



Since 1959

From Molecular Acorns to Institutional Oaks

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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

International Excellence Award of KIT and Fellowship of SCHROFF Foundation, KIT, November 27, 2023



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

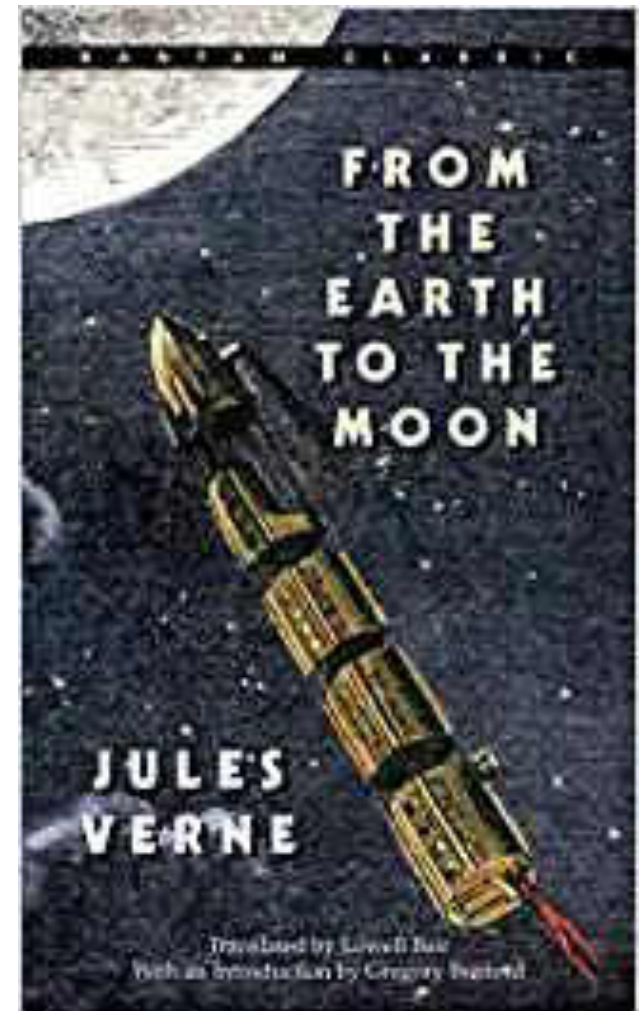
Water is the most important inheritance of our planet



From S. Vishwanath

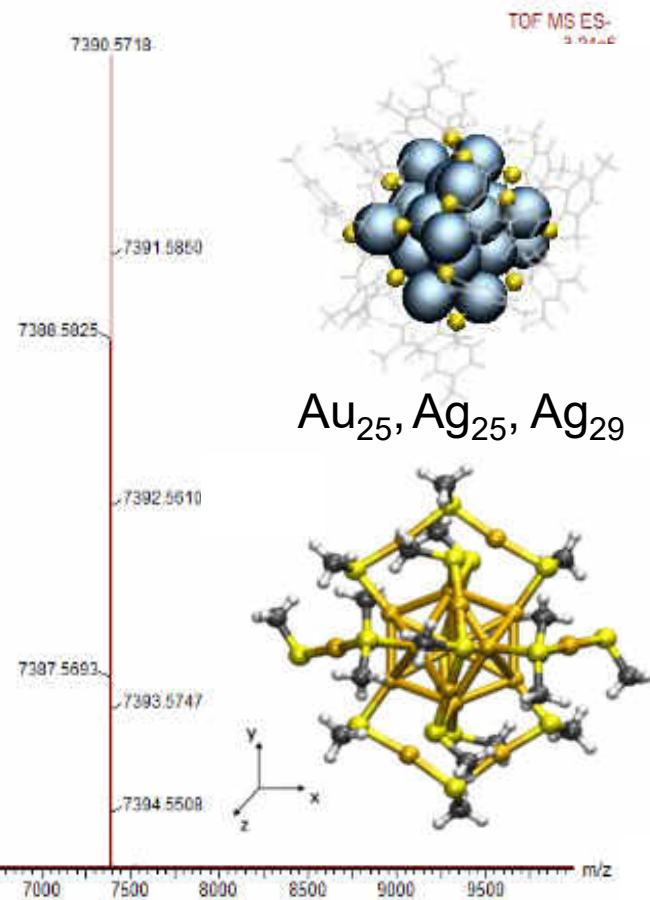
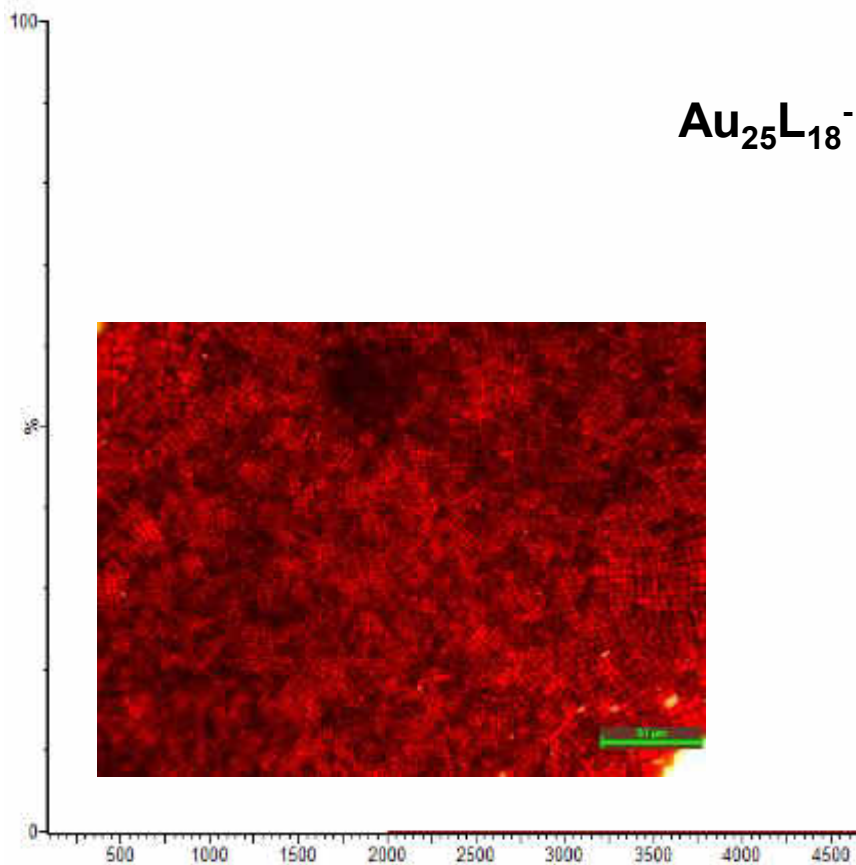
© Robert Szucs/Grasshopper Geography

Our dreams become reality with materials



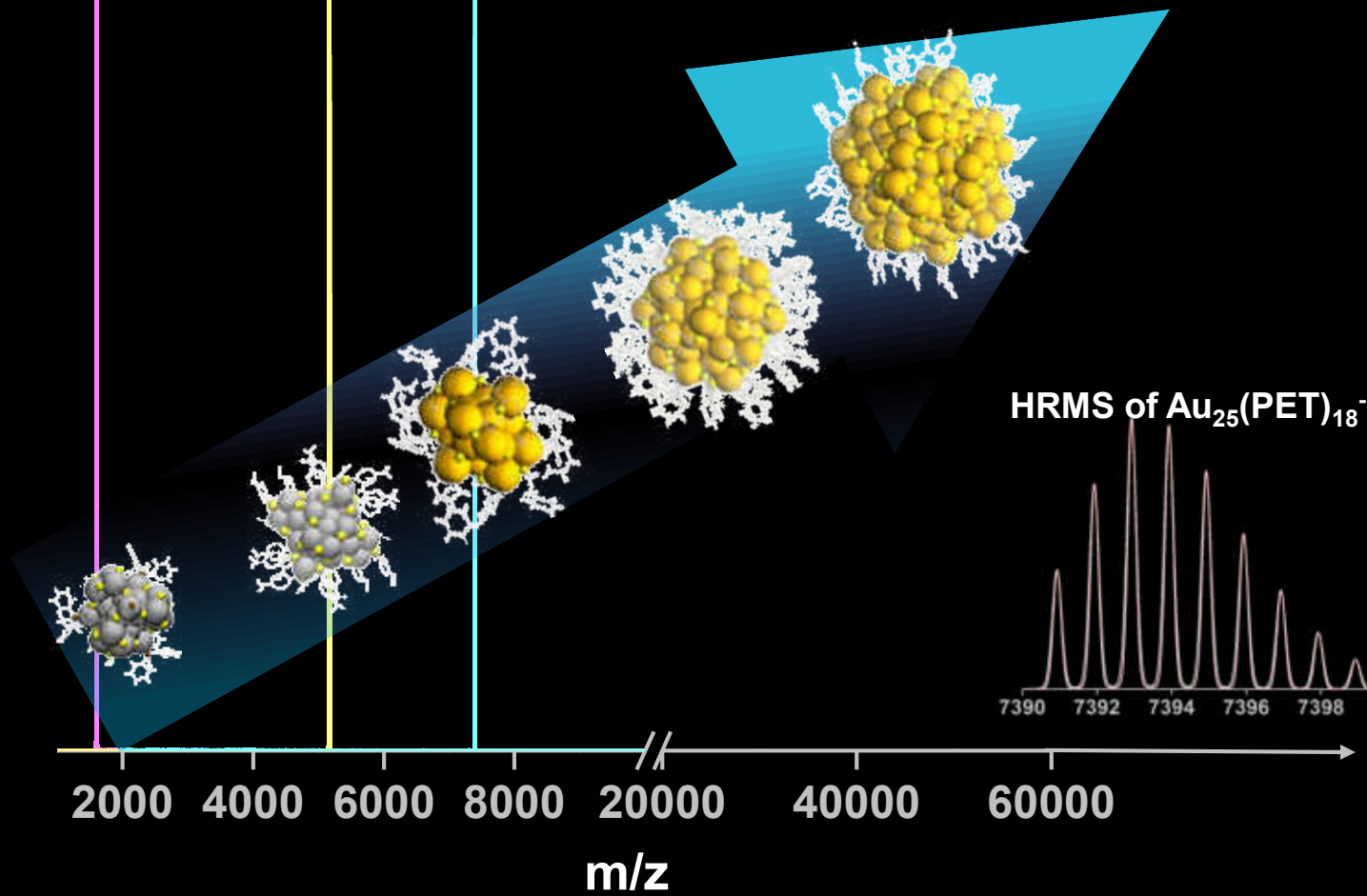
Nanomaterials are now atomically precise

AU25PET10_RES_NEG_MS_3 32 (0.558) Cm (5:00)



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

$\text{Ag}_{29}(\text{BDT})_{12}^{3-}$ $\text{Ag}_{25}(\text{DMBT})_{18}^{-}$ $\text{Au}_{25}(\text{PET})_{18}^{-}$



Molecular materials

ACCOUNTS

of chemical research

Article

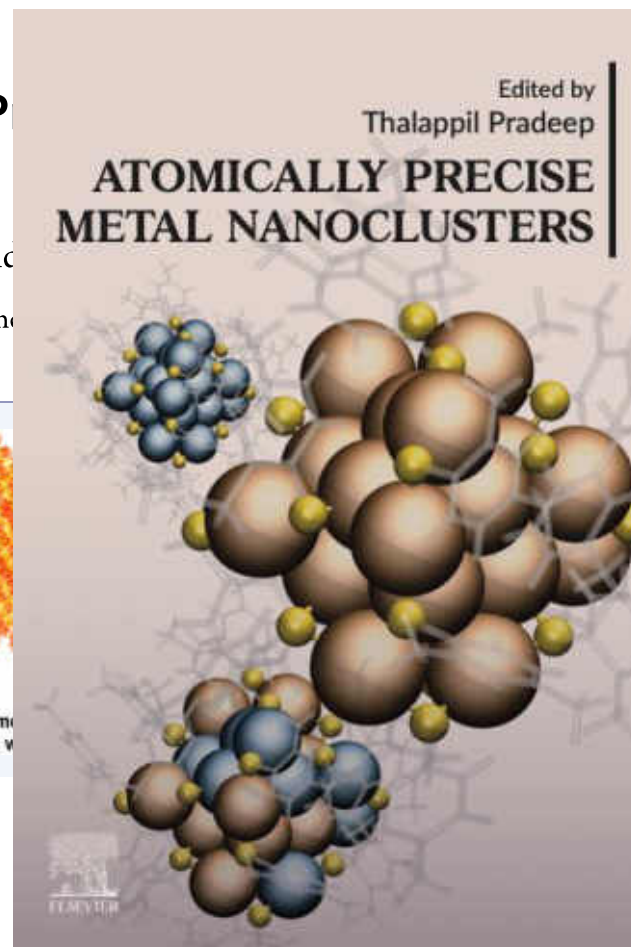
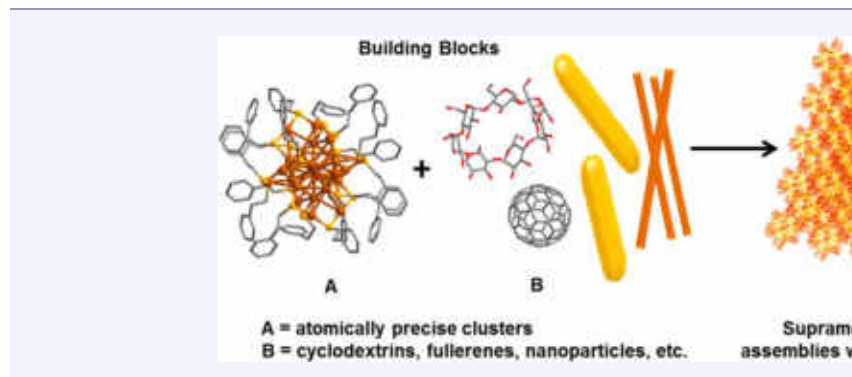
pubs.acs.org/accounts

