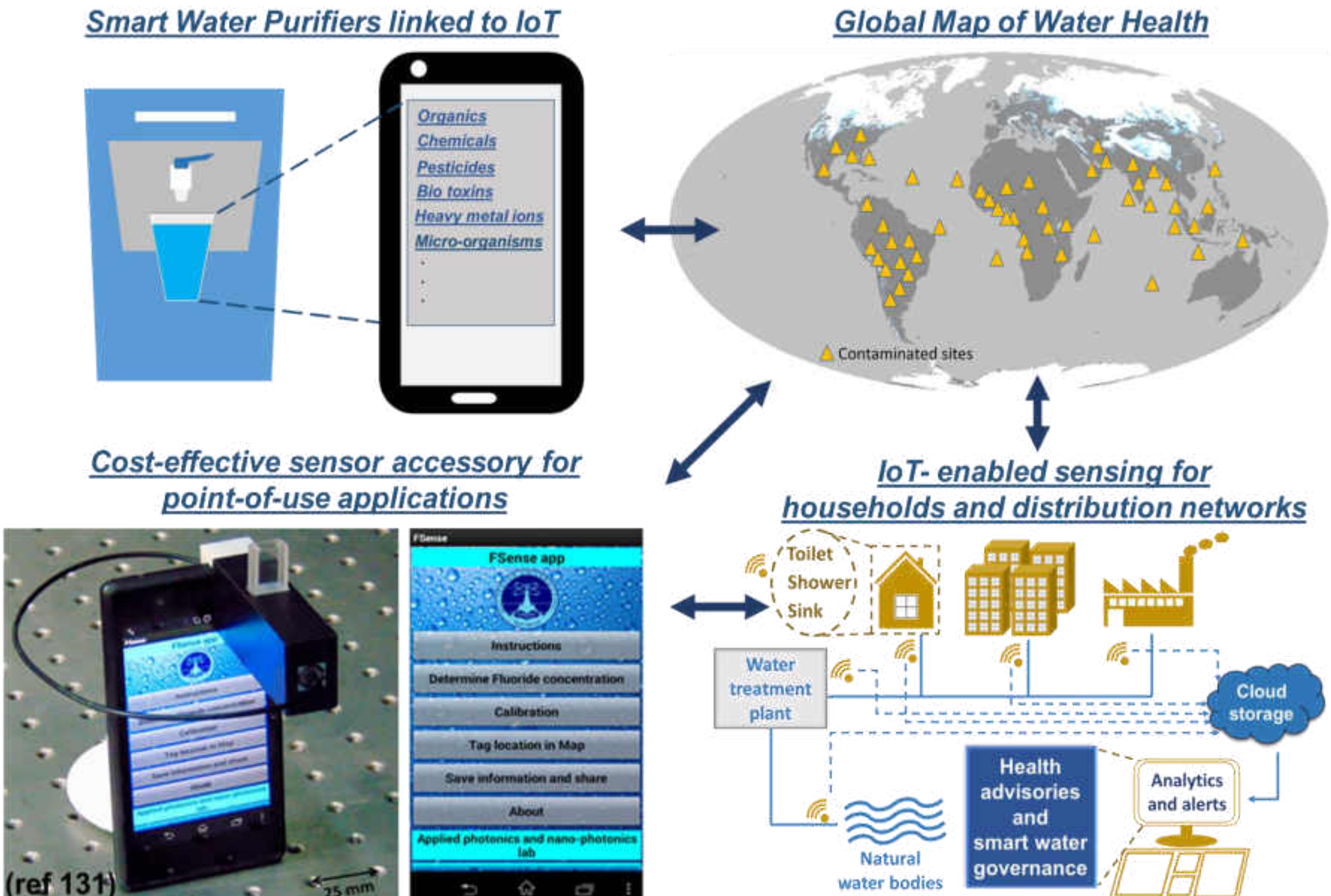
Retrofitted Water Purification Plant
Capacity: 0.1-1 MLD

Over 180 units in use across India

Cleanwater at 2.1 paise per litre!

Calculation for the Tariff to be collected for treated water (Revision if Required)			
	Design population	1,071	Plant capacity/70 LPCD
Sr.No.	**Item/Description**	**Cost / Quantity**	**Remarks**
1	Cost of Replacement of Iron removal media	56400	After minimum two years if Iron concentration is more than 5 ppm. But iron concentration is more than 5 ppm at only two to three places. Therefore media may work for 3 years also.
2	Cost of Replacement of Arsenic removal media	978660	After minimum two years if Arsenic concentration is more than 100 ppb. But arsenic concentration is more than 100 ppb at only two to three places. Therefore media may work for 3 years also.
3	Cost of replacement of Activated Carbon	28560	
4	Total cost of Replacement of media	1063620	After minimum two years.
5	Total cost of Replacement of media for one year	531810	
6	Plant capacity	75000	ltr per day
7	Design population	1,071	Plant capacity/70 LPCD
8	Cost per litr of water	2.1 Paise per ltr	0.025 cents
9	Cost of replacement of media	**1.36**	Rs. per head per day =Media replacement cost per year/365/Design population
		40.80	per head per month for 70 LPCD water

Smart water purifiers and big data



Ankit Nagar and T. Pradeep 14(2020). *ACS Nano*, 6420-6435

Waste management

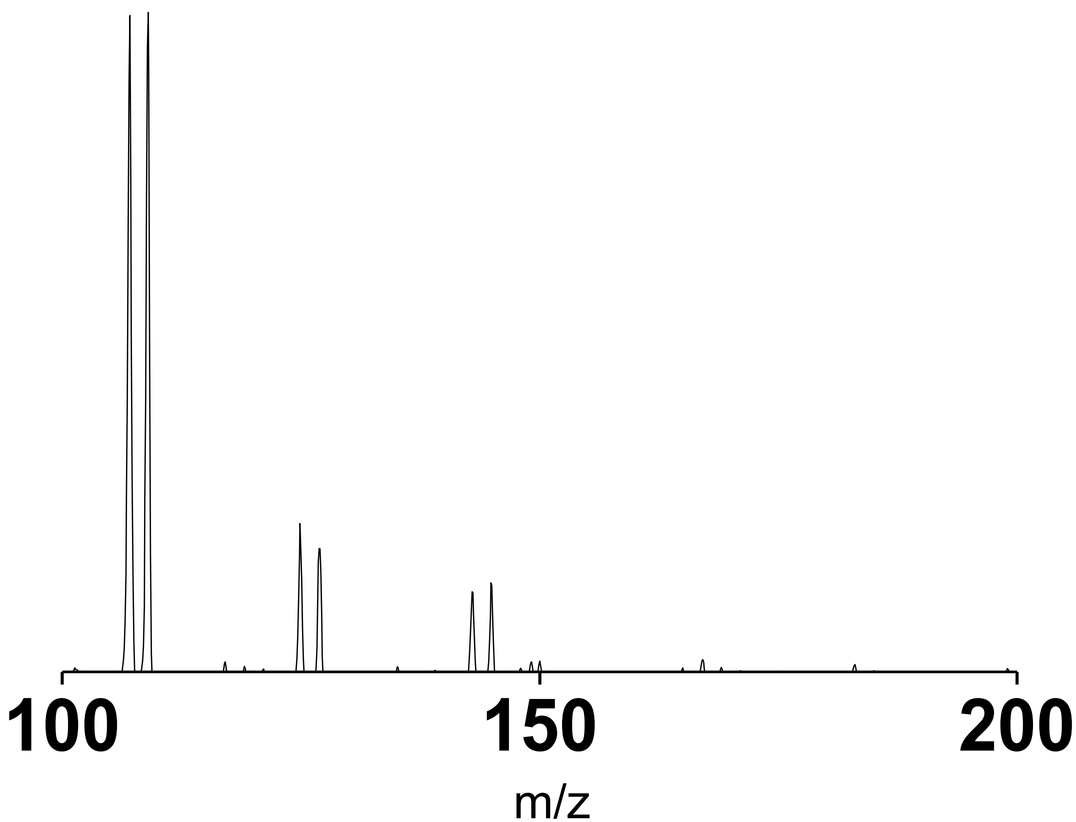
- Adsorbents conform to toxicity characteristic leaching procedure
- Elemental waste goes back to local environment
- Safe disposal of arsenic (or any other) laden waste
- Additional protection could be considered, if necessary
- Exploring viable uses

Across the country

Components of IoT architecture implemented by DWSS, GoP

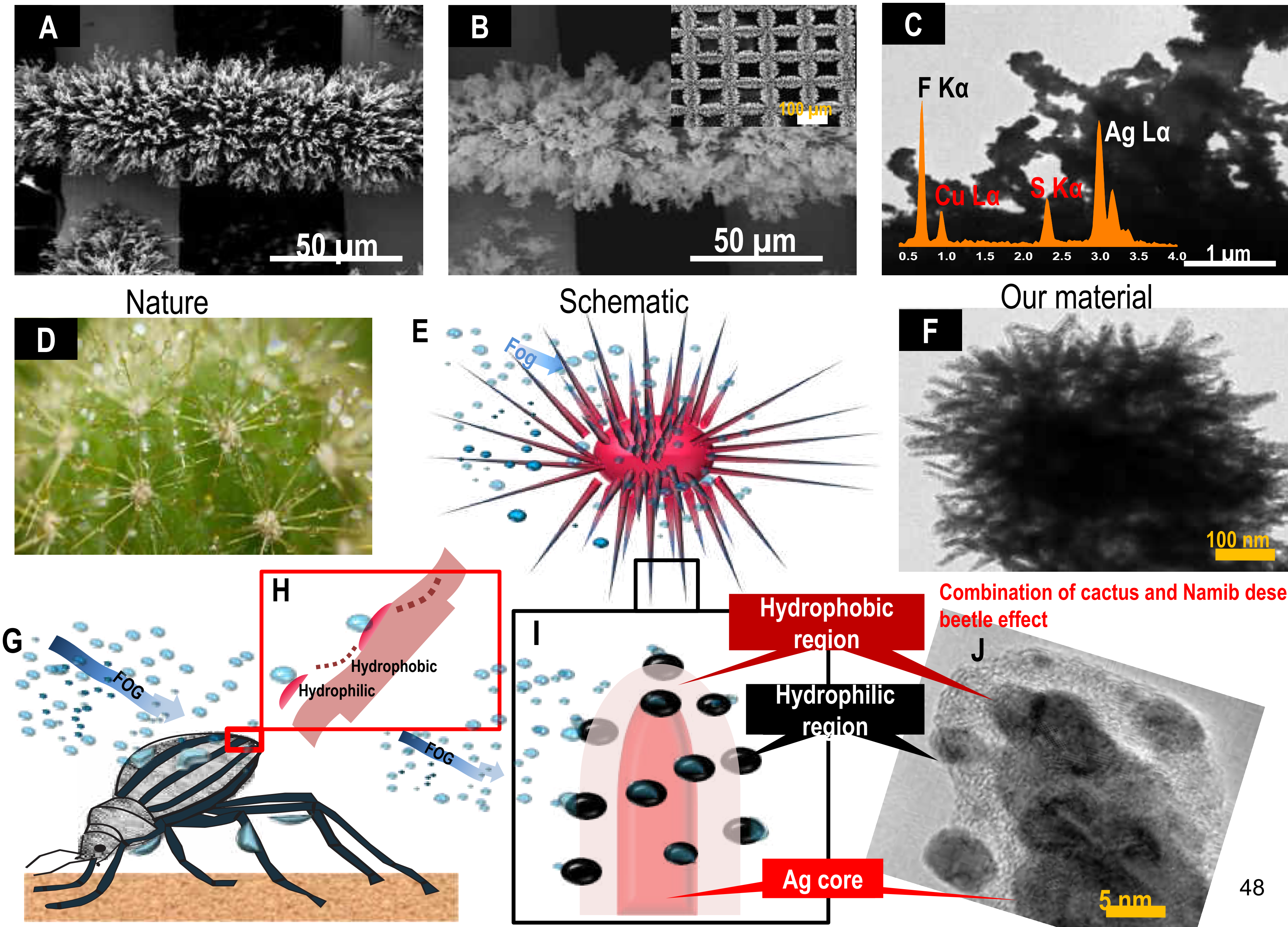
Typical IoT architecture comprises various sensors and meters, communication gateway, Cloud Server, SMS gateway, Webservices and mobile phone application for operator

Atmospheric water harvesting

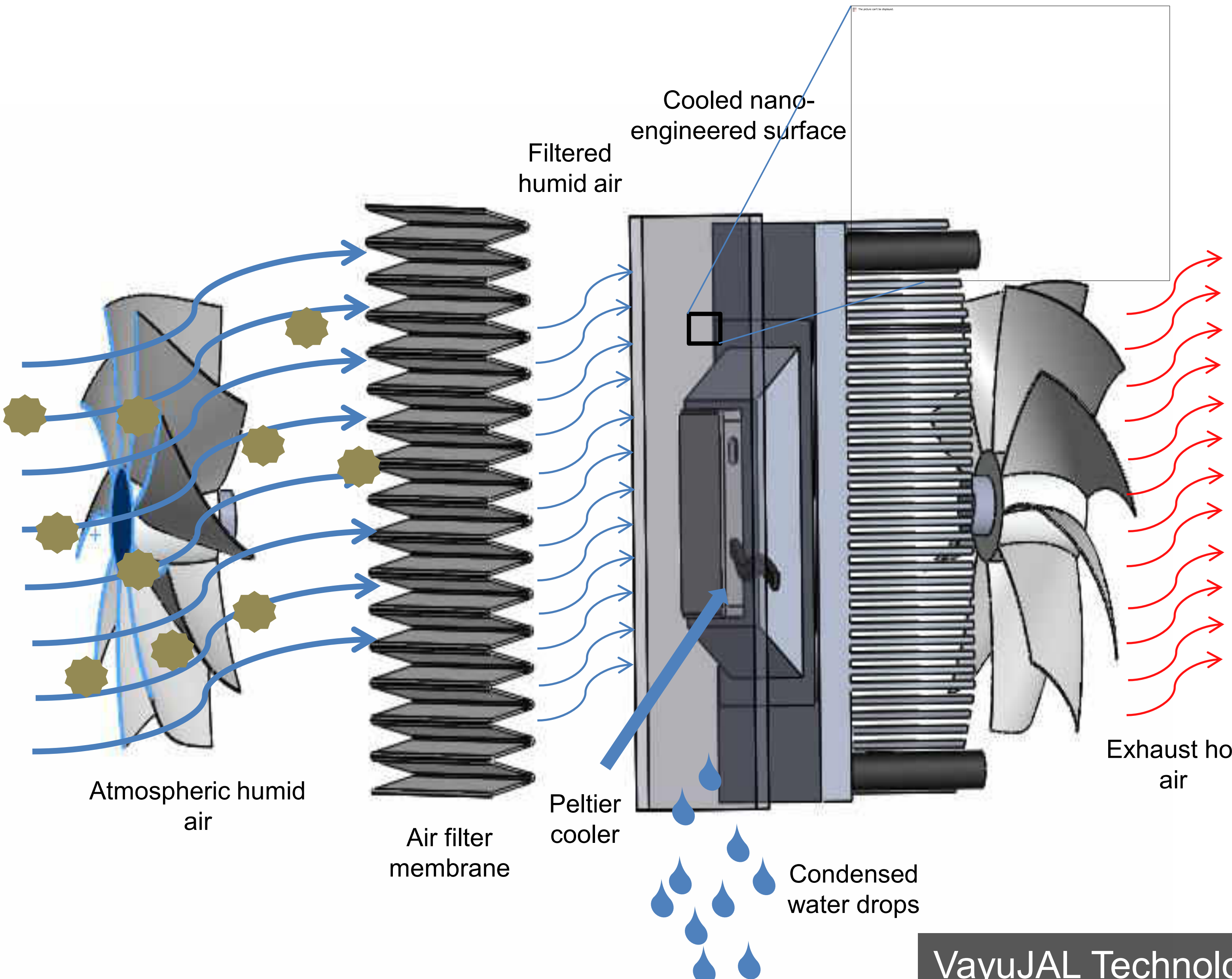


New harvesters

Depanjan Sarkar, et. al. *Advanced Materials*, 28 (11), 2016.