1 Approaching Materials with Atomic P 2 Cluster Assemblies 3

4 Papri Chakraborty, Abhijit Nag, Amrita Chakraborty, and

5 DST Unit of Nanoscience (DST UNS) and Thematic Unit of Excellence

6 Technology Madras, Chennai 600 036, India



Molecular reactions



Reactions on clusters
Reactions between clusters

Inter-cluster reactions



Article

pubs.acs.org/JACS

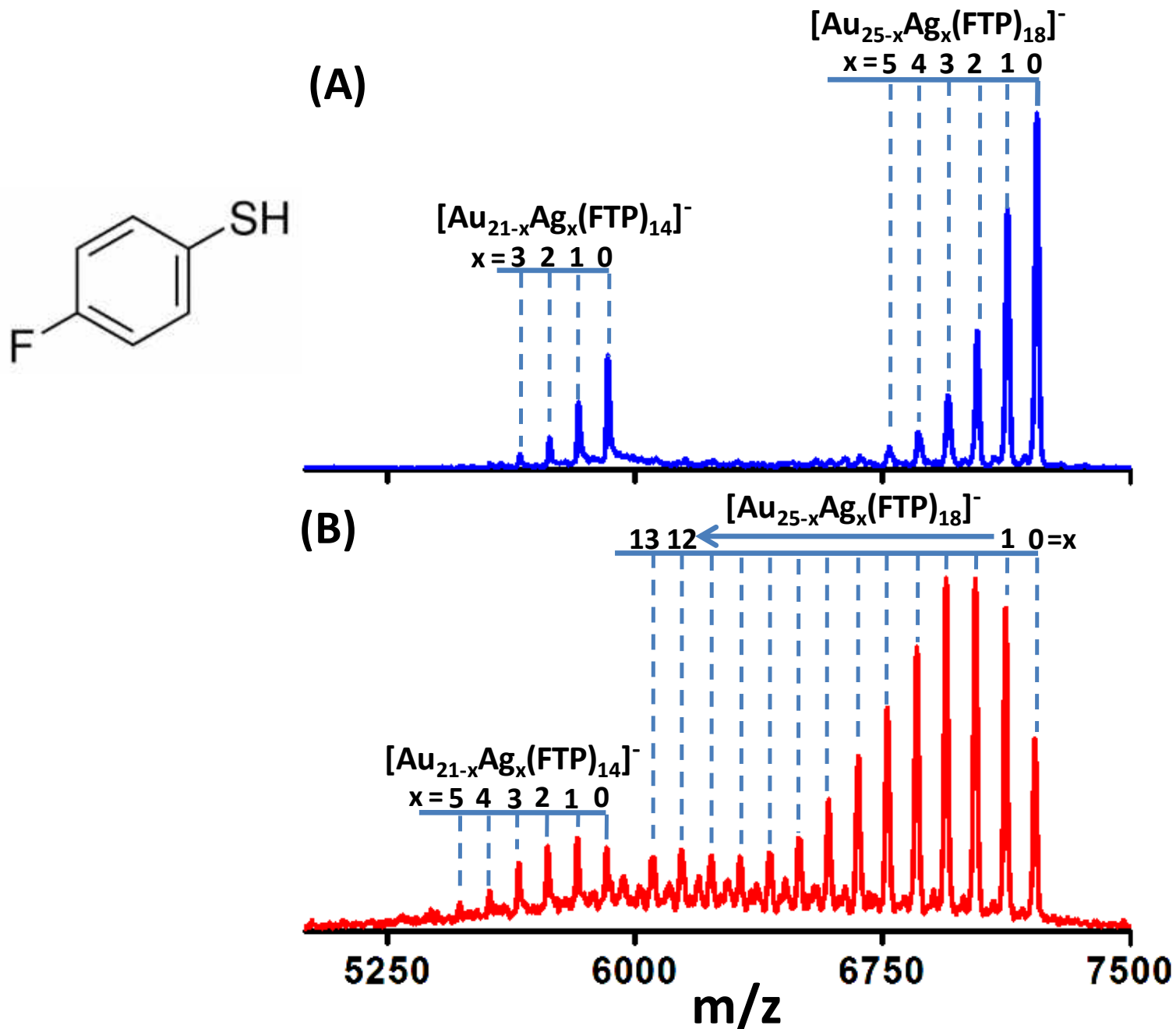
Intercluster Reactions between $\text{Au}_{25}(\text{SR})_{18}$ and $\text{Ag}_{44}(\text{SR})_{30}$

K. R. Krishnadas, Atanu Ghosh, Ananya Baksi, Indranath Chakraborty,[†] Ganapati Natarajan, and Thalappil Pradeep^{*}

DST Unit of Nanoscience (DST UNS) and Thematic Unit of Excellence, Department of Chemistry, Indian Institute of Technology Madras, Chennai, 600 036, India

 Supporting Information



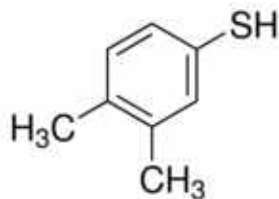


Ag₂₅-Au₂₅ experiments

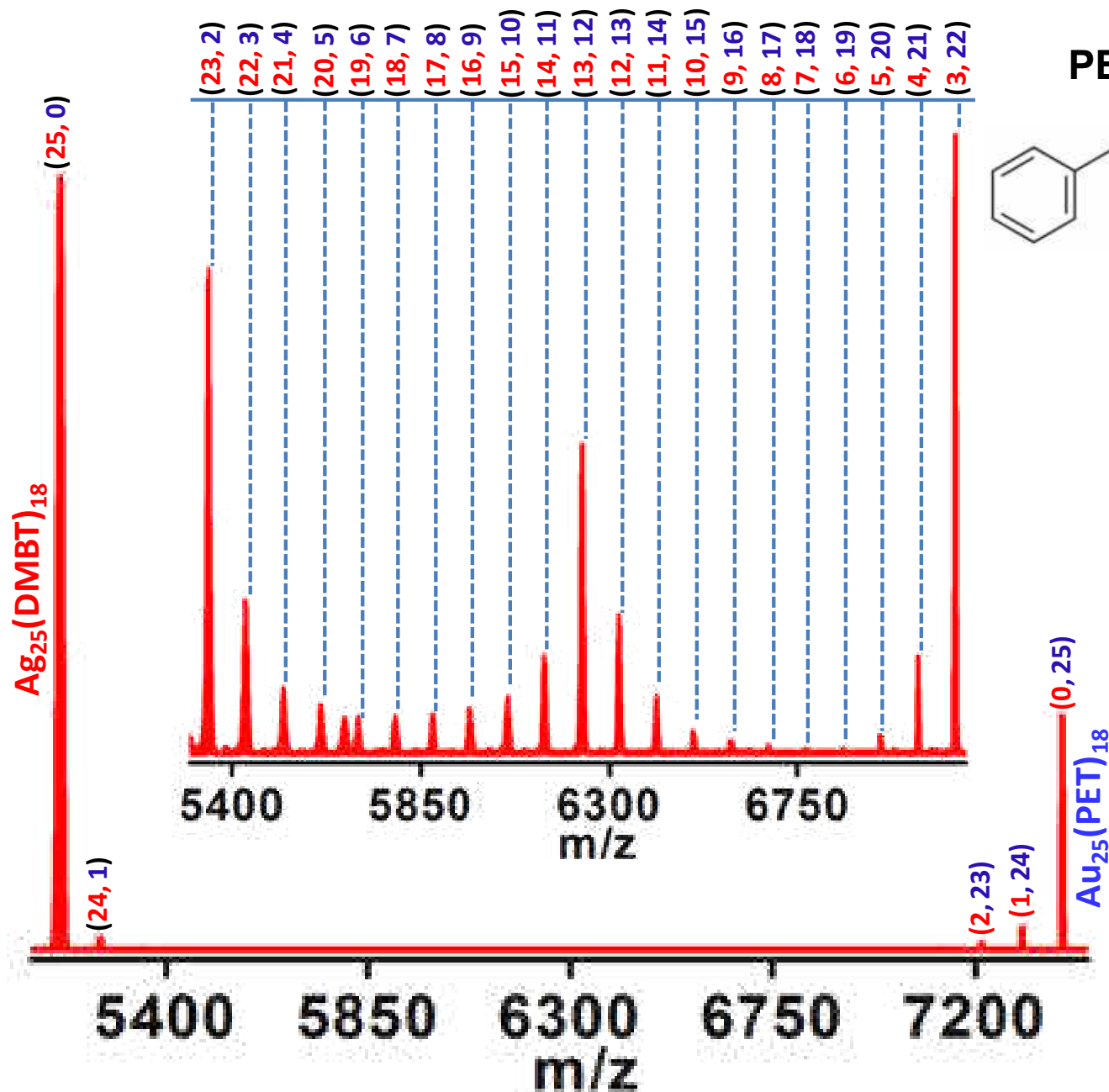
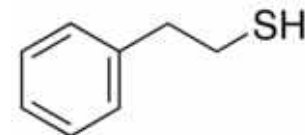
K. R. Krishnadas et al. *Nature Commun.* 2016

Reaction between $\text{Au}_{25}(\text{PET})_{18}$ and $\text{Ag}_{25}(\text{DMBT})_{18}$

DMBT

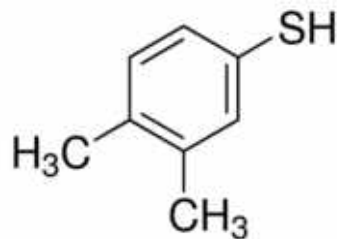


PET

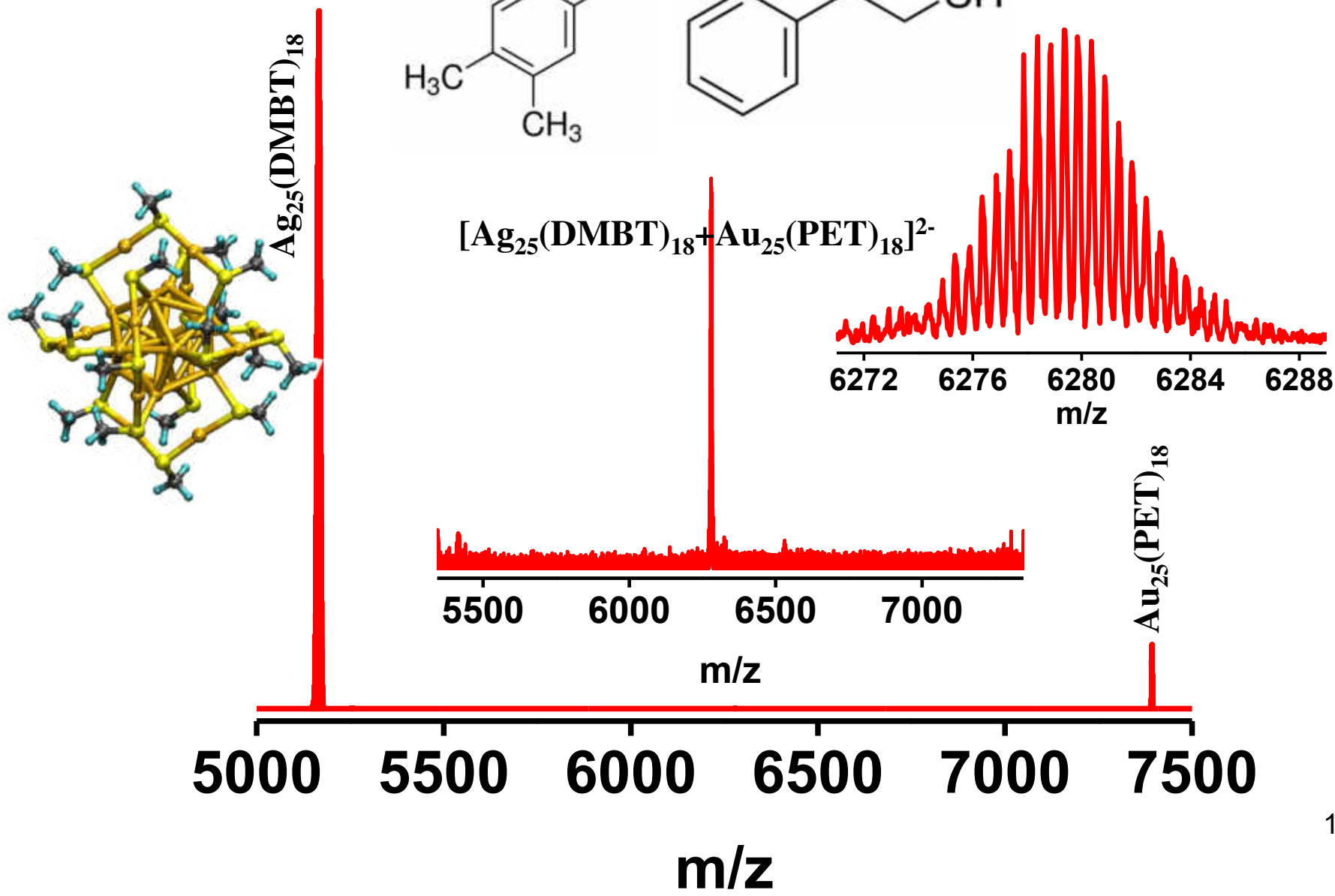
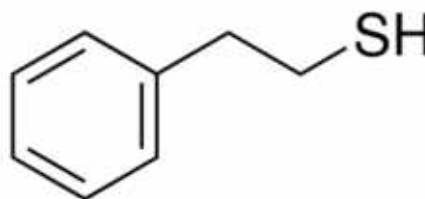




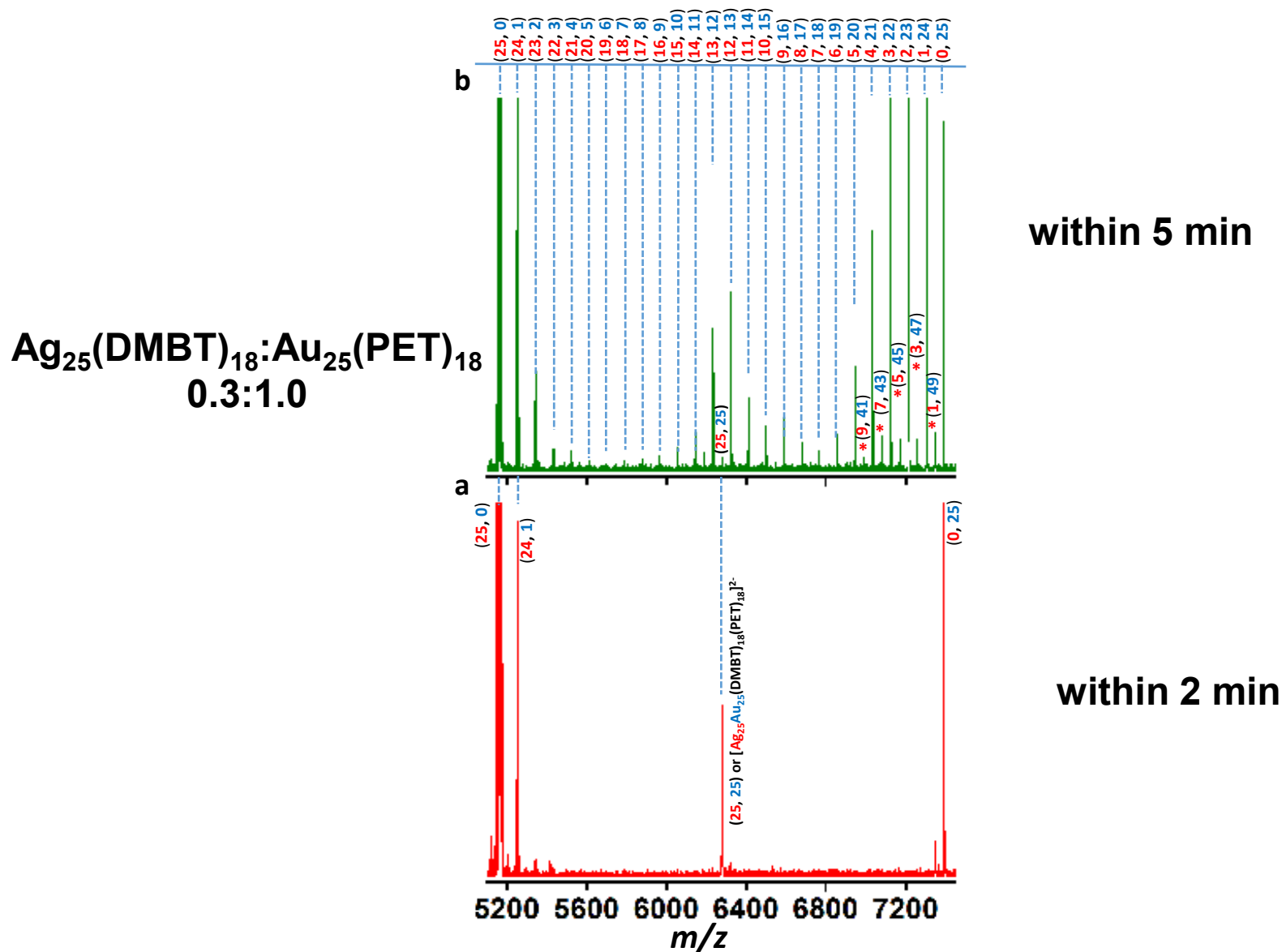
DMBT



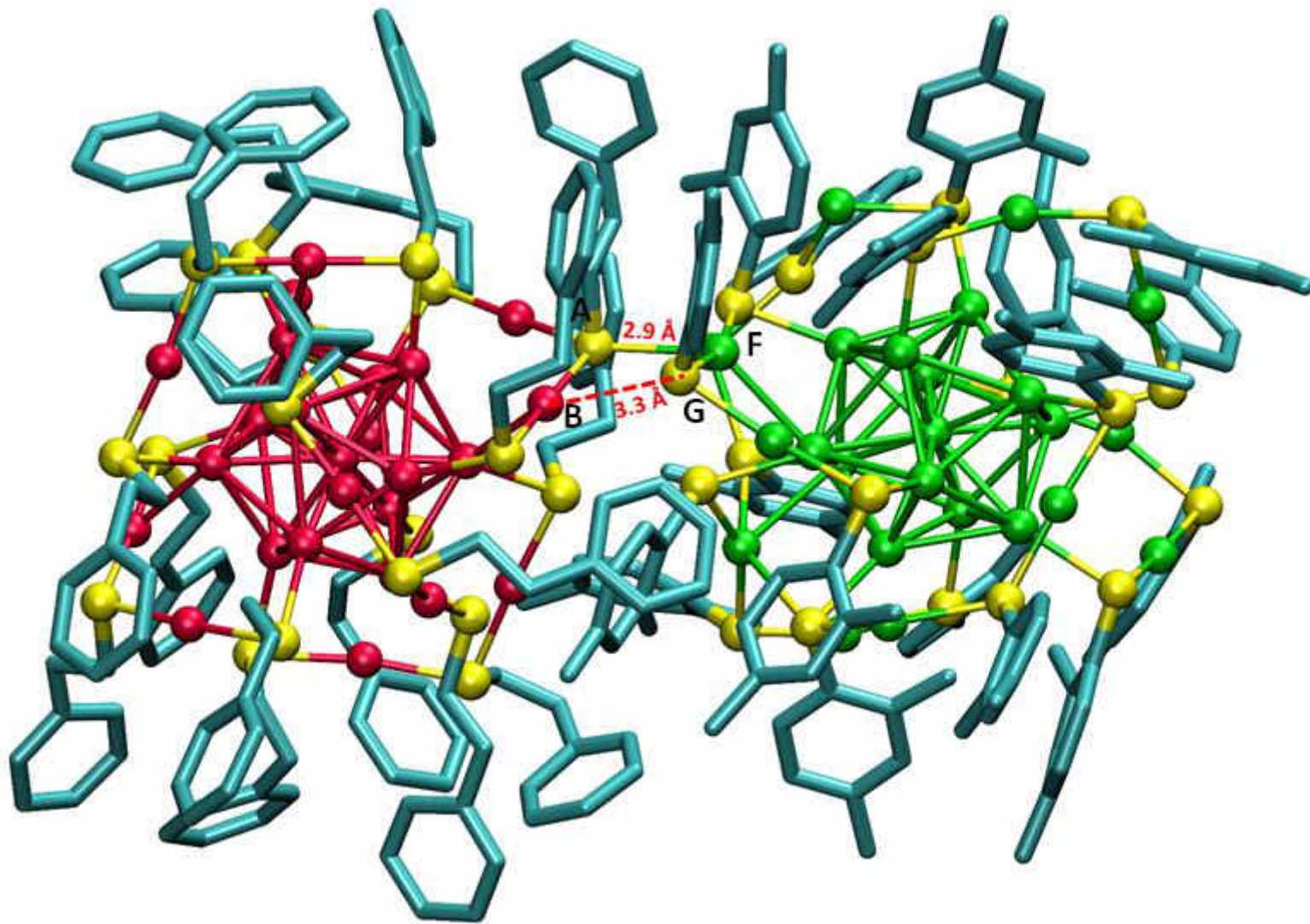
PET

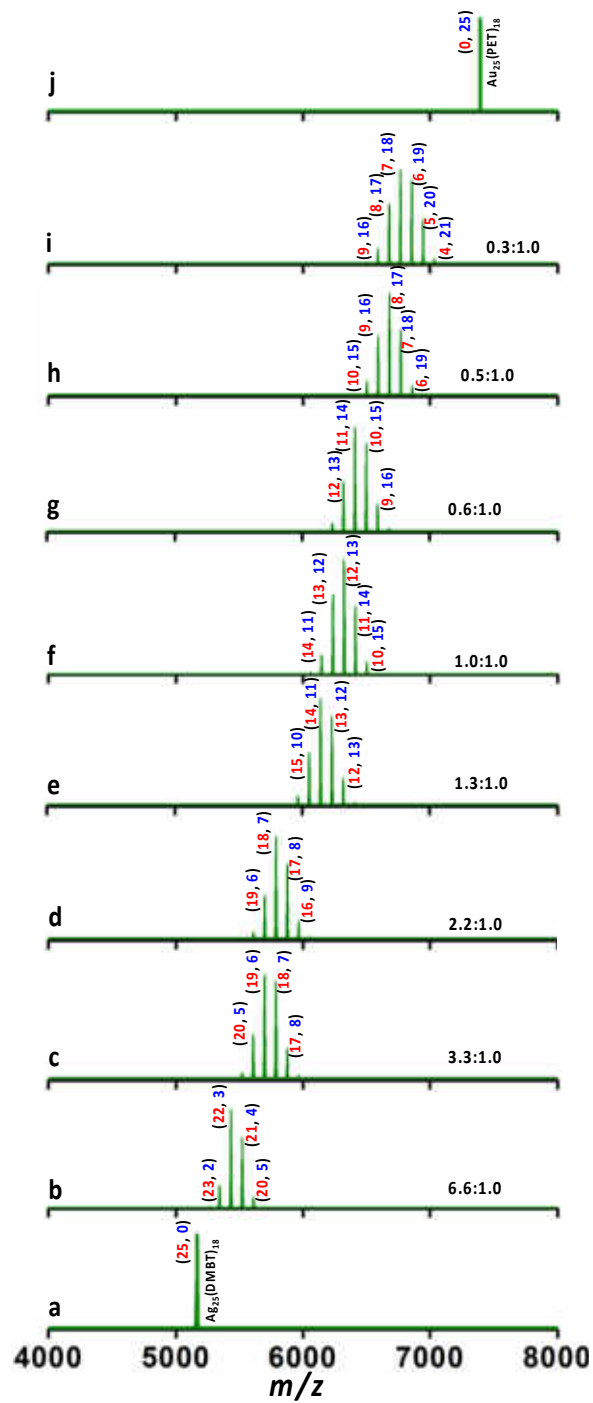


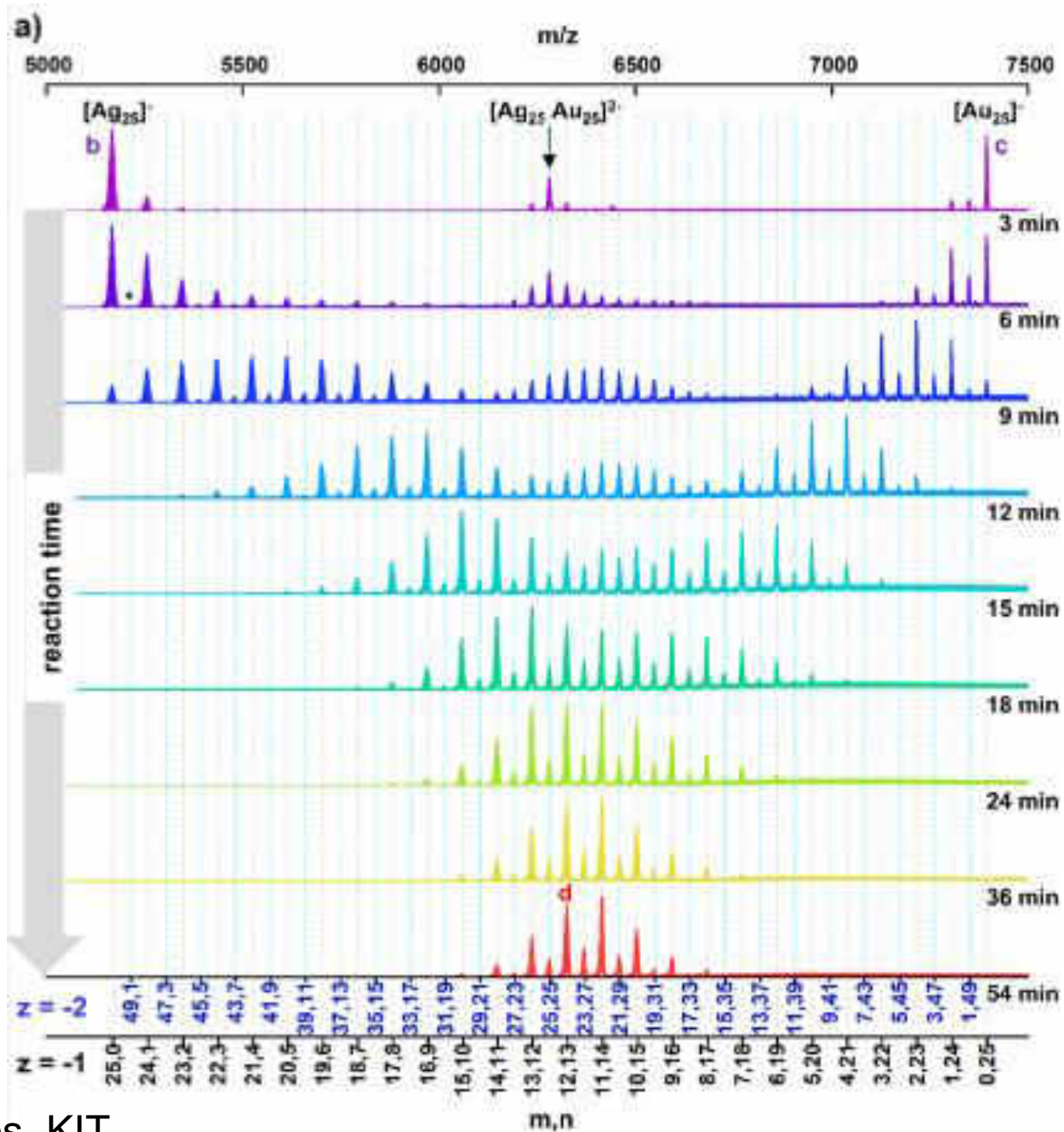
Evolution of alloy clusters from the dianionic adduct, $[\text{Ag}_{25}\text{Au}_{25}(\text{DMBT})_{18}(\text{PET})_{18}]^{2-}$



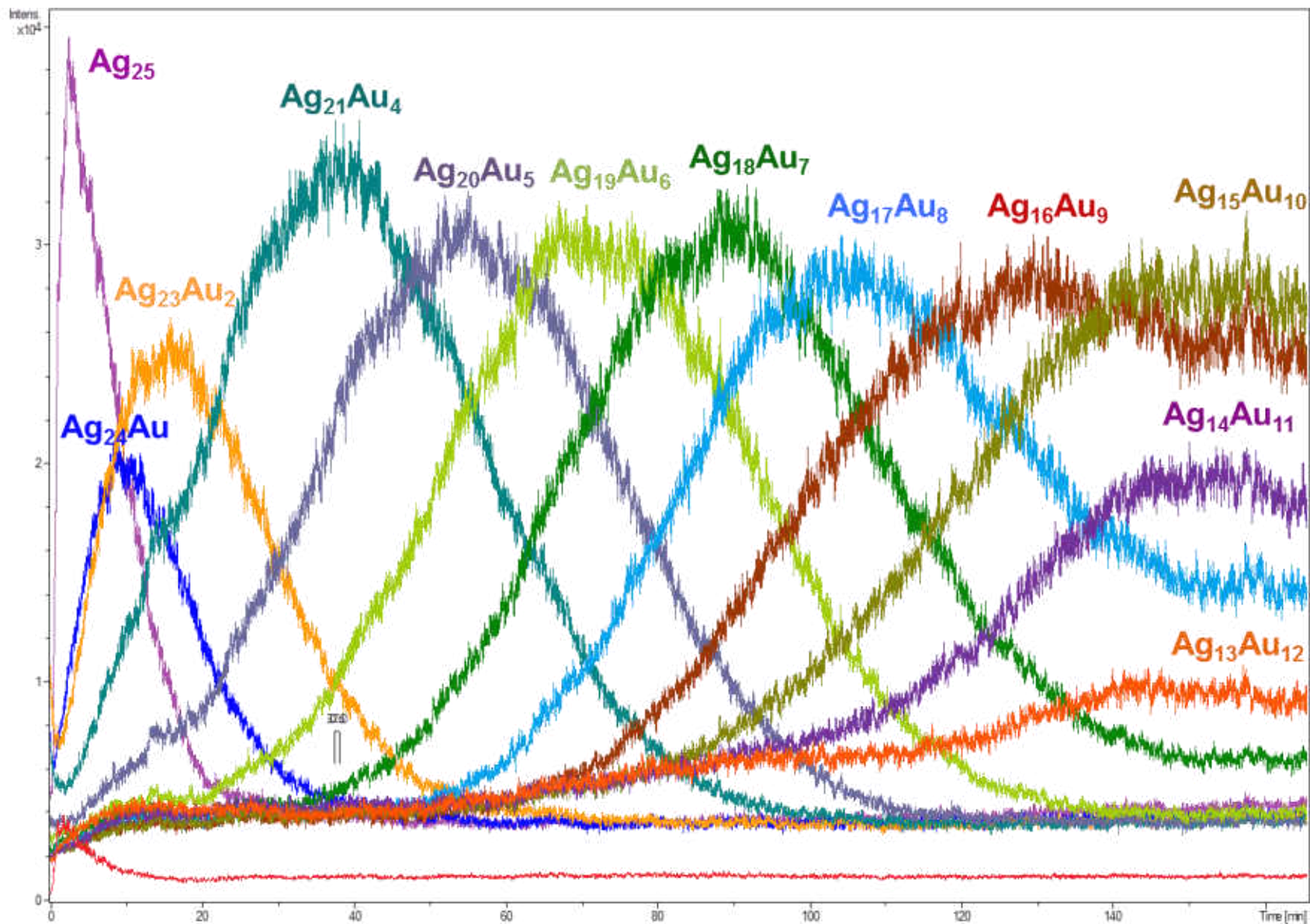