Depanjan Sarkar, et. al. Unpublished.



VayuJAL Technologies Pvt. Ltd.
Ramesh Kumar Soni and Ankit Nagar

Products in the field

35 LPD

120 LPD

400 LPD

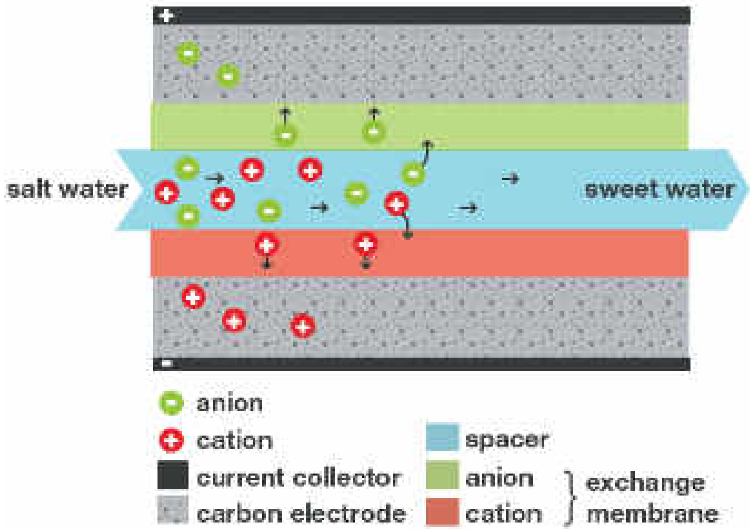
1000 LPD

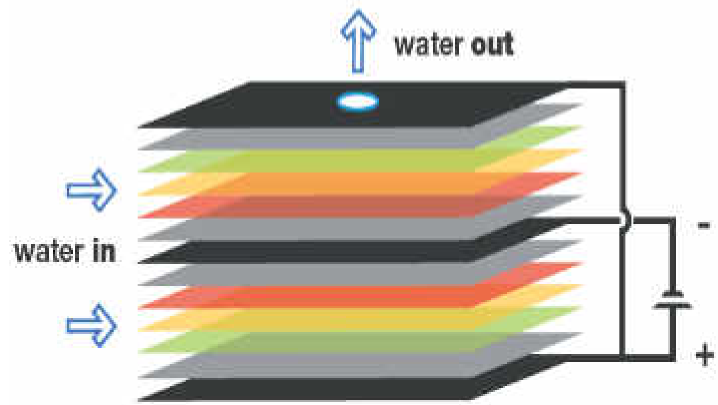
2000 LPD

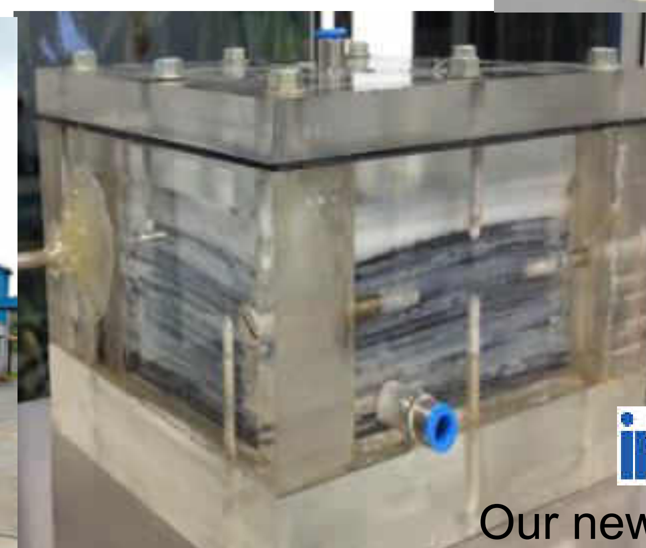
(LPD: Litres per day)

July 2023

Capacitive Desalination (CDI)



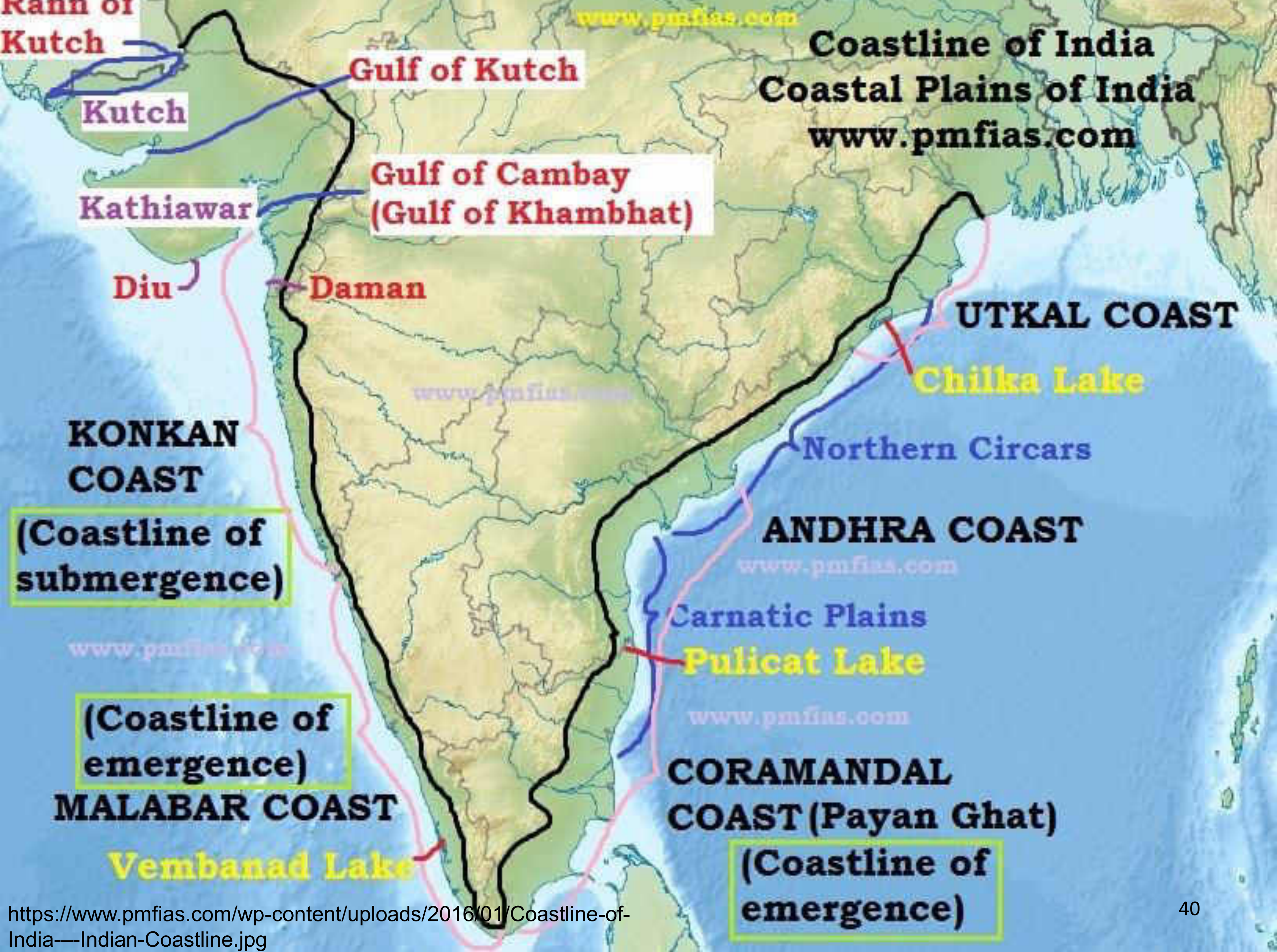




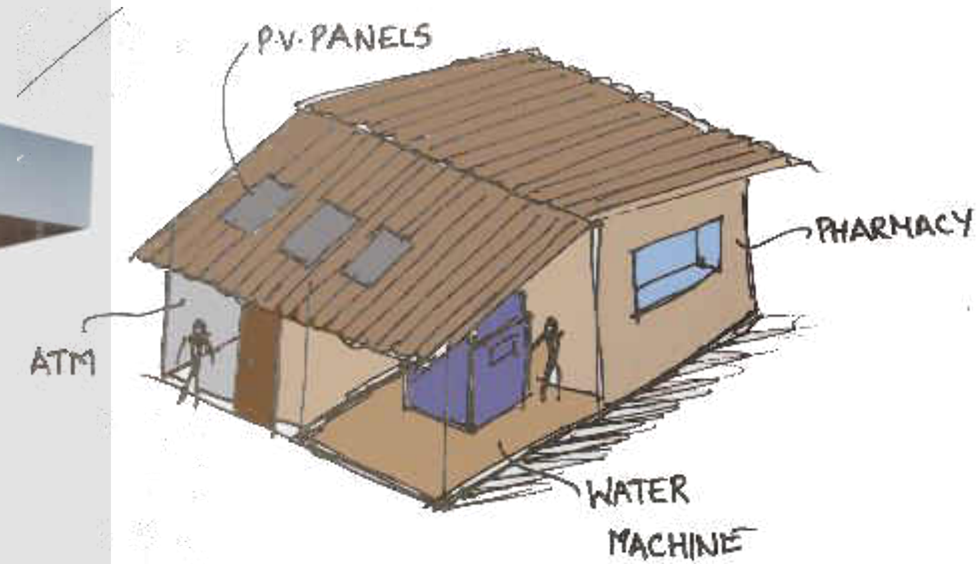
innoDI

Our new company

Soujit Sengupta, Rabiul Islam and others



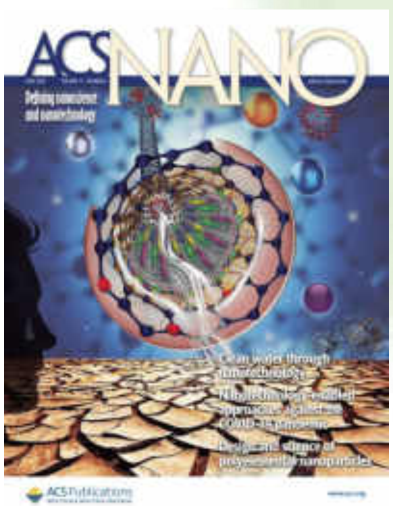
https://www.pmfias.com/wp-content/uploads/2016/01/Coastline-of-India-—-Indian-Coastline.jpg