Optimized structure of $[\text{Ag}_{25}\text{Au}_{25}(\text{DMBT})_{18}(\text{PET})_{18}]^{2-}$



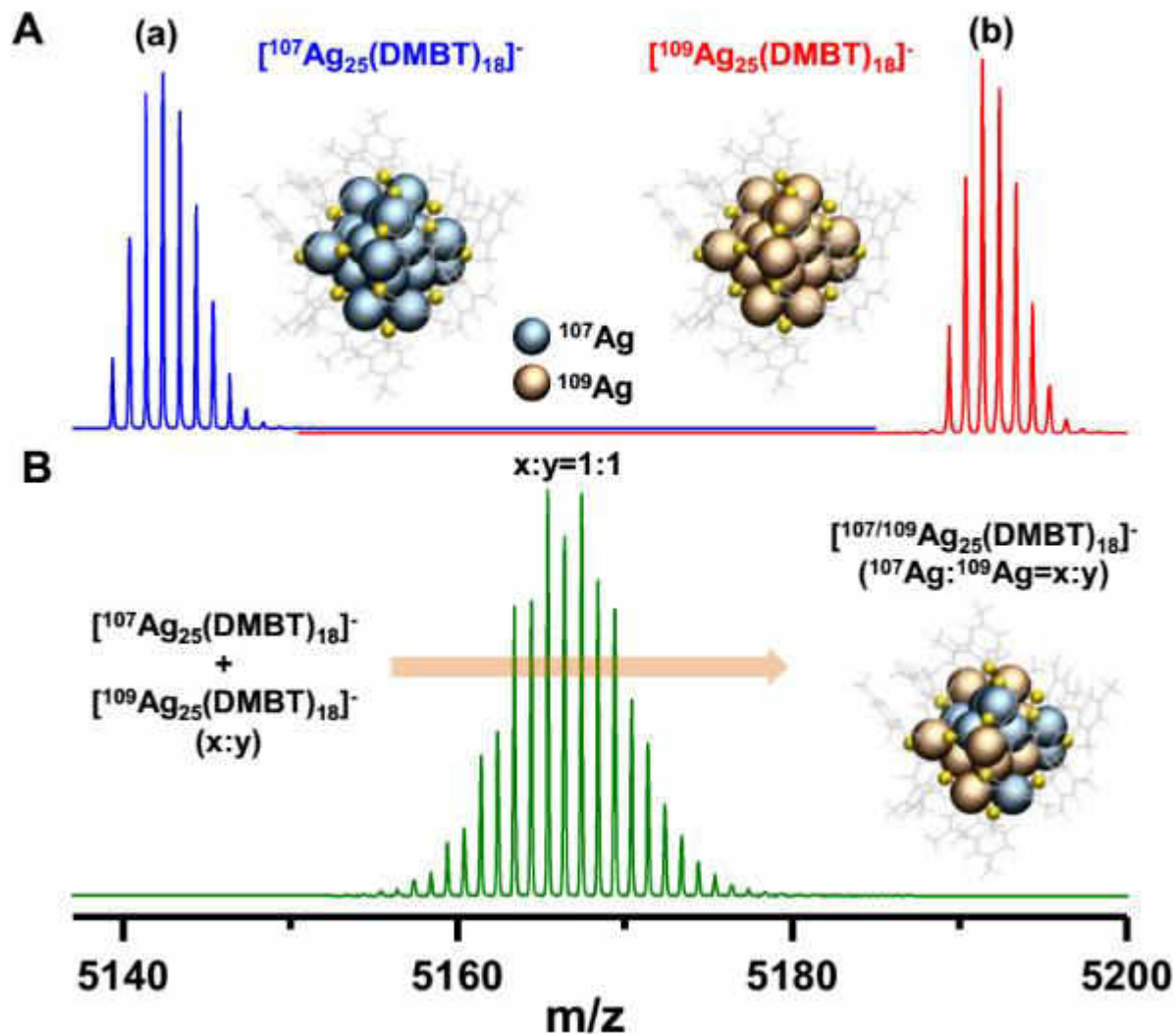




Kinetics of the exchange (monitored on the Ag_{25} side)

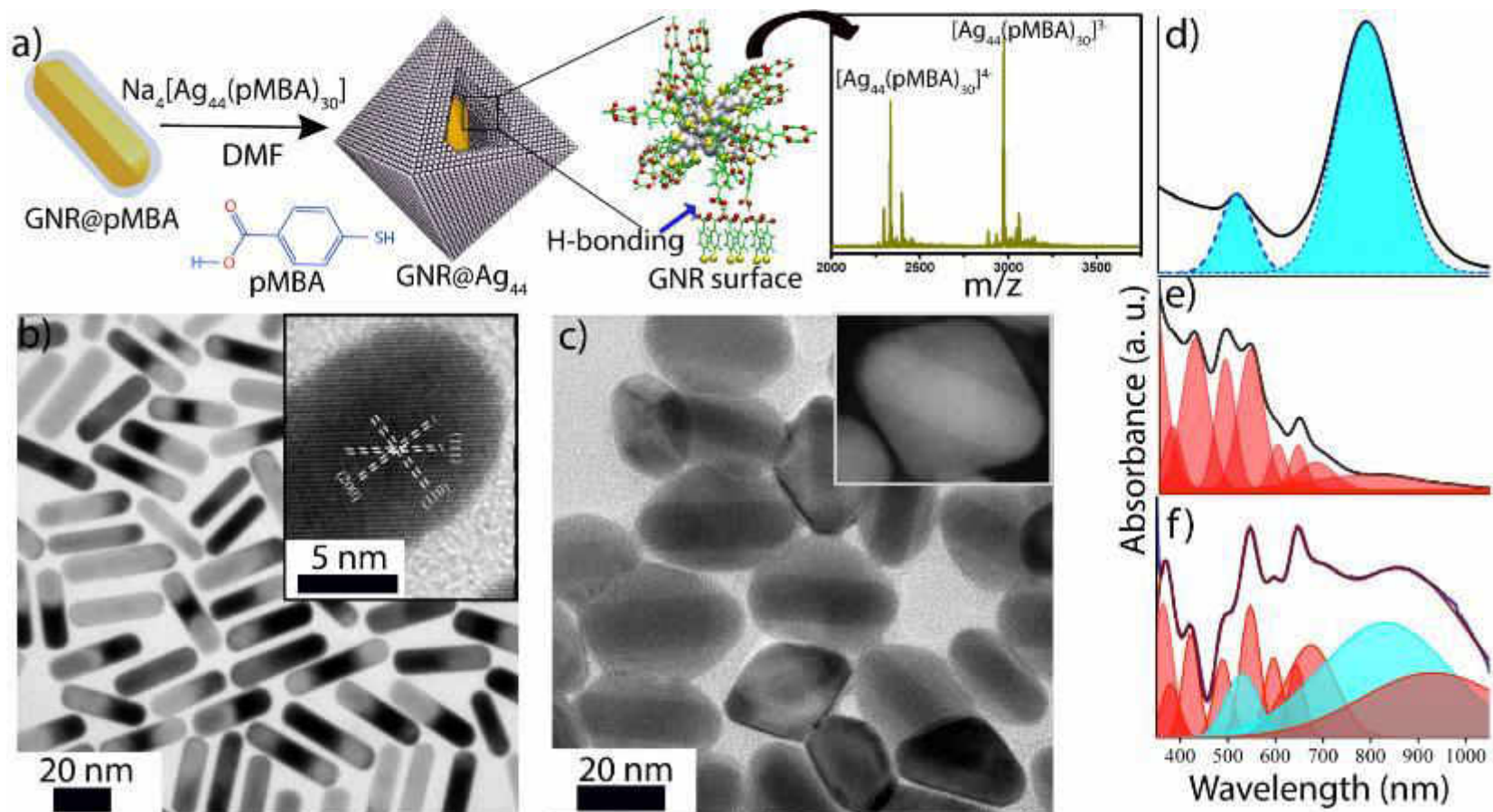


Isotopic exchange



Papri Chakraborti, et. al. Science Advances, 2019.