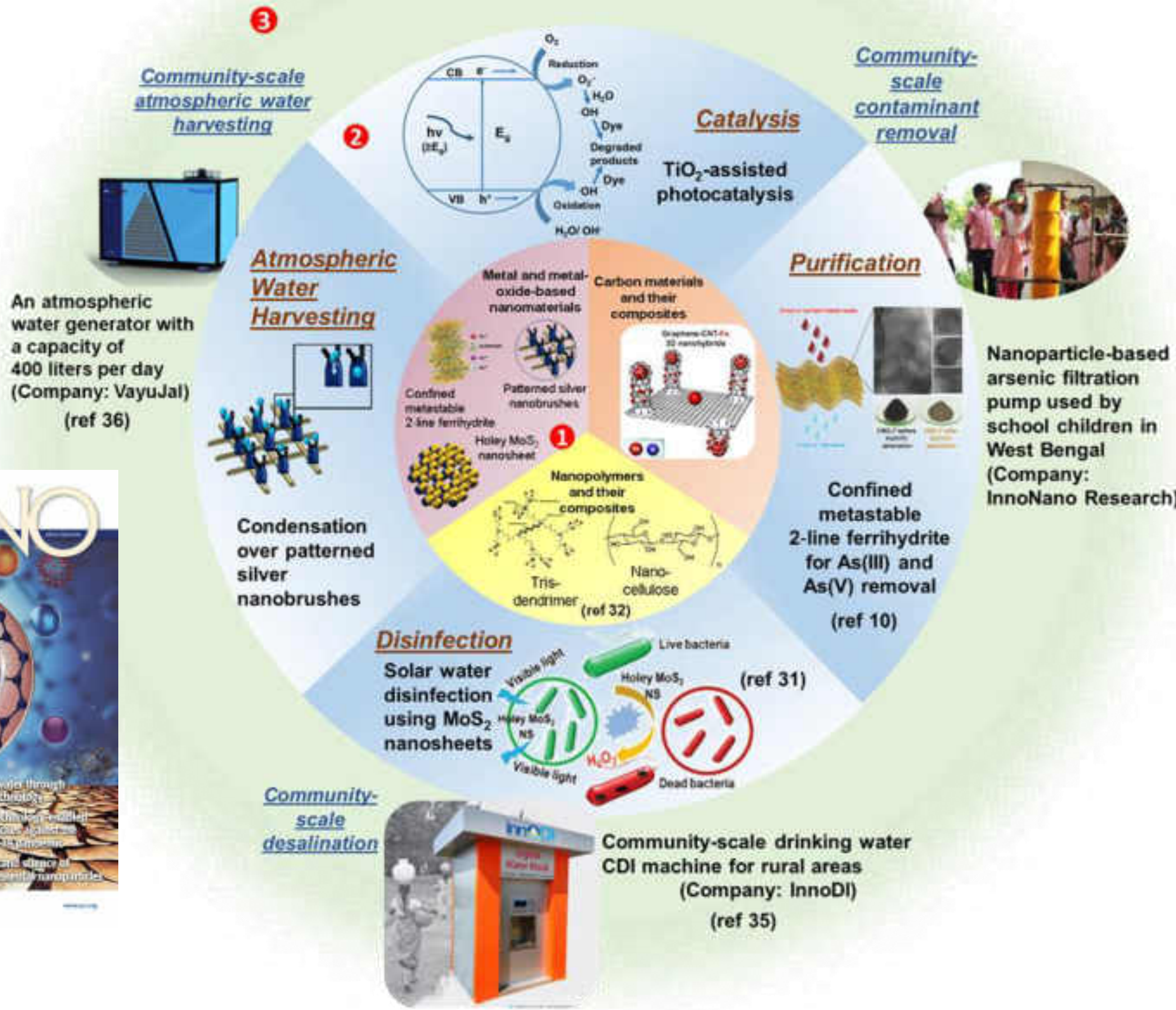


Products under implementation

Vijay Sampath and Tullio Servida

Evolution of materials to products





Ankit Nagar and T. Pradeep 14(2020). *ACS Nano*, 6420-6435

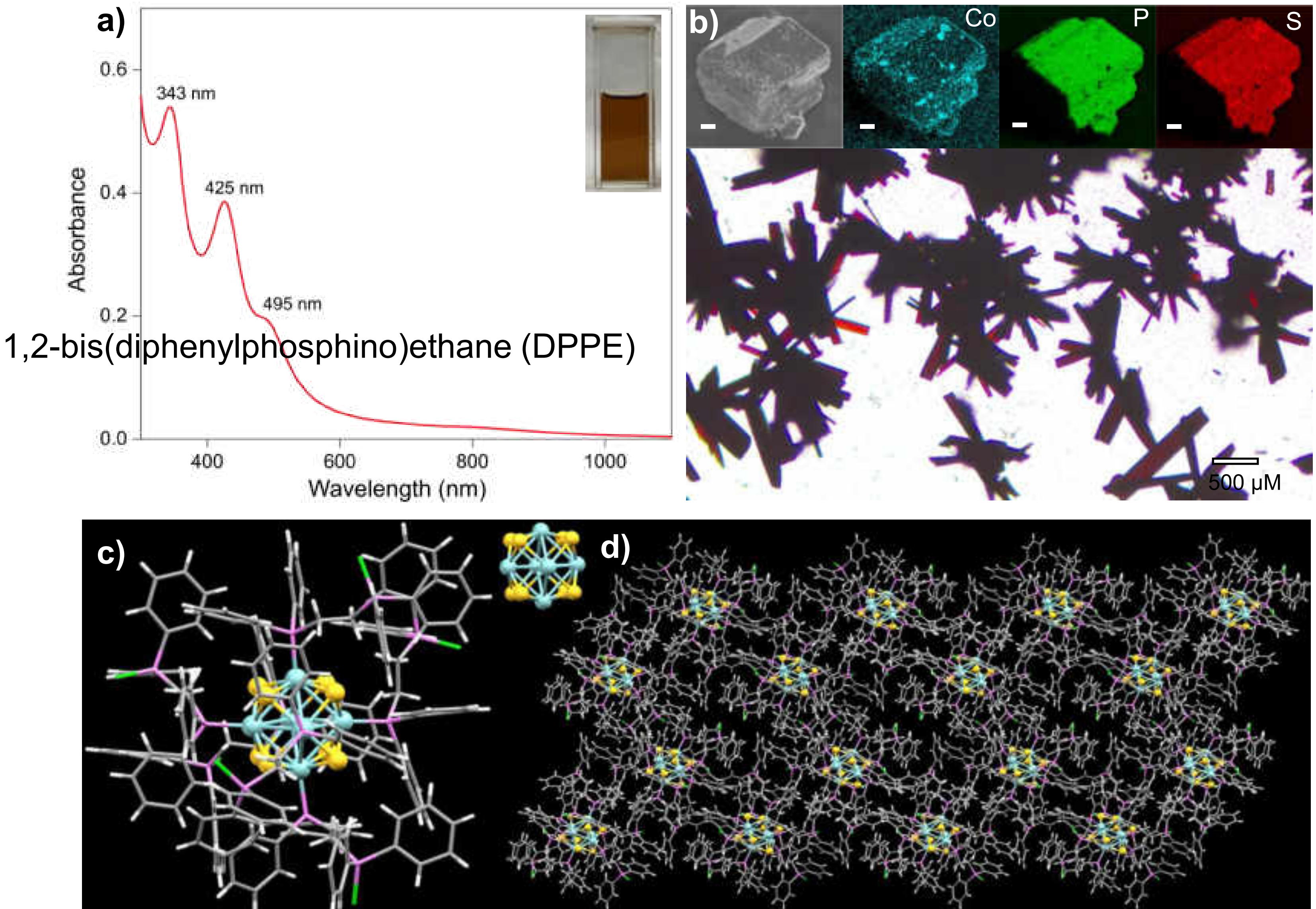
Sensors and new opportunities

Analog/Grating Equipment
$ 5~6 Billion (2017)
a few **100k units (2017)**

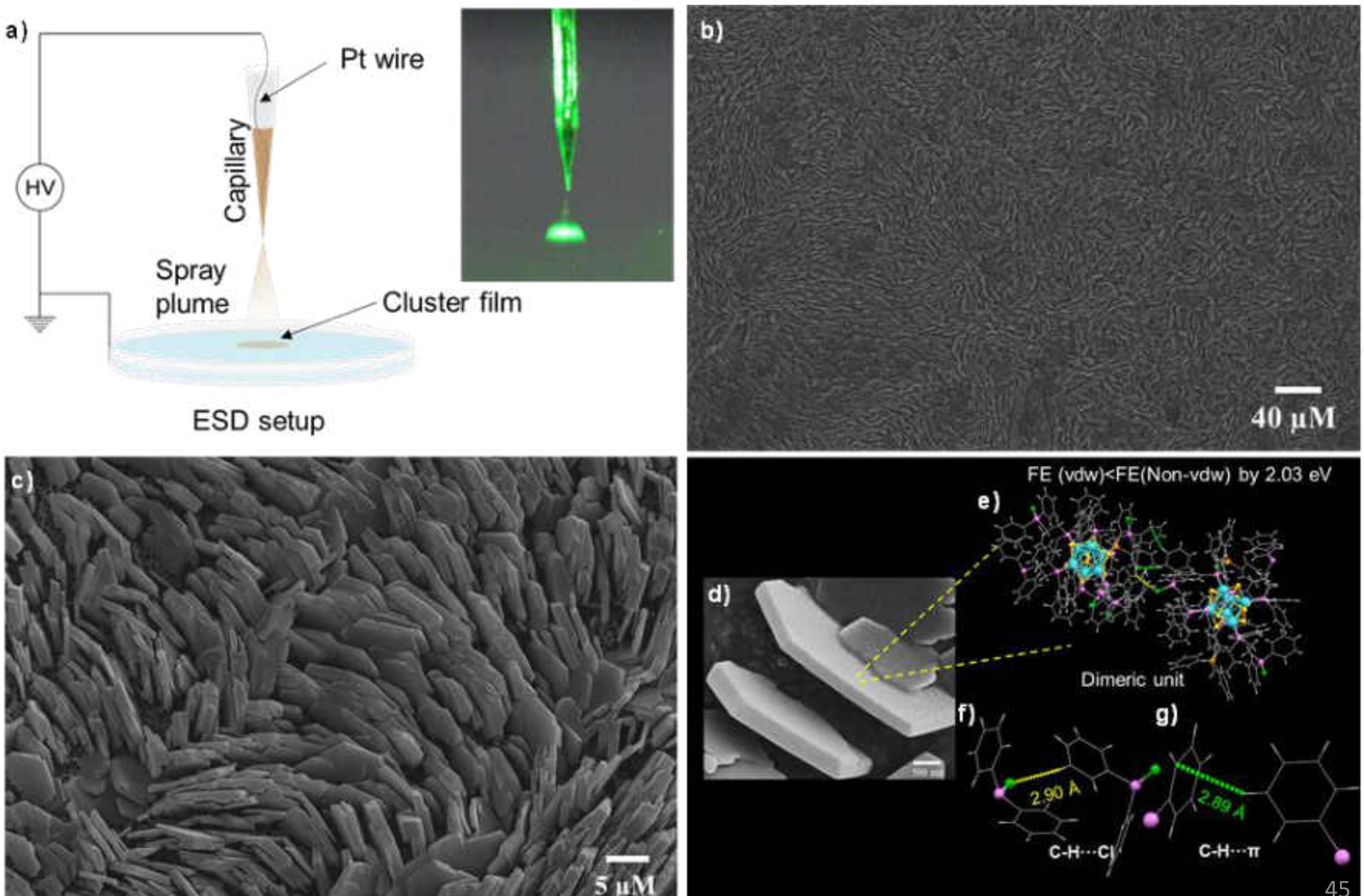
Ultra compact Low Cost Spectral Sensor Module
~ Billions units (? 2027)

Water quality measurement – In the pipeline

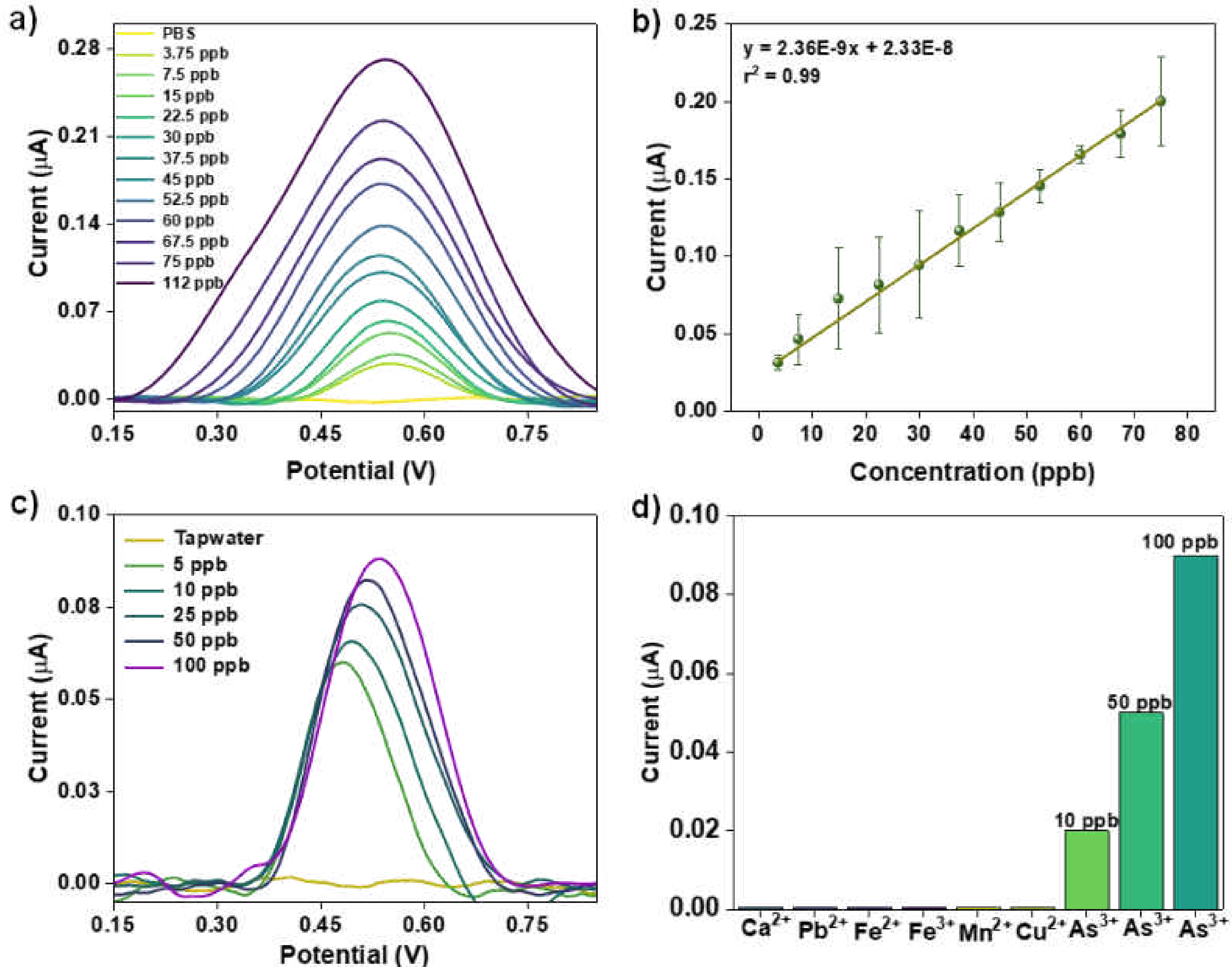
New electrodes - Aligned nanoplates of Co_6S_8