Atomically precise nanocluster assemblies encapsulating plasmonic gold nanorods



Chakraborty, A. et al., Angew. Chem. Int. Ed. **2018**, 57, 6522–6526.

Pesticide filter debuts in India

20 April 2007

Kilugudi Jayaraman/Bangalore, India

A domestic water filter that uses metal nanoparticles to remove dissolved pesticide residue is about to enter the Indian market. Its developers at the Indian Institute of Technology (IIT) in Chennai (formerly Madras) believe it is the first product of its kind in the world to be commercialised.

Madras-based Eureka Forbes Limited, a company that sells water purification systems, is collaborating with IIT and has tested the device in the field for over six months. Jayachandra Raddi, a technical consultant to the company, expects the first 1000 units to be sold door-to-door from late May.

"Our pesticide filter is an offshoot of basic research on the chemistry of nanoparticles," Thirupathi Pradeep who led the team at IIT Chennai told Chemistry World. He and his student Gireekumar Rao discovered in 2003 that halocarbons such as carbon tetrachloride (CCl₄) completely break down into metal halides and amorphous carbon upon reaction with gold and silver nanoparticles.

Pradeep said this prompted them to extend their study to include organochlorine and organophosphorus pesticides, whose presence in water is posing a health risk in rural India. Research funded by the Department of Science and

Technology in New Delhi, his team found^{1,2} that gold and silver nanoparticles coated on alumina were indeed able to completely remove aldrin, malathion and chlorpyrifos – three pesticides that have been found at elevated levels in Indian water supplies.

Use and recycle

The mechanism of removal is "adsorption followed by catalytic destruction," Pradeep explained. "The chemistry occurs in a wide concentration range of environmental significance." He added that the filter was not released, and the nanoparticles perform better than conventional



The pesticide filter

Nanochemistry-based water purifier



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 malathion and chlorpyrifos 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.

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 ily. 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

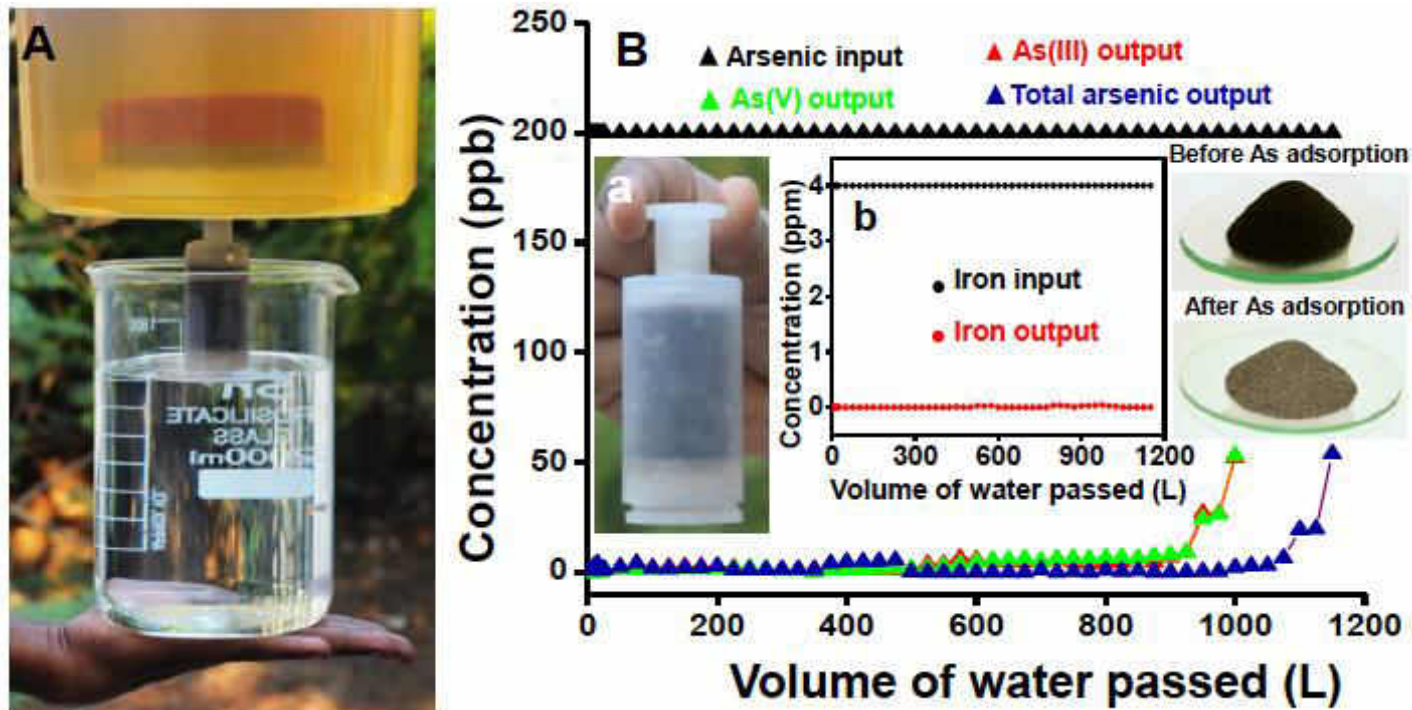
(received for review November 21, 2012)

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

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

Range of materials, their affordability and safety



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

Safety of the spent media, TCLP

Clean water for everyone





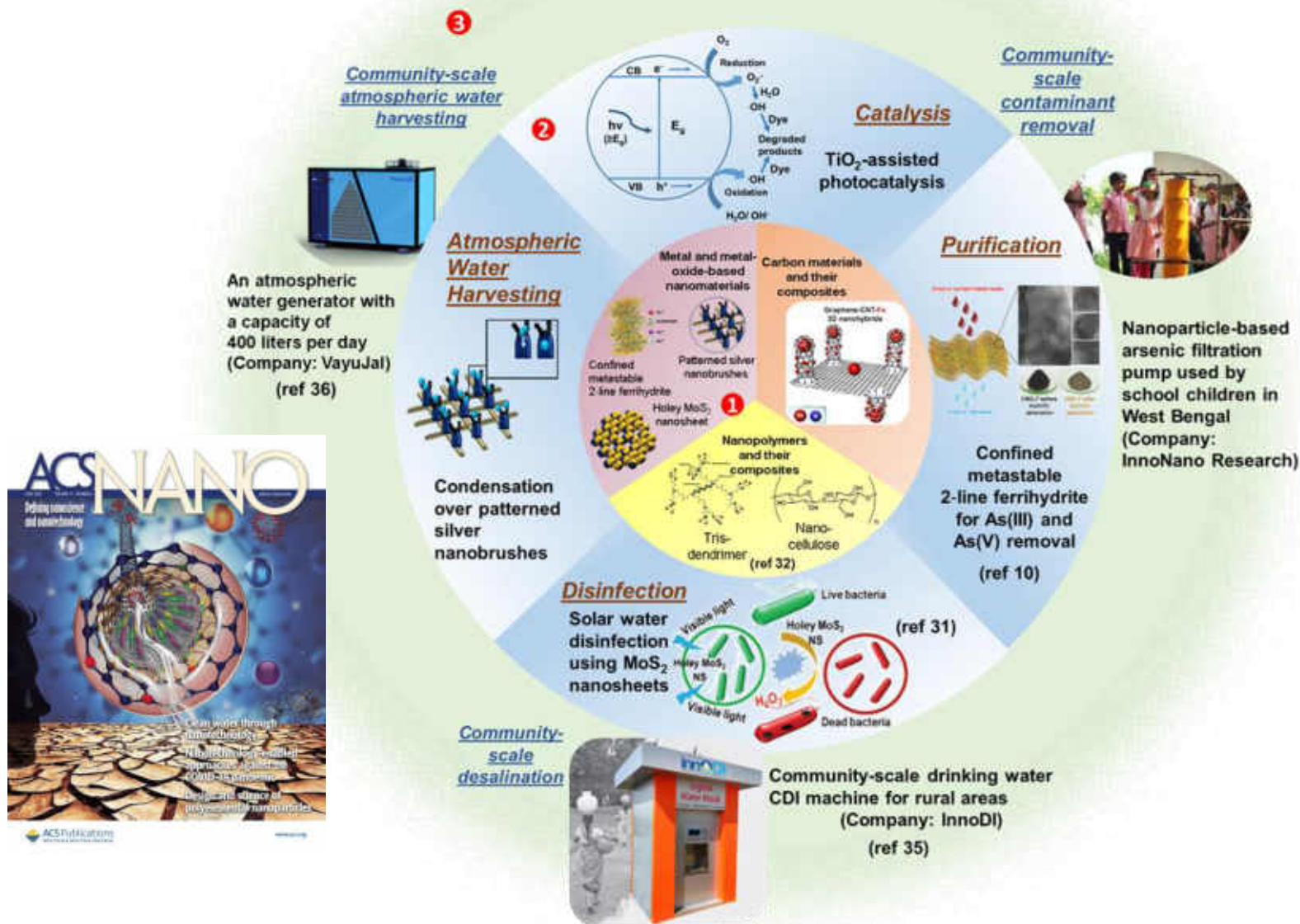
Nature Nanotechnology, July 2014 issue



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

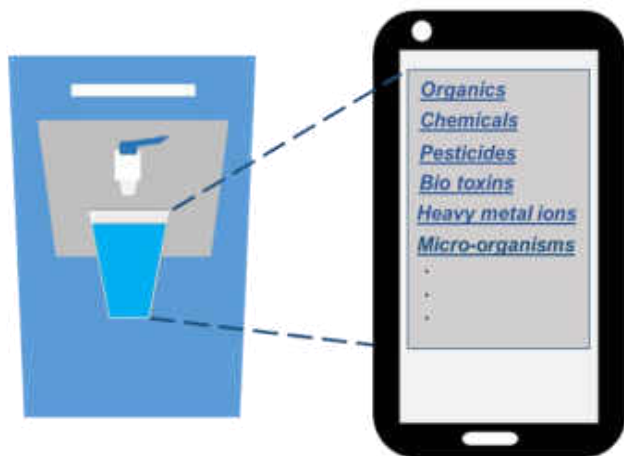
There are over 1700 community installations across the country, serving 1.3 million people with arsenic and iron-free water every day.