Electrospray deposition

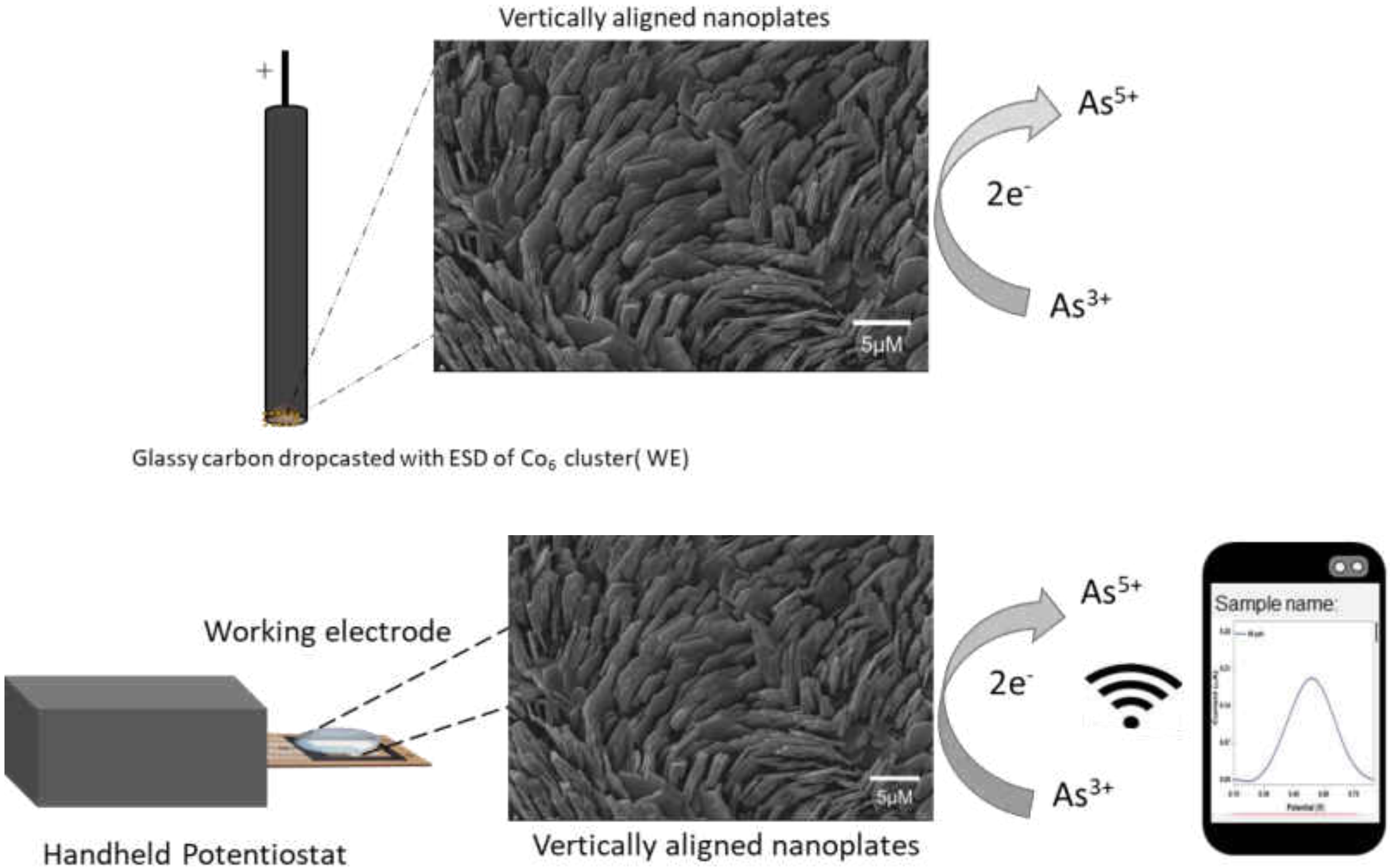


Sensing



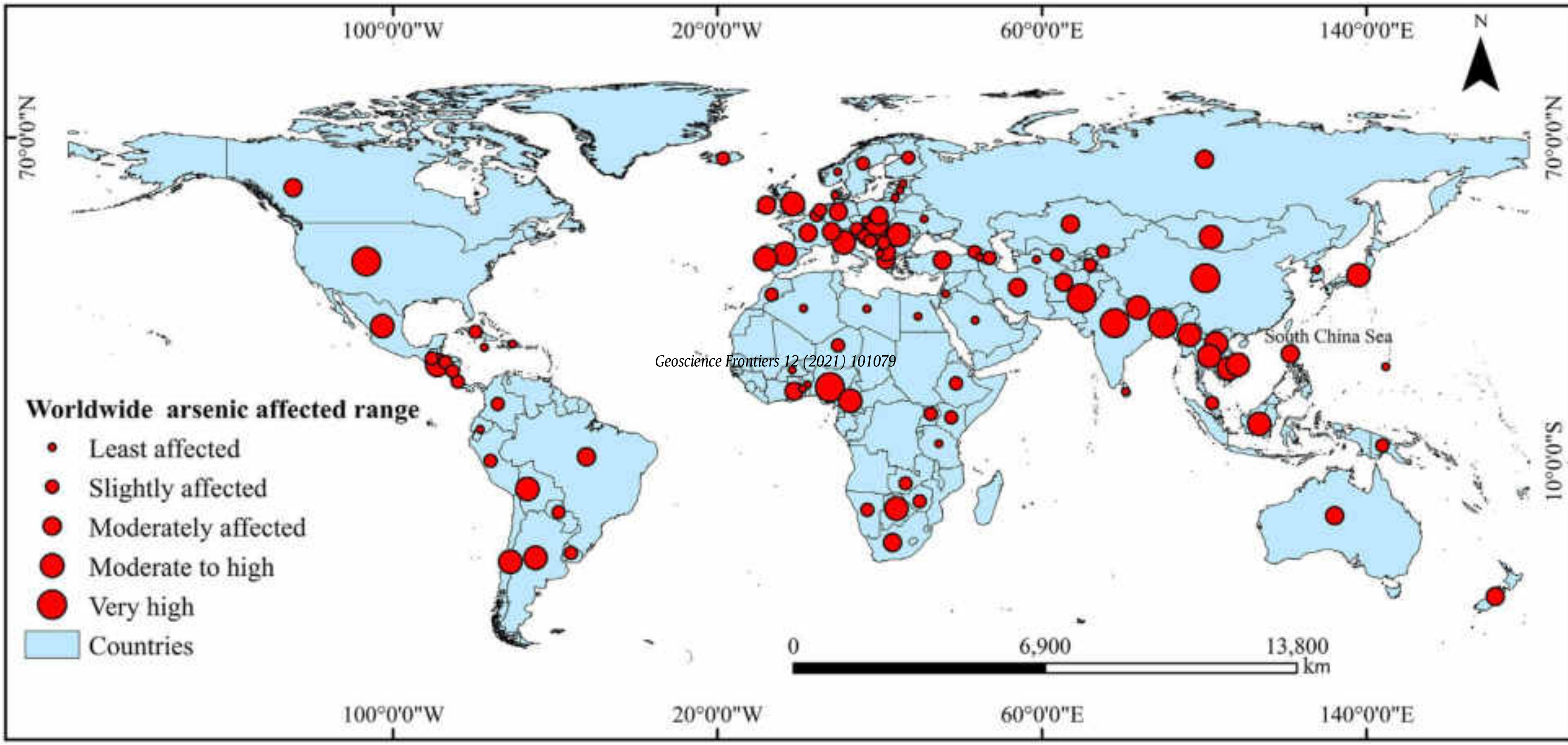
a)
PBS
3.75 ppb
7.5 ppb
15 ppb
22.5 ppb
30 ppb
37.5 ppb
45 ppb
52.5 ppb
60 ppb
67.5 ppb
75 ppb
112 ppb
Current (μA)
Potential (V)
b)
y = 2.36E-9x + 2.33E-8
r² = 0.99
Current (μA)
Concentration (ppb)
c)
Tapwater
5 ppb
10 ppb
25 ppb
50 ppb
100 ppb
Current (μA)
Potential (V)
d)
100 ppb
50 ppb
10 ppb
Current (μA)
Ca²⁺ Pb²⁺ Fe²⁺ Fe³⁺ Mn²⁺ Cu²⁺ As³⁺ As³⁺ As³⁺

Working electrode



Anagha Jose et al. *ACS Materials Lett.,* 5 (2023) 893–899.

Arsenic poisoning across the world



E. Shaji, M. Santosh, K. V. Sarath, Pranav Prakash, V. Deepch and B. V. Divya, Geoscience Frontiers, 12 (2021) 101079.

Monitoring in the field

EyeNetAqua Solutions Pvt. Ltd.
An ICCW incubated company

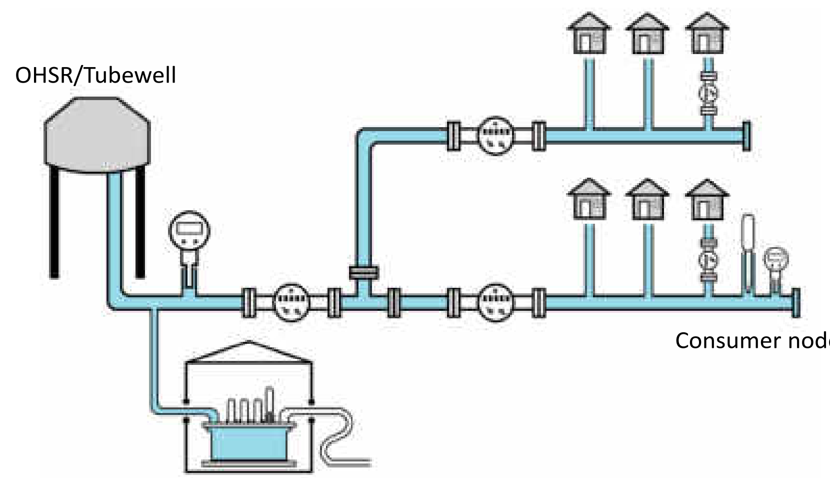
Eye of internet on quality, quantity and compliance for all

EyeNetAqua Solutions Private Limited

Installation model as per NJJM specifications

Tubewell/OHSR (Source node):

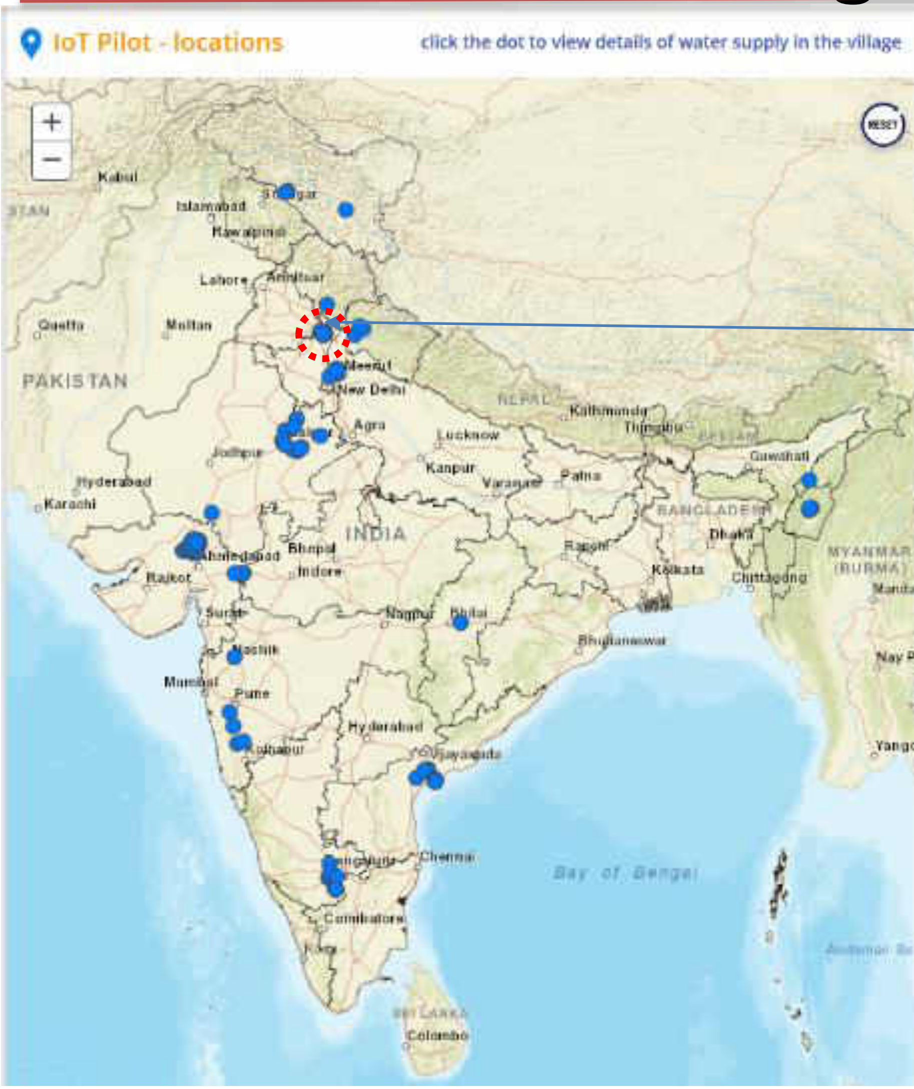
1. Flow meter (80-150mm) x 1
2. Pressure sensor x 1
3. pH sensor x 1
4. TDS sensor x 1
5. Residual Chlorine sensor x 1
6. In-house MVP of Free Residual Chlorine sensor x 1



Consumer tap (End tail node):

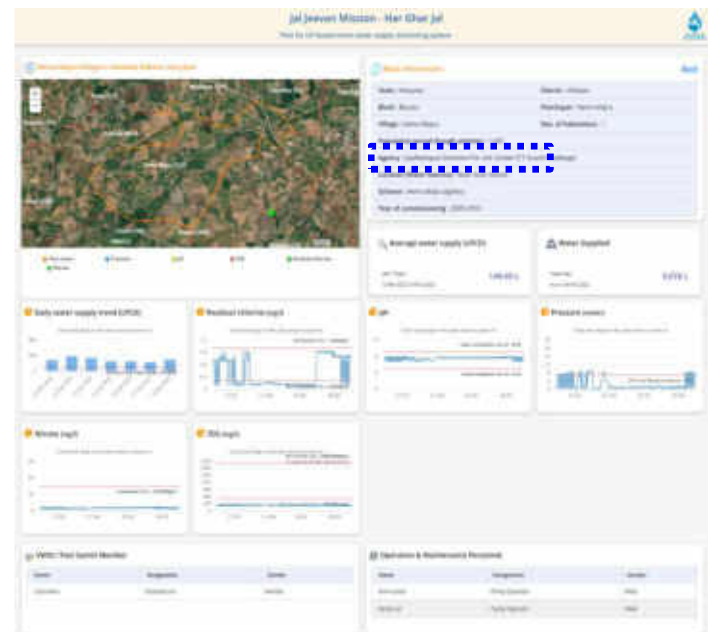
1. Flow meter (15-20mm) x 1
2. Pressure sensor x 1
3. Residual Chlorine sensor x 1
4. In-house MVP of Free Residual Chlorine sensor x 1

India’s water is being monitored



IITM/IISc

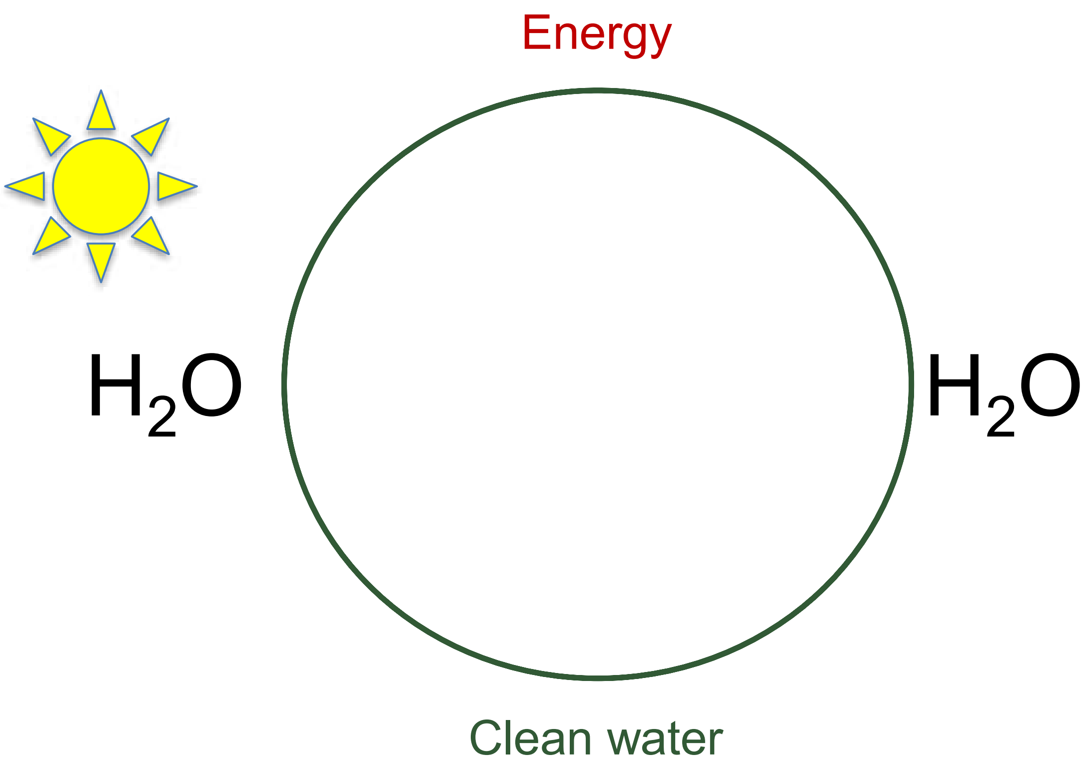
Installations made by four companies

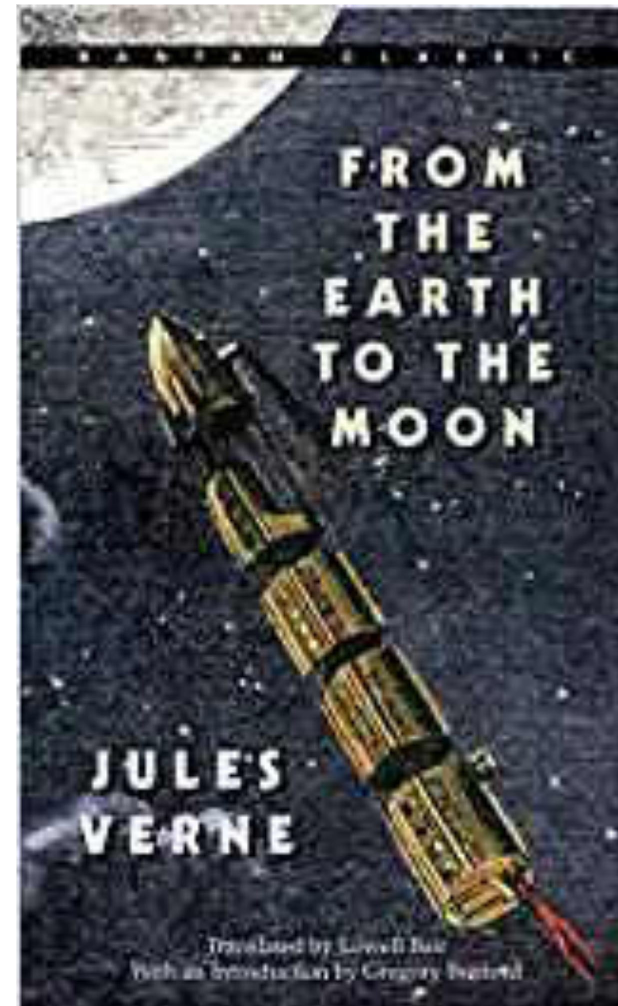



Policy

https://www.youtube.com/watch?v=fiJyptbXBtM

Our dreams become reality with materials





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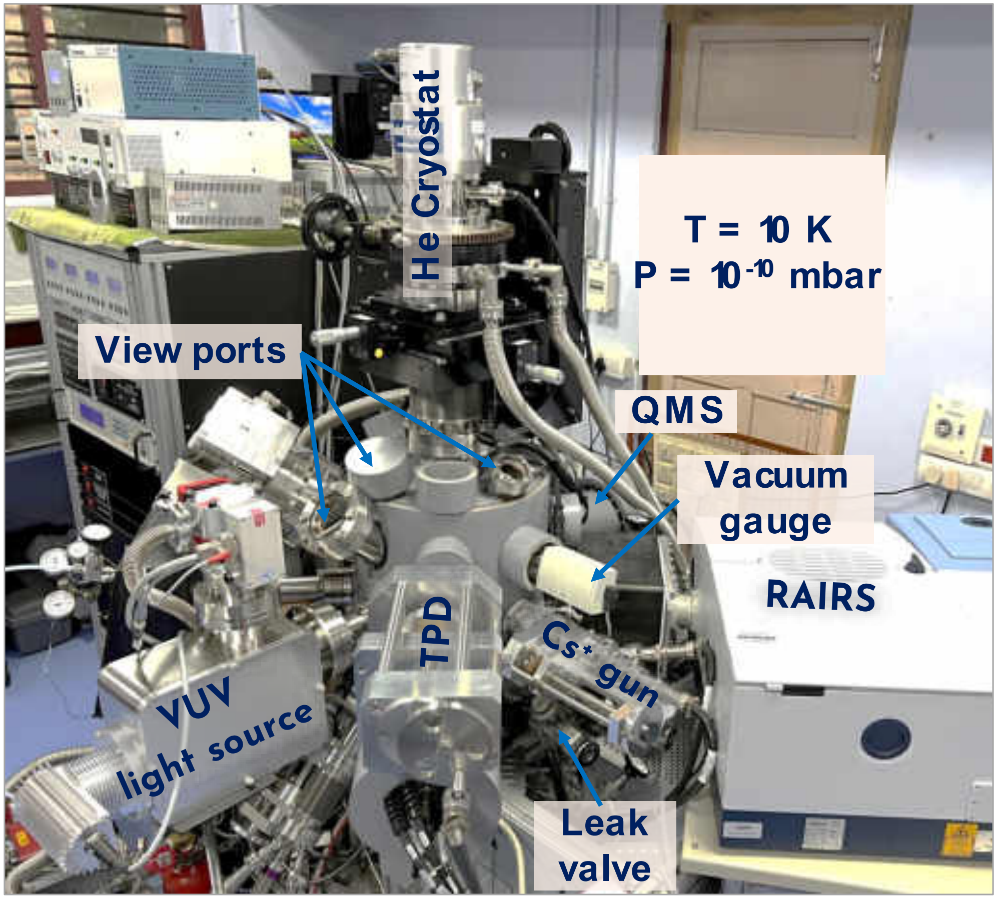
IIT Madras Research Park

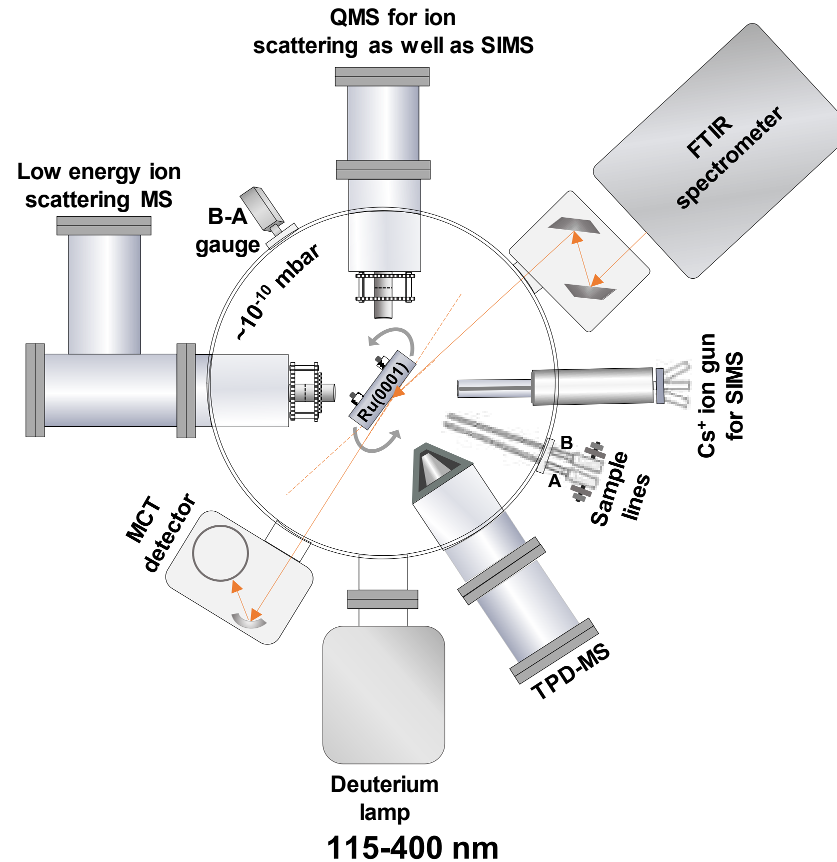
Clathrate hydrates

Ice – why should we care?

- **Ice is big in scale - 10 percent of the land area on Earth is covered with glacial ice. Glacierized areas cover over 15 million square kilometers.**
- **Ice is there everywhere, including in space - naturally**
- **Ice could be a vehicle for life on Earth - astrobiology**
- **Ice can make clathrates**
- **Water is not understood – especially in its condensed form**
- **Condensed molecular solids are all ices**

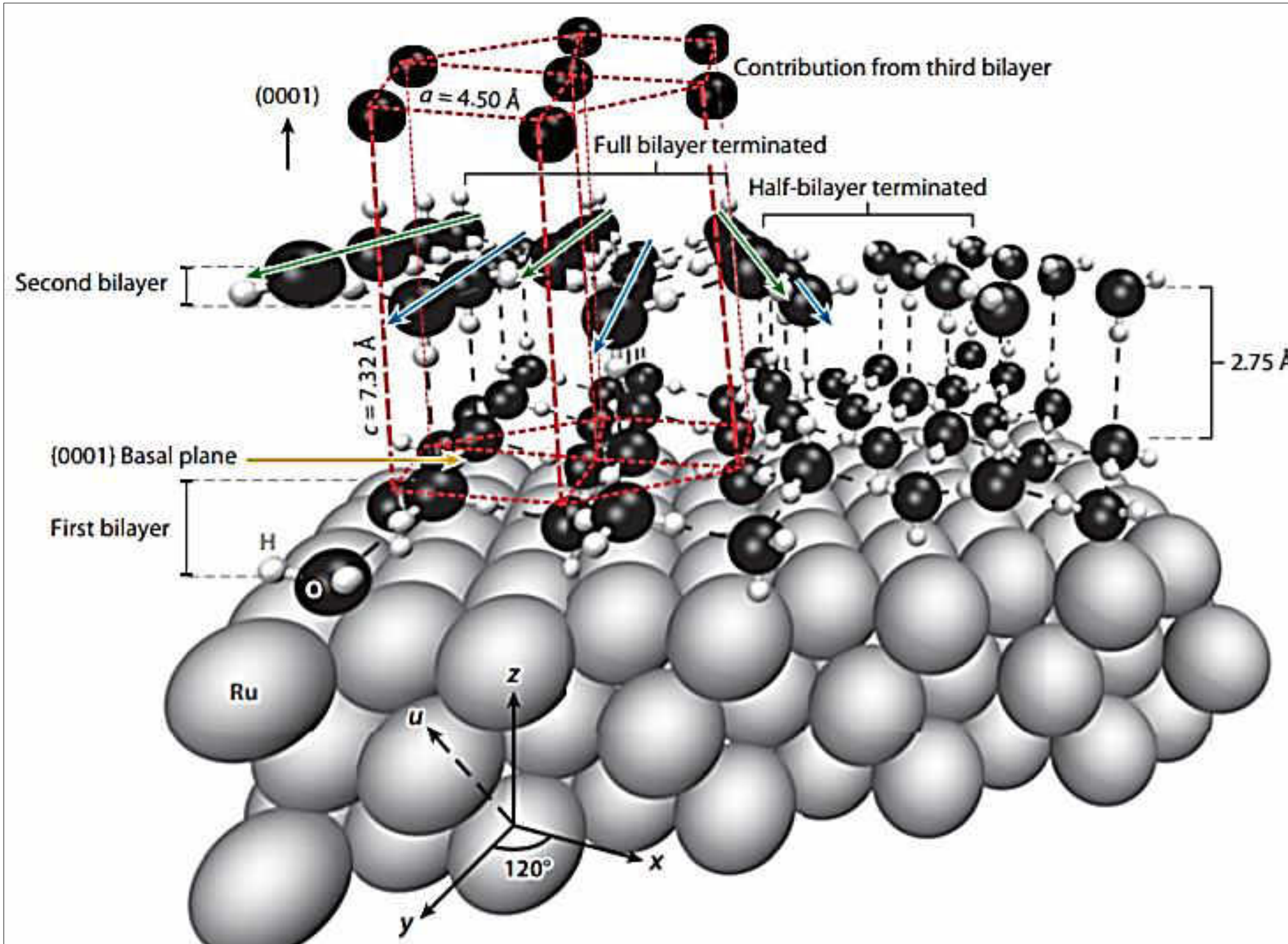
Instrumentation





Bag, S. *et al*., *Rev. Sci. Instrum.* **2014**, *85*, 014103/1-014103/7

Viswakarma, *G. et al., J. Phys. Chem. Lett.*, **2023**, *14*, 2823–2829



Bag, S. *et al.*, *Annu. Rev. Anal. Chem.* **2013**, *6*, 97–118

Instrumentation

ACCOUNTS
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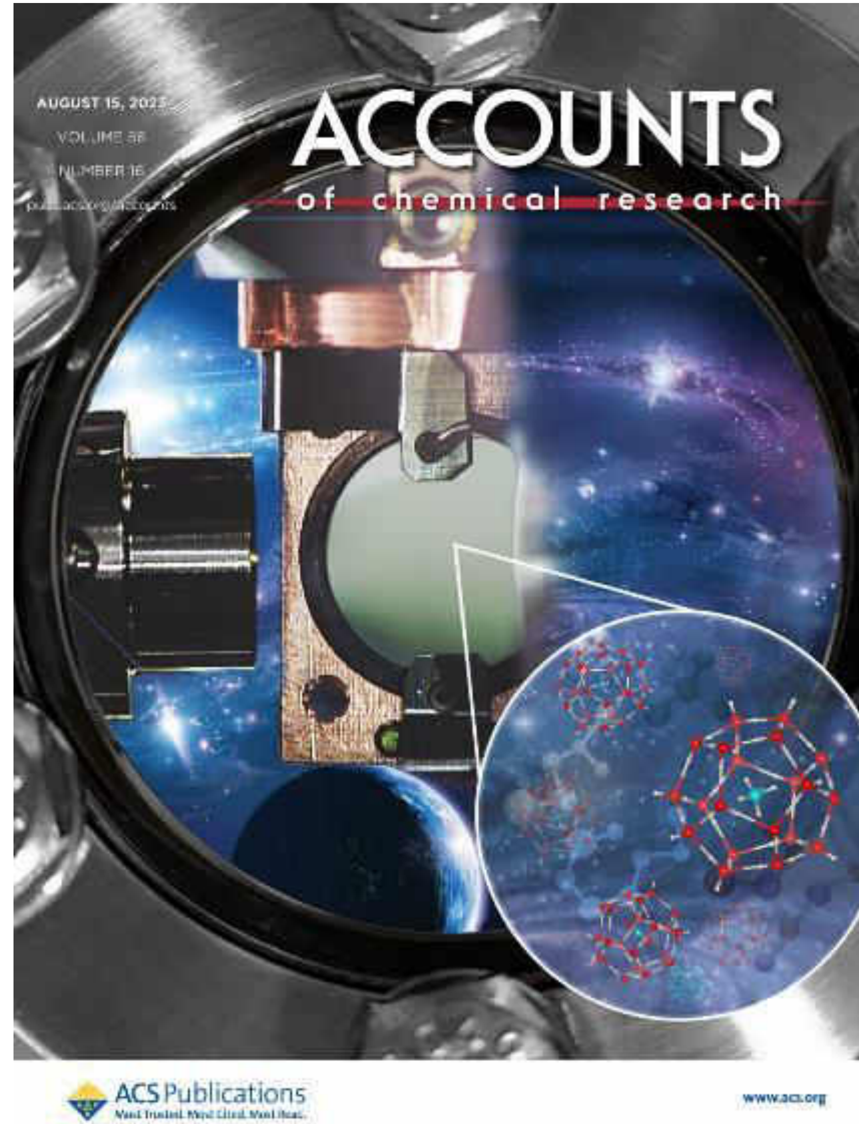
Formation and Transformation of Clathrate Hydrates under Interstellar Conditions