Evolution of materials to products



Smart water purifiers and big data

Smart Water Purifiers linked to IoT



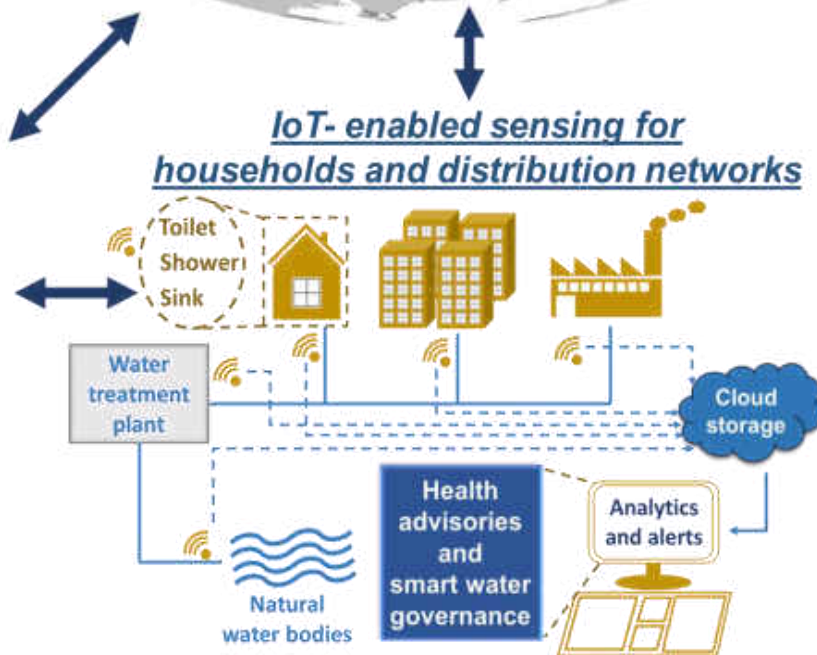
Cost-effective sensor accessory for point-of-use applications



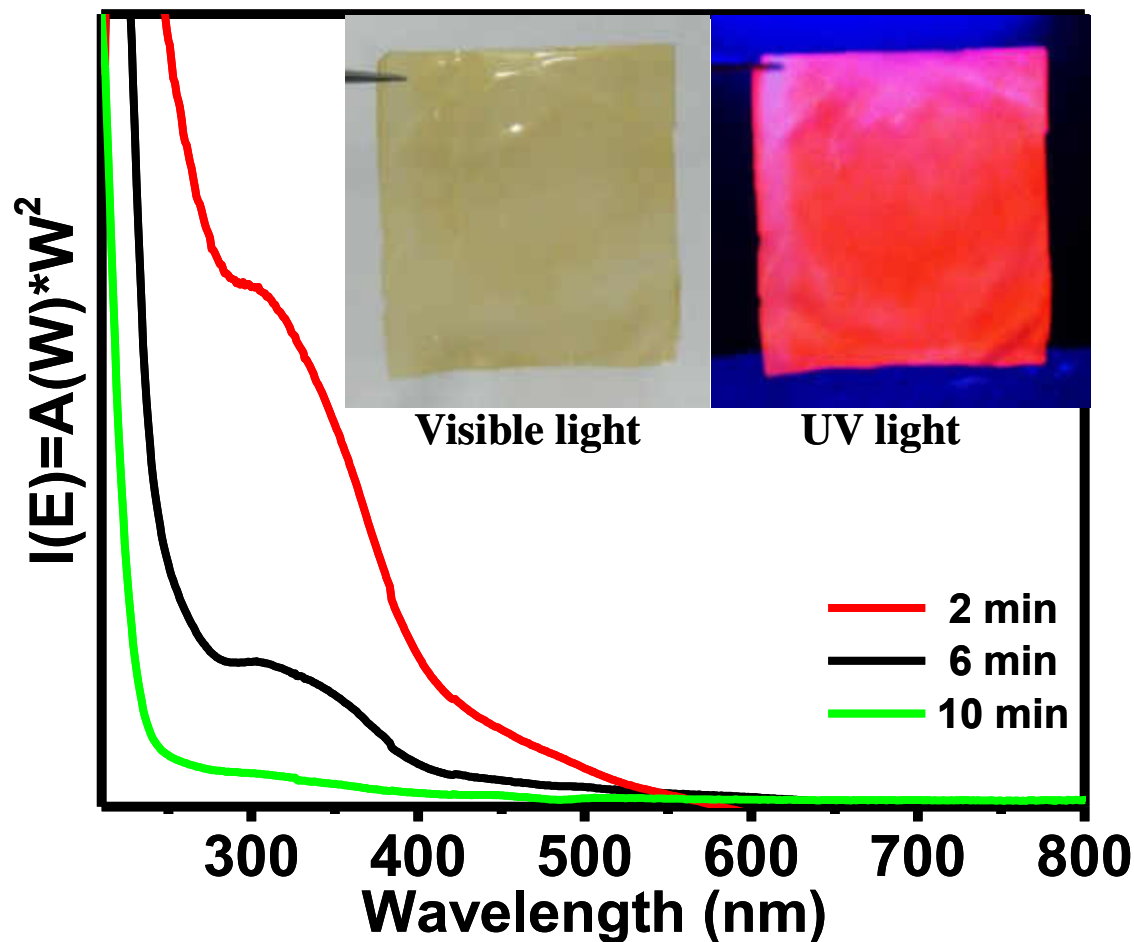
Global Map of Water Health



IoT-enabled sensing for households and distribution networks

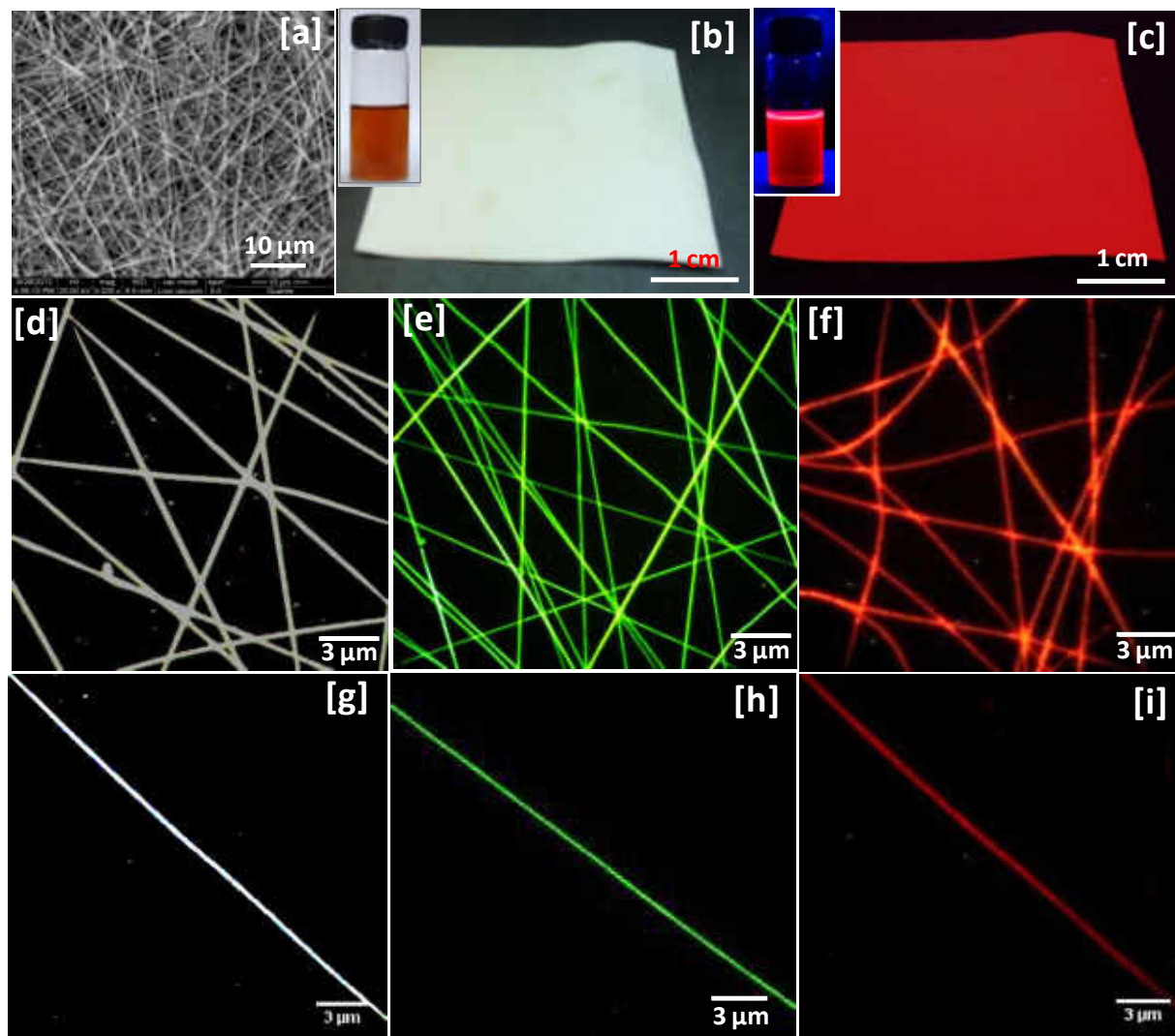


Cluster-based metal ion sensing

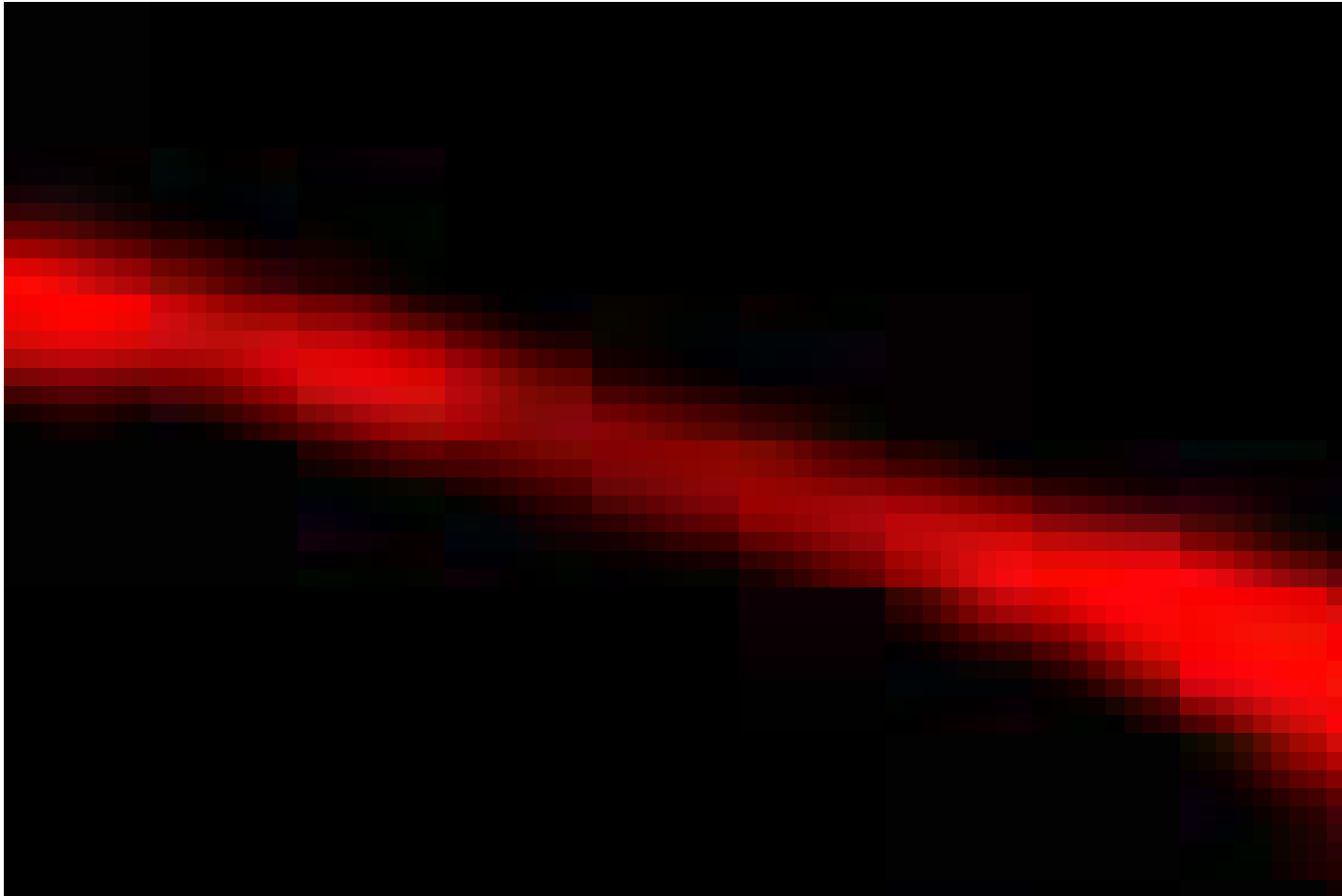


Decrease in the absorption of Au_{15} as a biofilm is dipped into the cluster solution. Inset: Free standing quantum cluster loaded film in visible light and UV light.