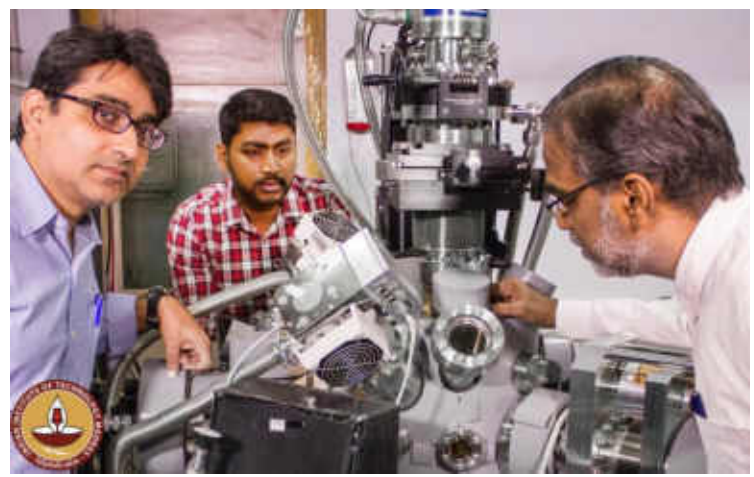
Jyotirmoy Ghosh, Gaurav Vishwakarma, Rajnish Kumar,* and Thalappil Pradeep*

Cite This: https://doi.org/10.1021/acs.accounts.3c00317 Read Online

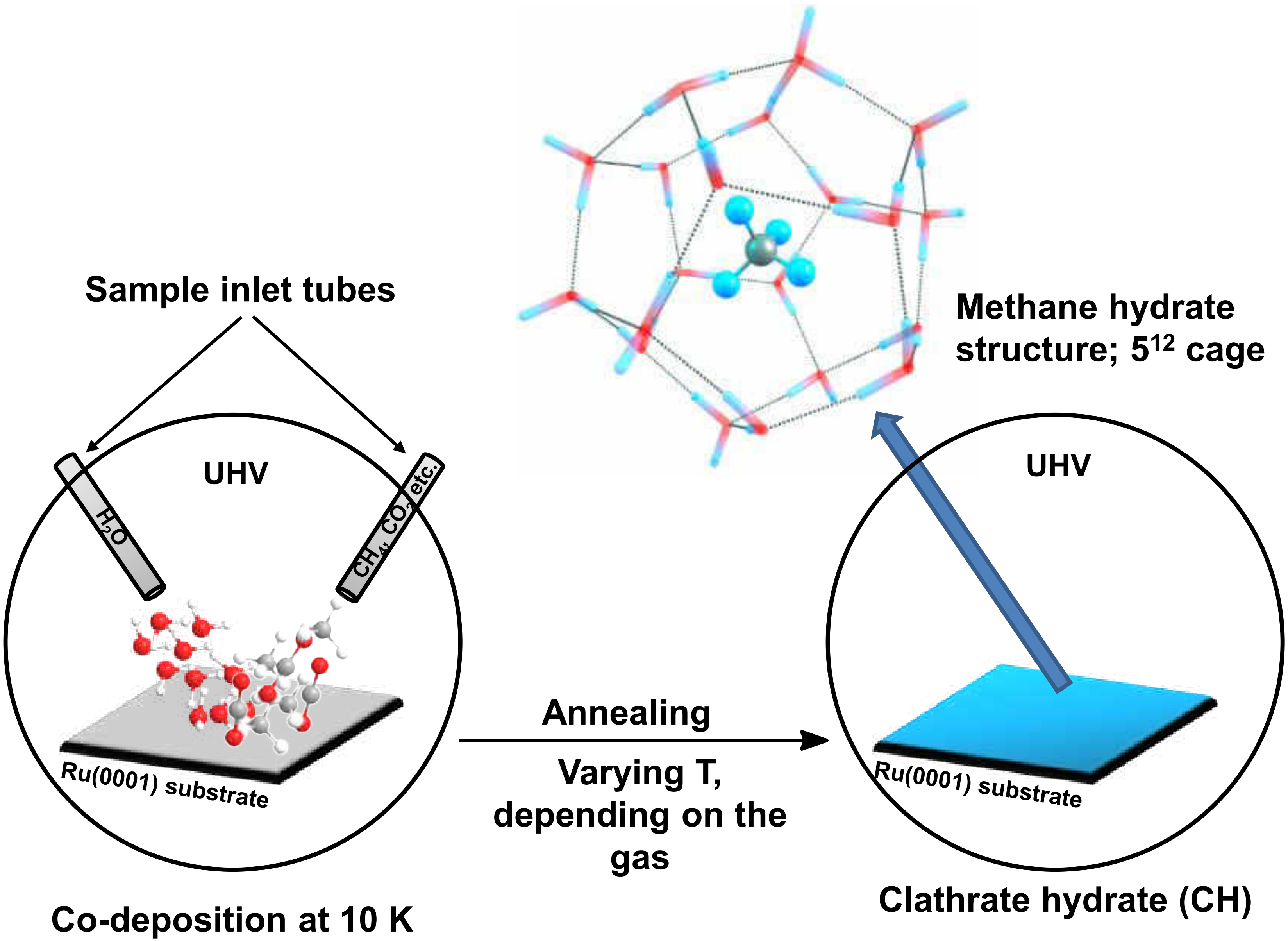


Clathrate hydrates in interstellar environment

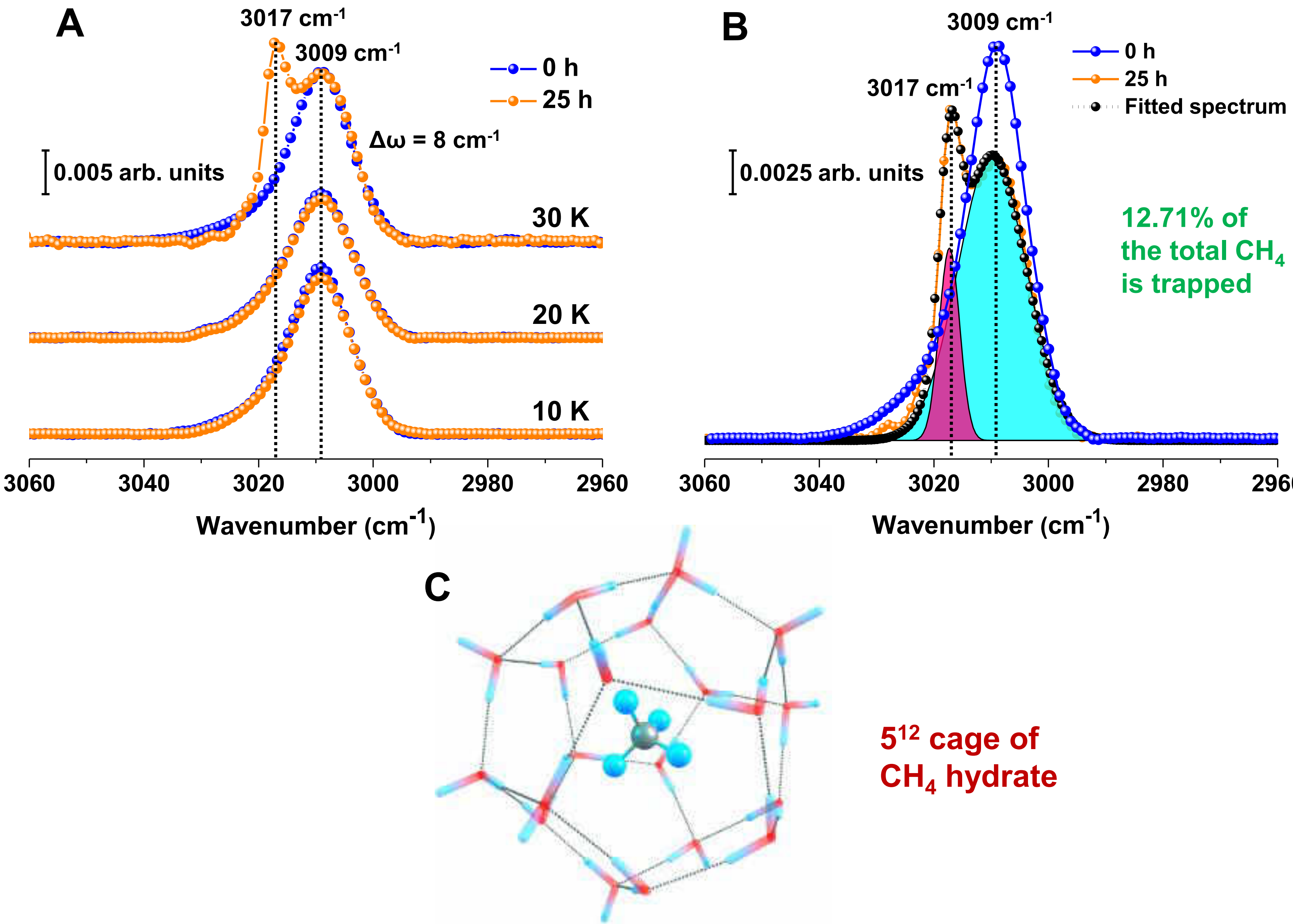
Ghosh, J. *et al., Proc. Natl. Acad. Sci. U.S.A.*, **2019**, *116*, 1526-1531



Experimental method



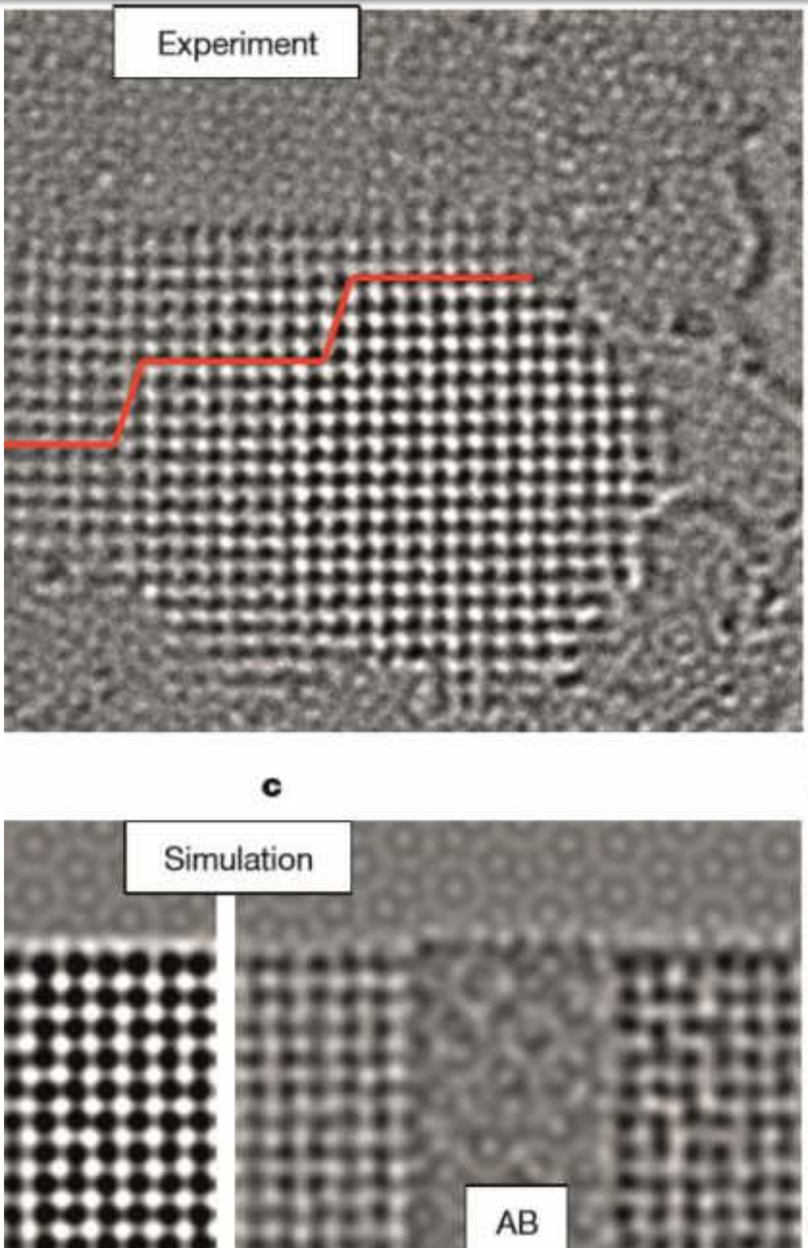
Clathrate hydrates in interstellar environment

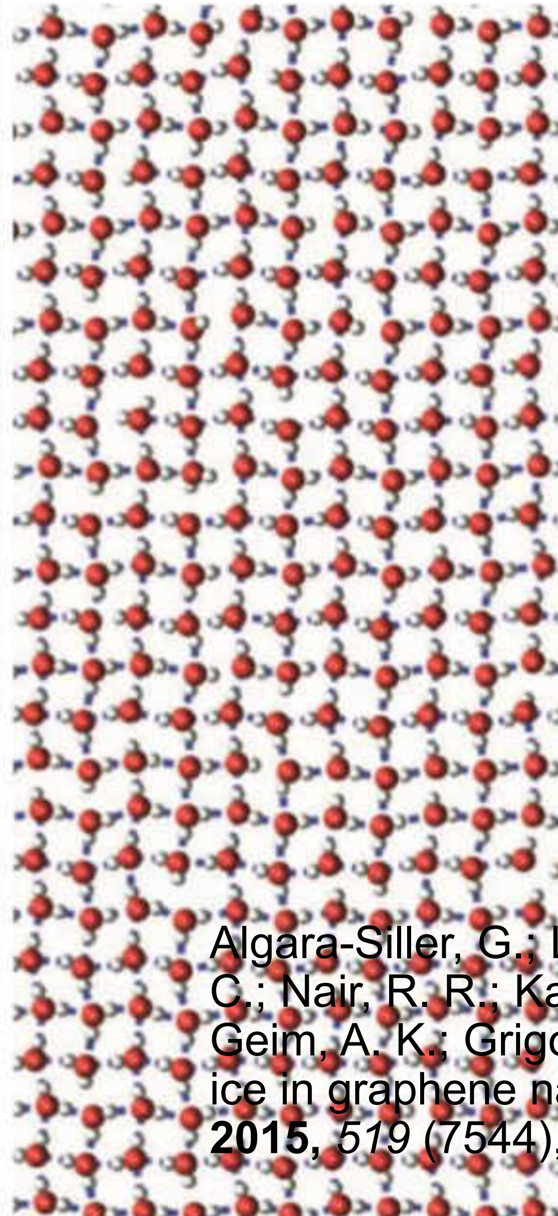


Ghosh, J. *et al., Proc. Natl. Acad. Sci. U.S.A.* **2019**, *116*, 1526-1531

Future

Observing clathrate hydrates?

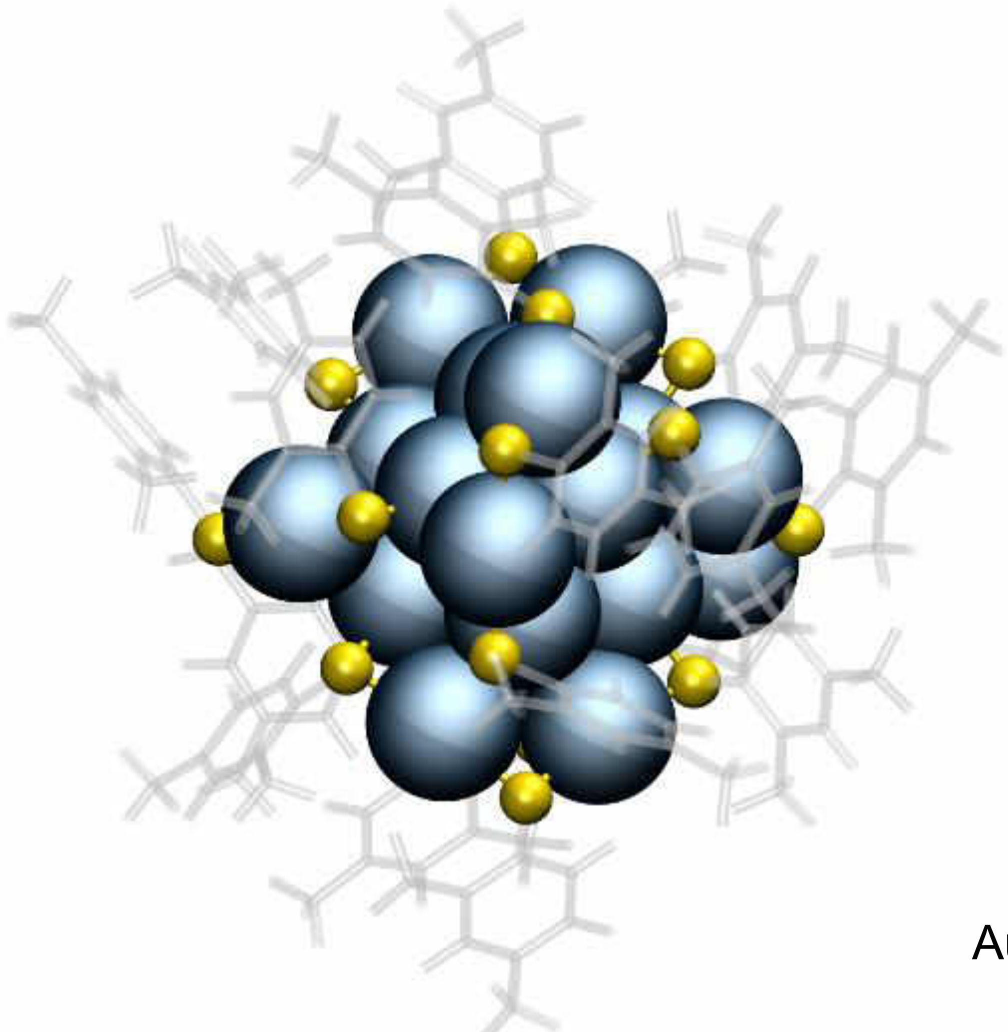




Algara-Siller, G.; Lehtinen, O.; Wang, F. C.; Nair, R. R.; Kaiser, U.; Wu, H. A.; Geim, A. K.; Grigorieva, I. V., Square ice in graphene nanocapillaries. *Nature* **2015**, *519* (7544), 443-445.

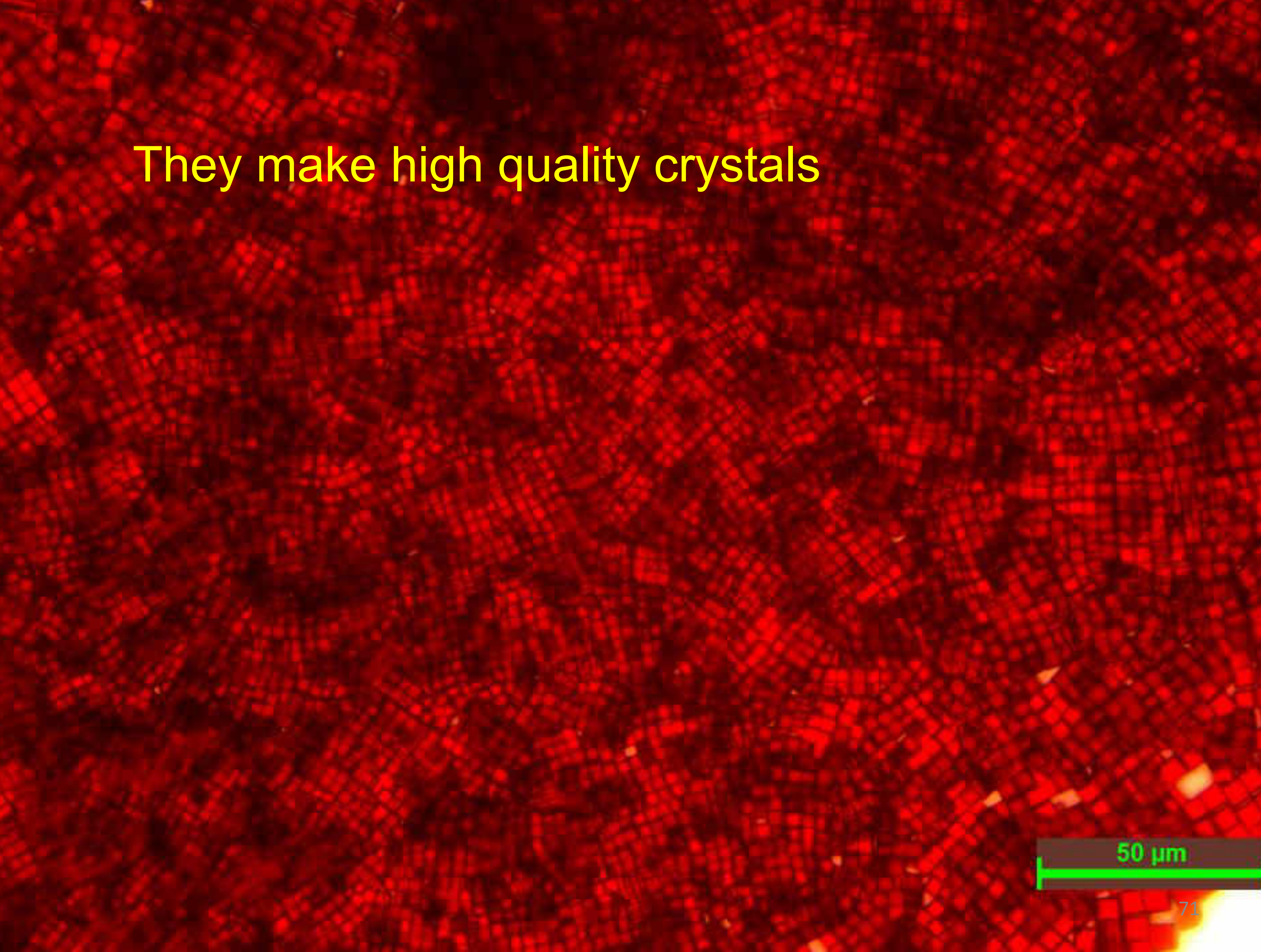
Atomically Precise Clusters

New molecules



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

They make high quality crystals



CHEMICAL REVIEWS

Review

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Atomically Precise Clusters of Noble Metals: Emerging Link between Atoms and Nanoparticles

Indranath Chakraborty[†] and Thalappil Pradeep*

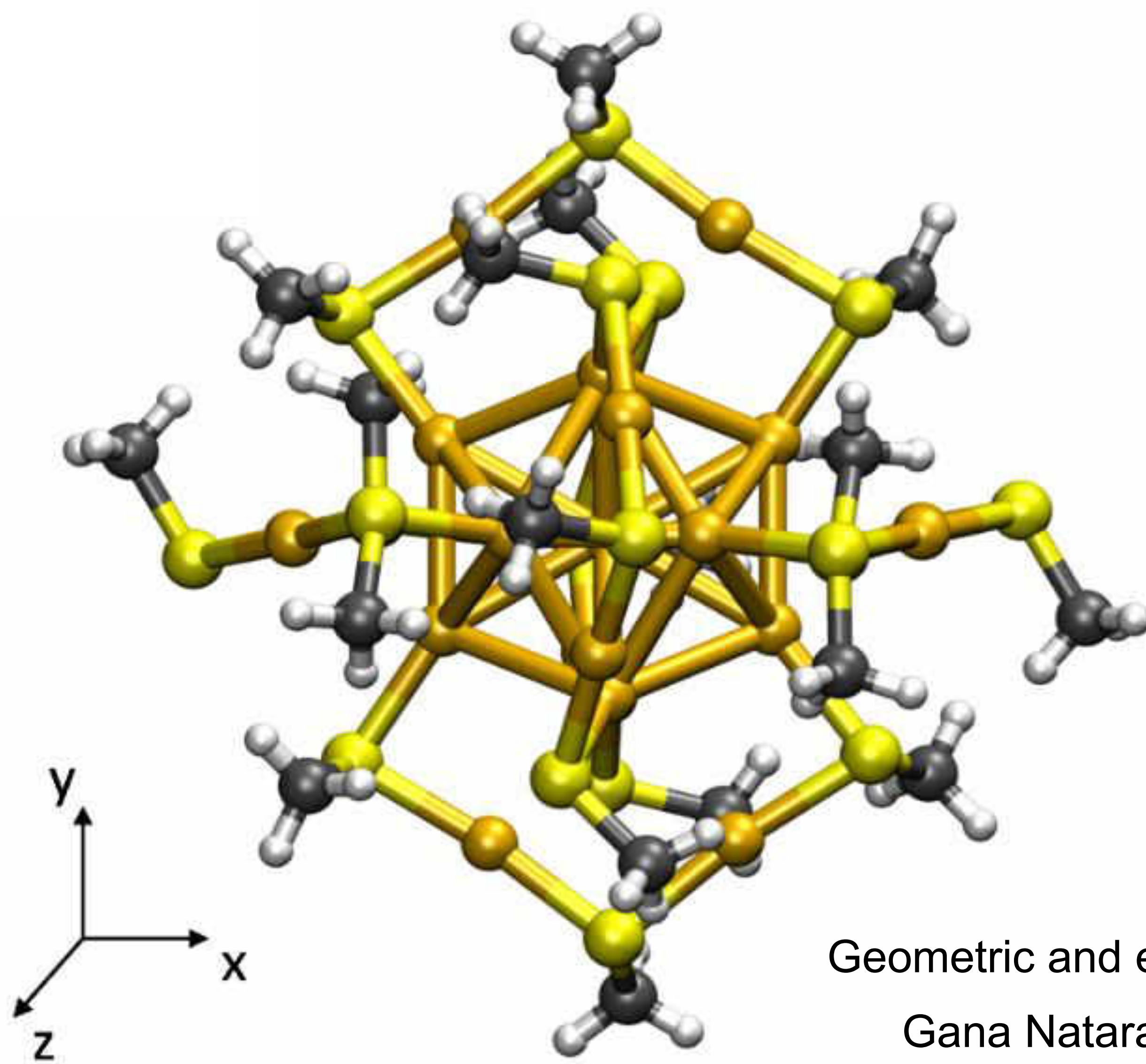
DST Unit of Nanoscience (DST UNS) and Thematic Unit of Excellence, Department of Chemistry, Indian Institute of Technology Madras, Chennai 600036, India

Supporting Information

ABSTRACT: Atomically precise pieces of matter of nanometer dimensions composed of noble metals are new categories of materials with many unusual properties. Over 100 molecules of this kind with formulas such as $Au_{25}(SR)_{18}$, $Au_{38}(SR)_{24}$, and $Au_{102}(SR)_{44}$ as well as $Ag_{25}(SR)_{18}$, $Ag_{29}(S_2R)_{12}$, and $Ag_{44}(SR)_{30}$ (often with a few counterions to compensate charges) are known now. They can be made reproducibly with robust synthetic protocols, resulting in colored solutions, yielding powders or diffractable crystals. They are distinctly different from nanoparticles in their spectroscopic properties such as optical absorption and emission, showing well-defined features, just like molecules. They show isotopically resolved molecular ion peaks in mass spectra and provide diverse information when examined through multiple instrumental methods. Most important of these properties is luminescence, often in the visible—near-infrared window, useful in biological applications. Luminescence in the visible region, especially by clusters protected with proteins, with a large Stokes shift, has been used for various sensing applications, down to a few tens of molecules/ions, in air and water. Catalytic properties of clusters, especially oxidation of organic substrates, have been examined. Materials science of these systems presents numerous possibilities and is fast evolving. Computational insights have given reasons for their stability and unusual properties. The molecular nature of these materials is unequivocally manifested in a few recent studies such as intercluster reactions forming precise clusters. These systems manifest properties of the core, of the ligand shell, as well as that of the integrated system. They are better described as protected molecules or *aspicules*, where *aspis* means shield and *cules* refers to molecules, implying that they are "shielded molecules". In order to understand their diverse properties, a nomenclature has been introduced with which it is possible to draw their structures with positional labels on paper, with some training. Research in this area is captured here, based on the publications available up to December 2016.