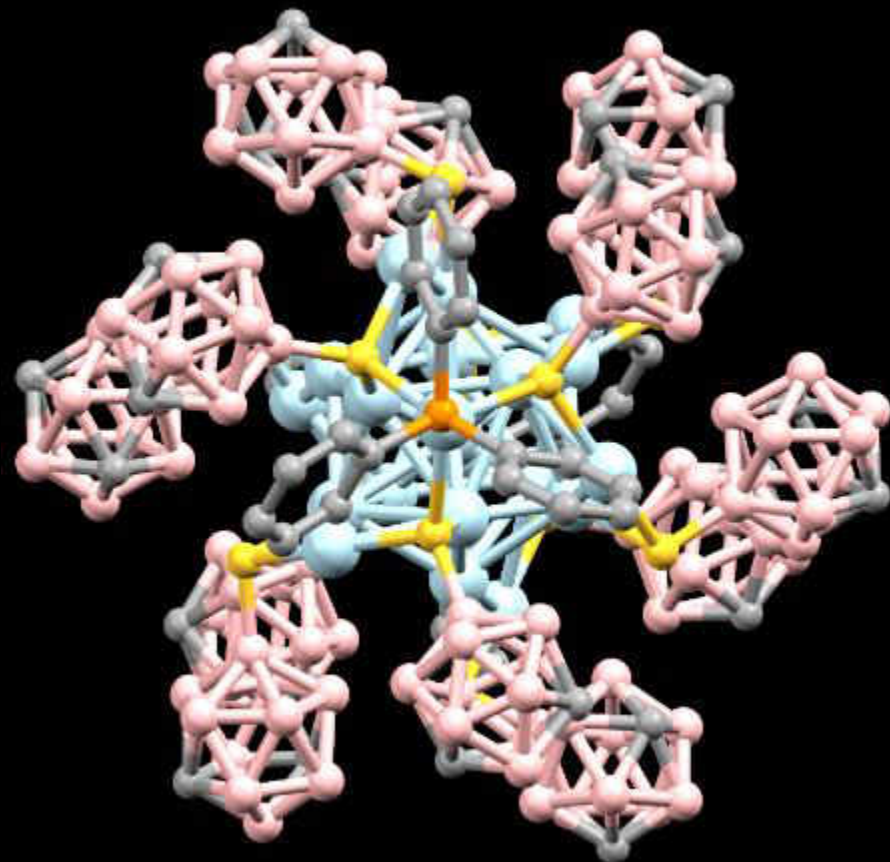
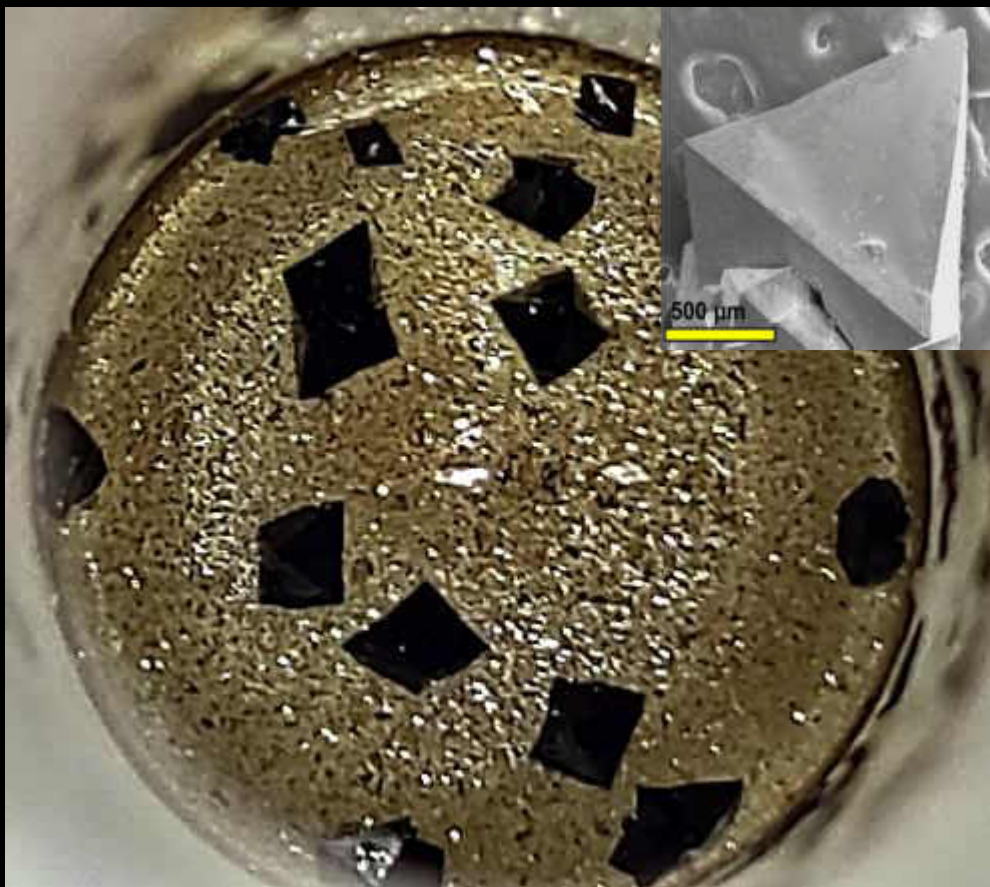
Approaching detection limits of tens of Hg^{2+}



Mercury quenching experiment using nanofiber



Clusters stable up to 300 °C!



Jana *et. al*, Inorganic Chemistry (2022)

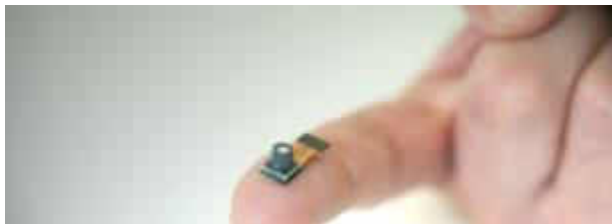
Sensors and new opportunities



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



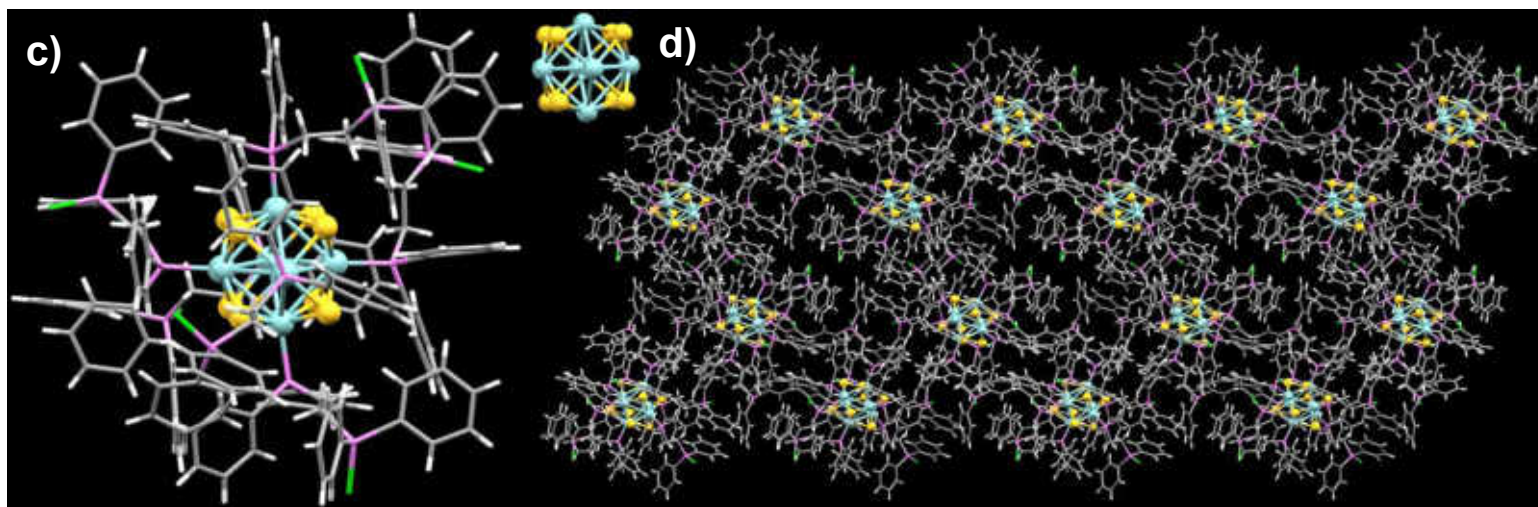
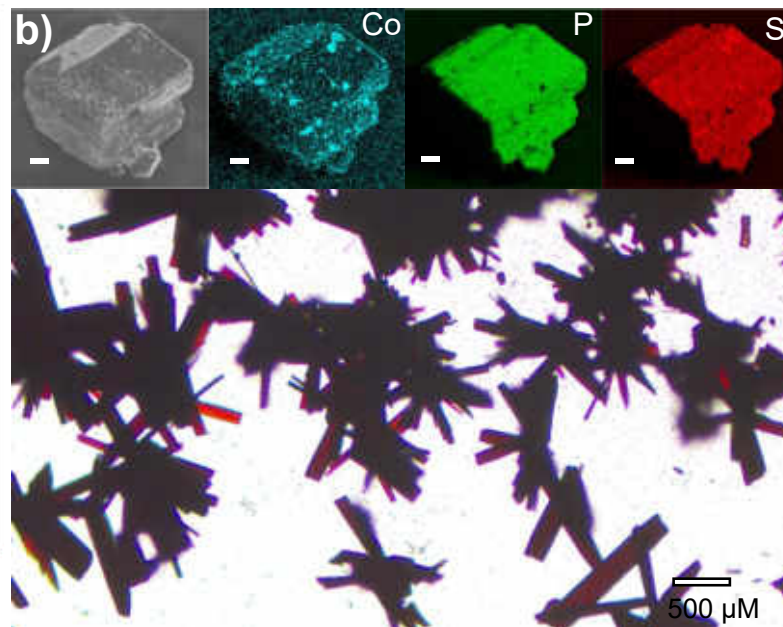
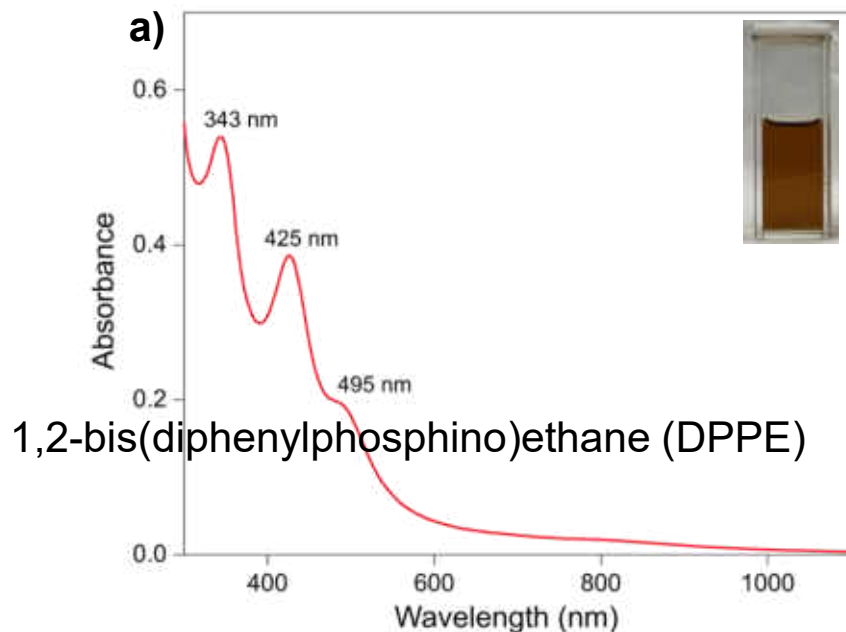
**Ultra compact Low Cost
Spectral Sensor Module**
~ **Billions units** (? 2027)