Also the pioneering work of R. W. Murray, Robert L. Whetten, Uzi Landman, Tatuya Tsukuda, Yuichi Negishi, Hannu Hakkinen, Rongchao Jin, Nanfeng Zheng, Terry Bigioni, Osman Bakr, Kornberg, Jianping Xie, C. M. Aikens, Thomas Buergi, Amala Dass, Ackerson, De-en Jiang, …. A. W. Castleman Jr., H. Schmidbauer, …. Robin Ras, Olli Ikkala

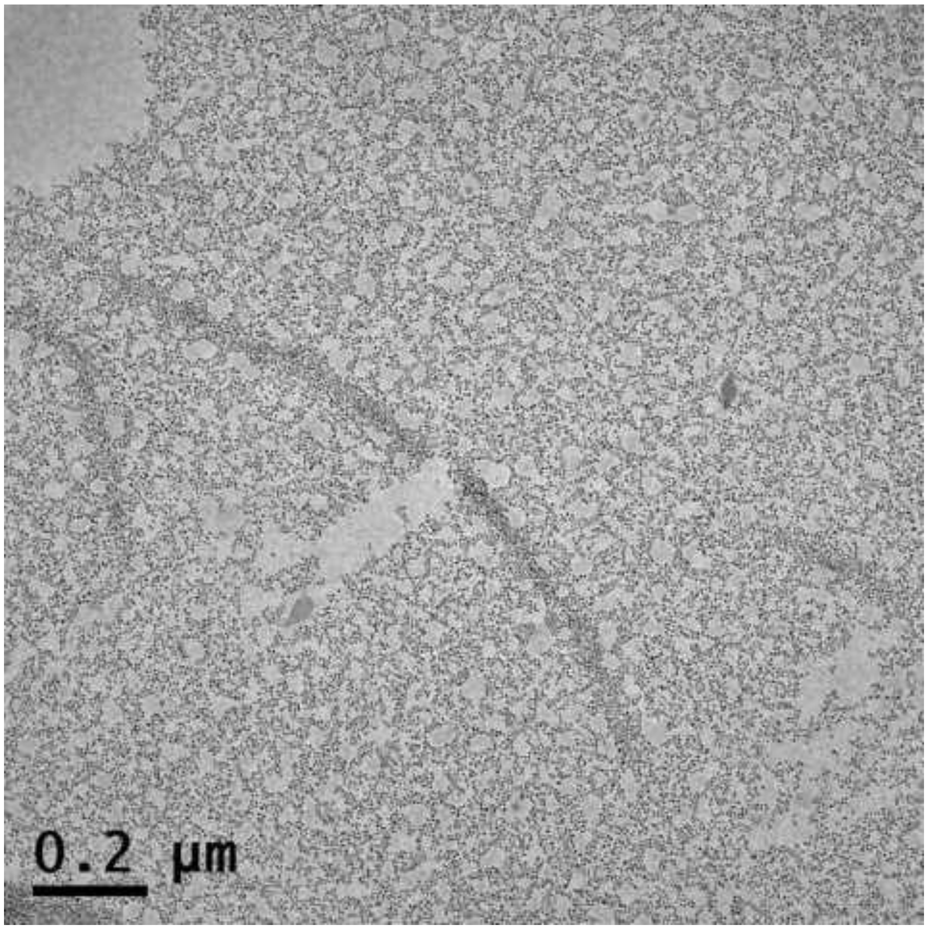
Molecular structure

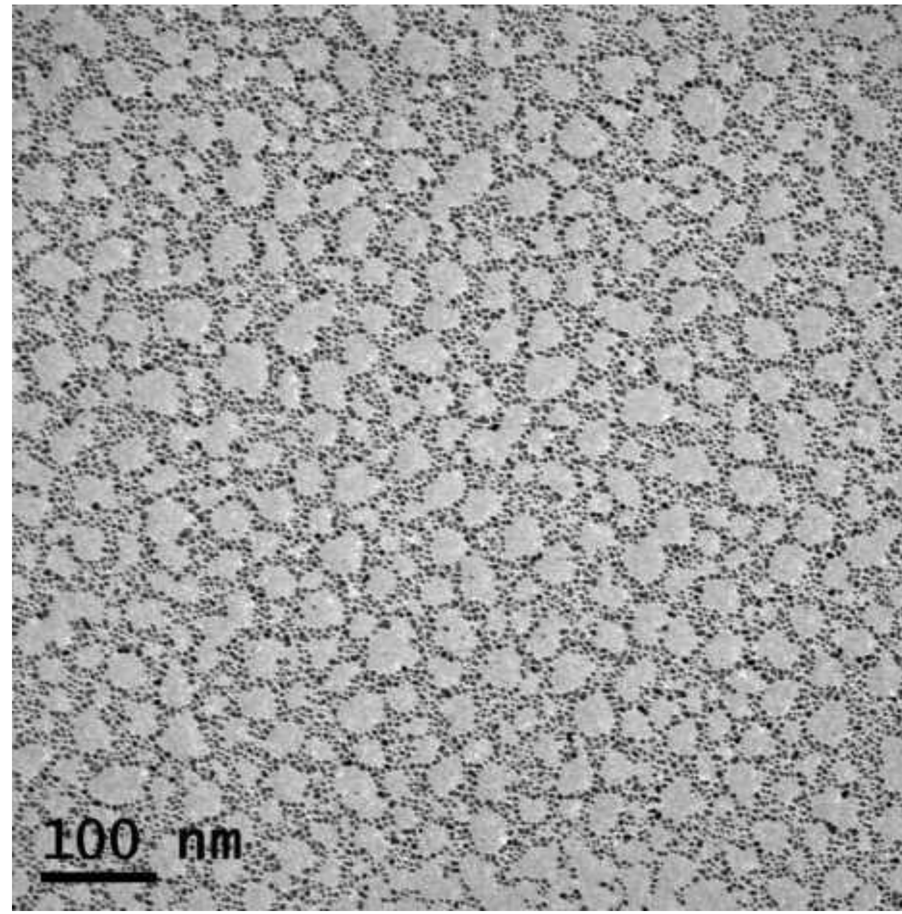


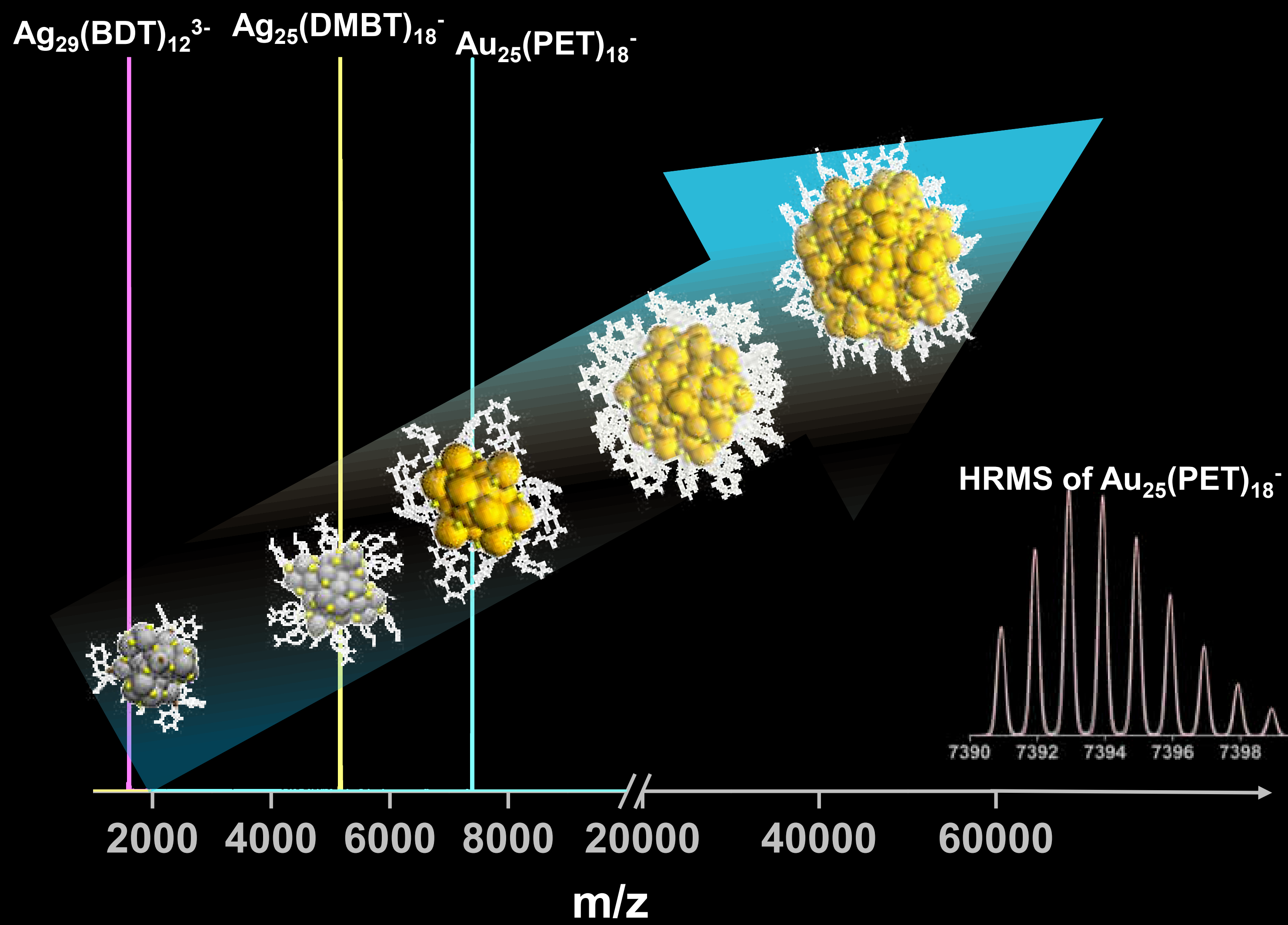
Geometric and electronic shells

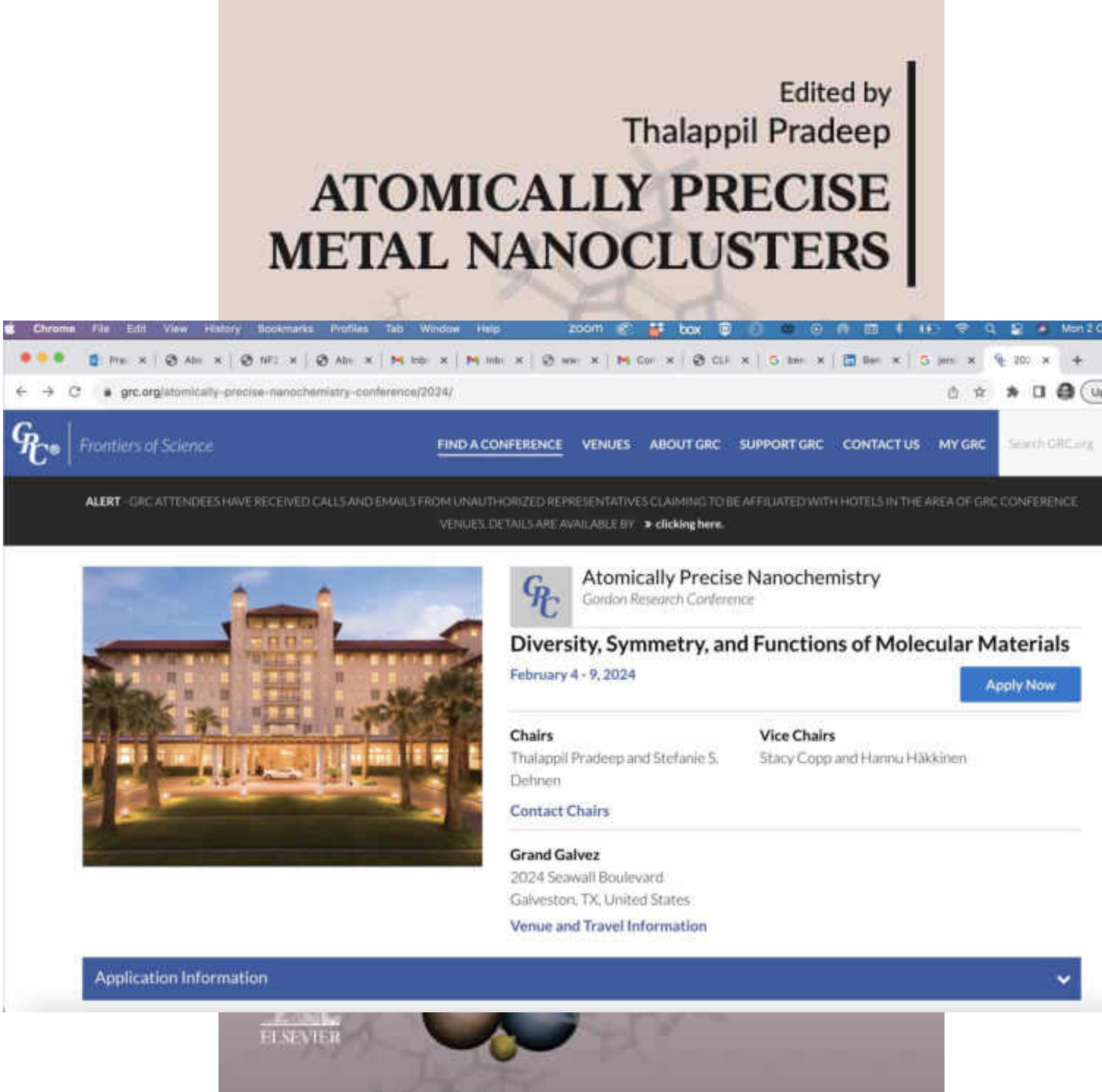
Gana Natarajan

TEM images of Au_{25} and Au_{144}






$Ag_{29}(BDT)_{12}^{3-}$
$Ag_{25}(DMBT)_{18}^{-}$
$Au_{25}(PET)_{18}^{-}$
HRMS of $Au_{25}(PET)_{18}^{-}$
7390
7392
7394
7396
7398
2000
4000
6000
8000
20000
40000
60000
m/z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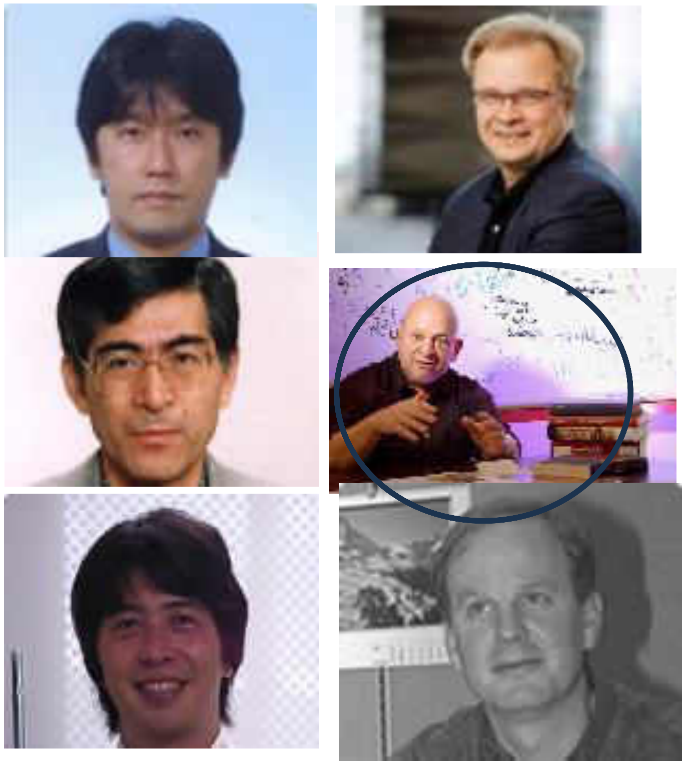
Collaborators



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Keisaku Kimura
Yuichi Negishi
Uzi Landman
Hannu Hakkinen
Rob Whetten

Shiv Khanna

Robin Ras

Nonappa

Tomas Base

Manfred Kappes

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Funding: Department of Science and Technology, Government of India

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THEMATIC UNIT OF EXCELLENCE

Manswita Mandal for help with the slides

My lessons

- Look into local issues.
- Use every opportunity to visit an industry.
- Keep friends from other disciplines.
- Follow your urge. Your most important companion is just you.
- Never compromise on work. 24x7.
- Throw away ideas for others because you cannot solve all.
- Words kill

An ocean of opportunities

Water presents a unique opportunity to find a purpose in life.

Earthrise, taken on December 24, 1968, by Apollo astronaut William Anders.
From Wikipedia