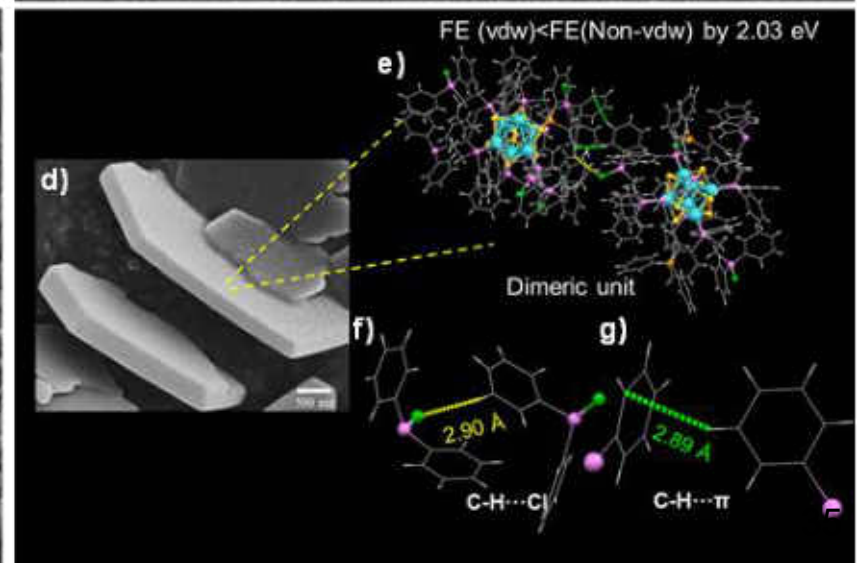
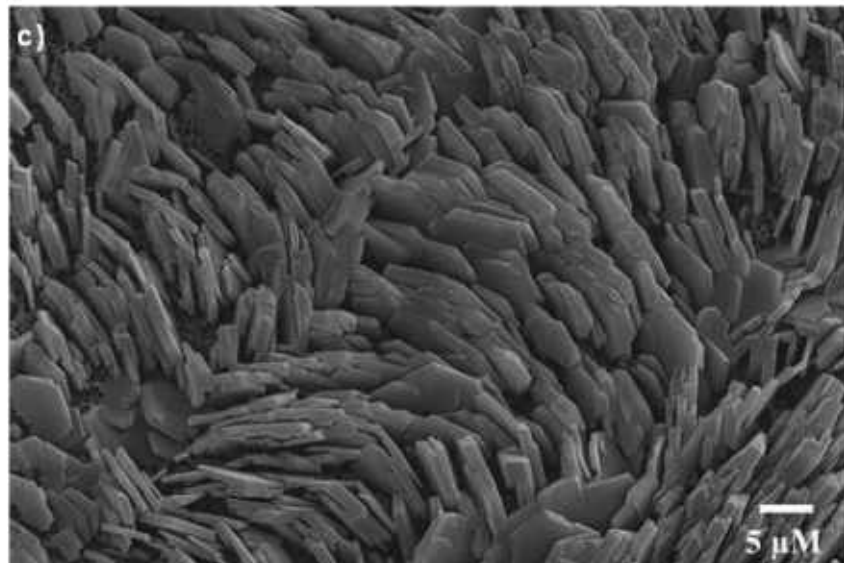
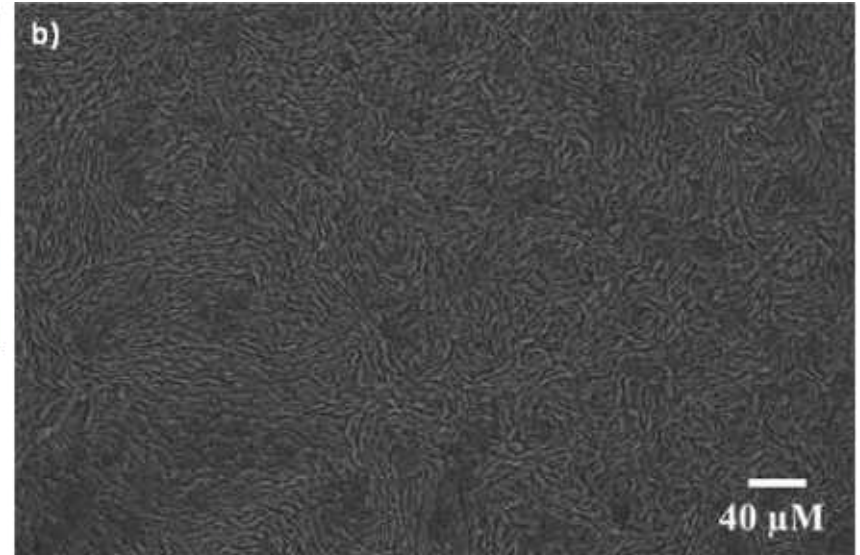
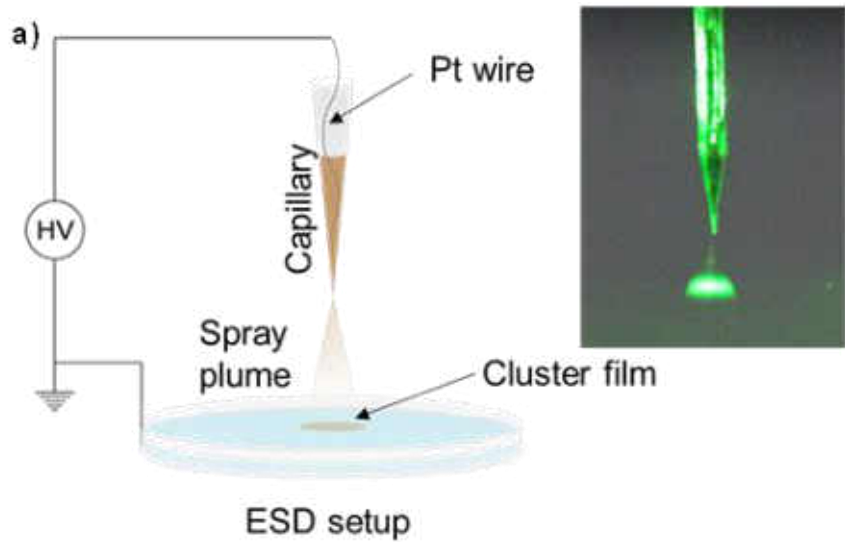
Water quality measurement – In the pipeline

nano λ

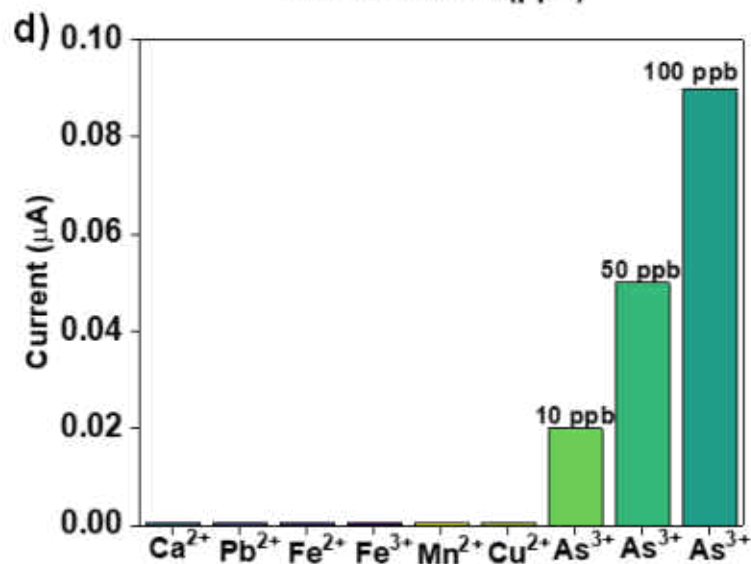
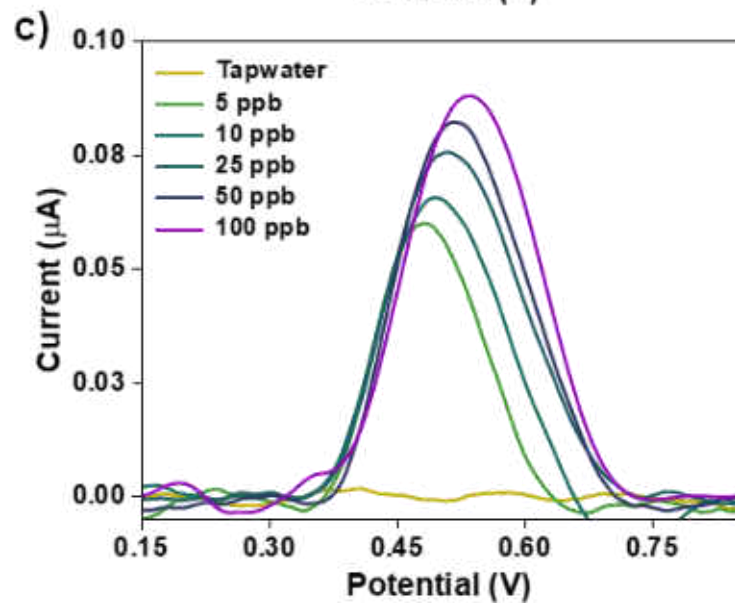
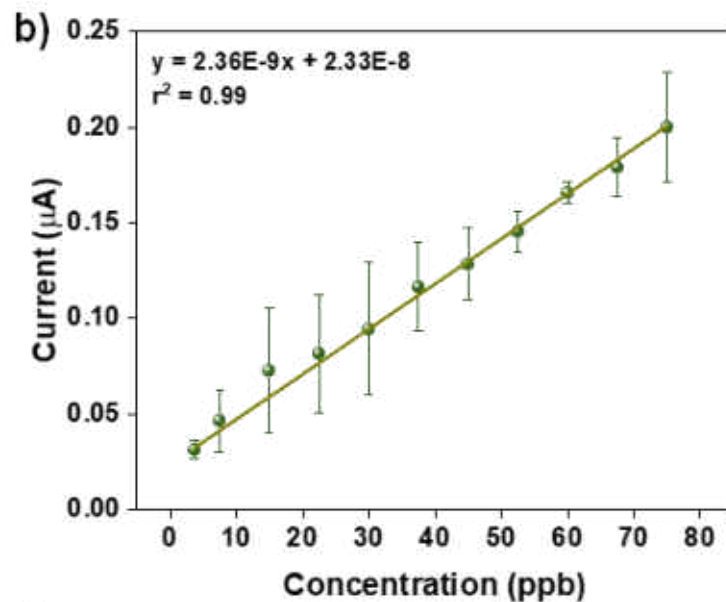
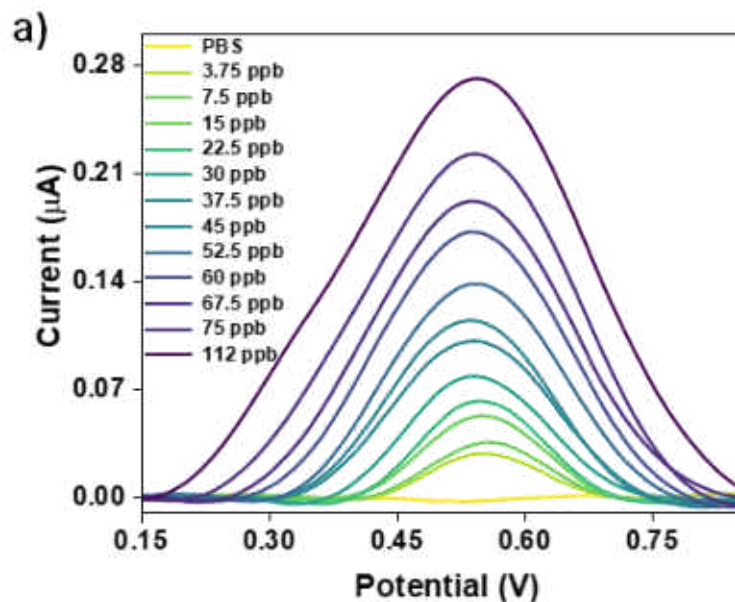
New electrodes - Aligned nanoplates of Co_6S_8



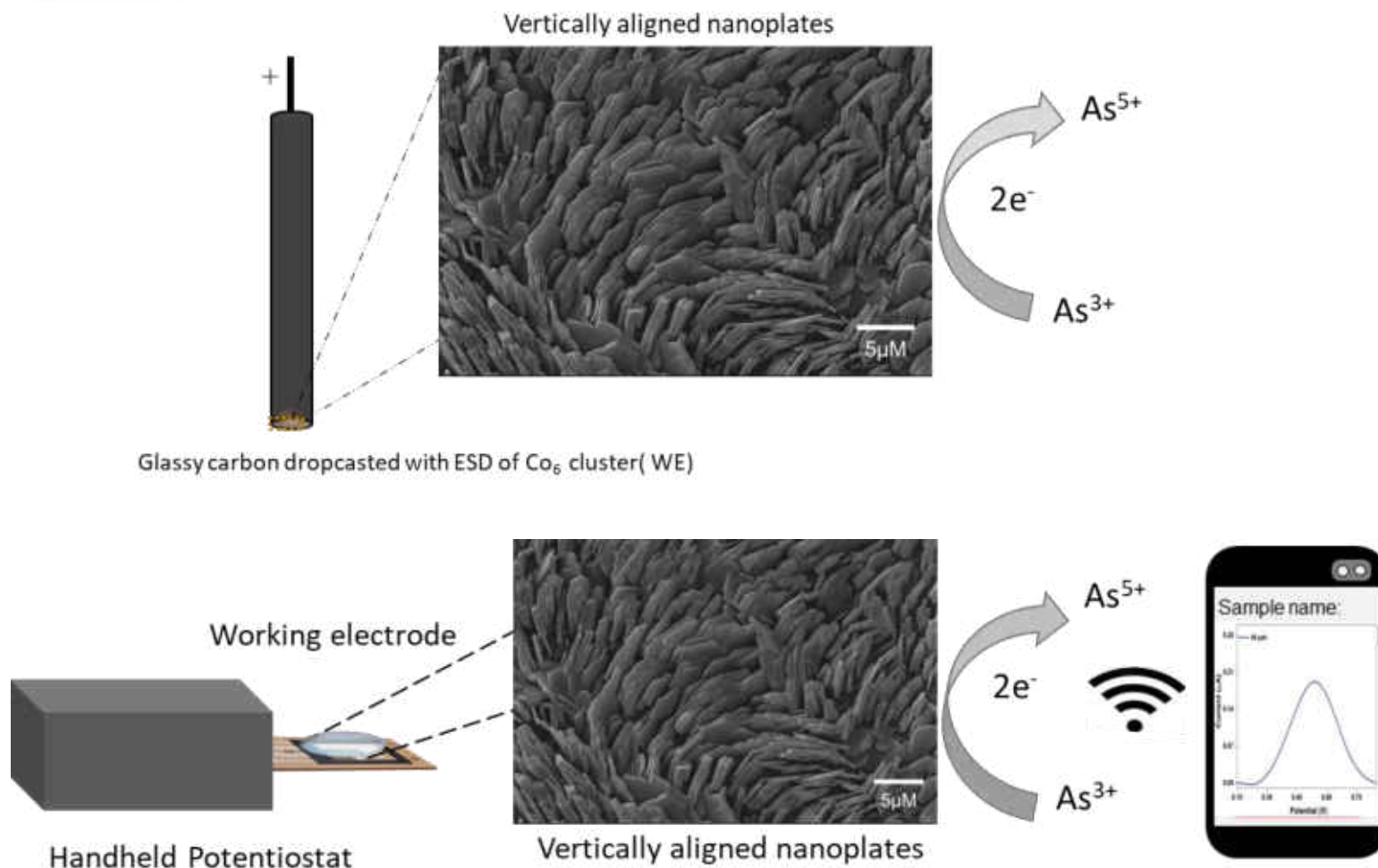
Electrospray deposition



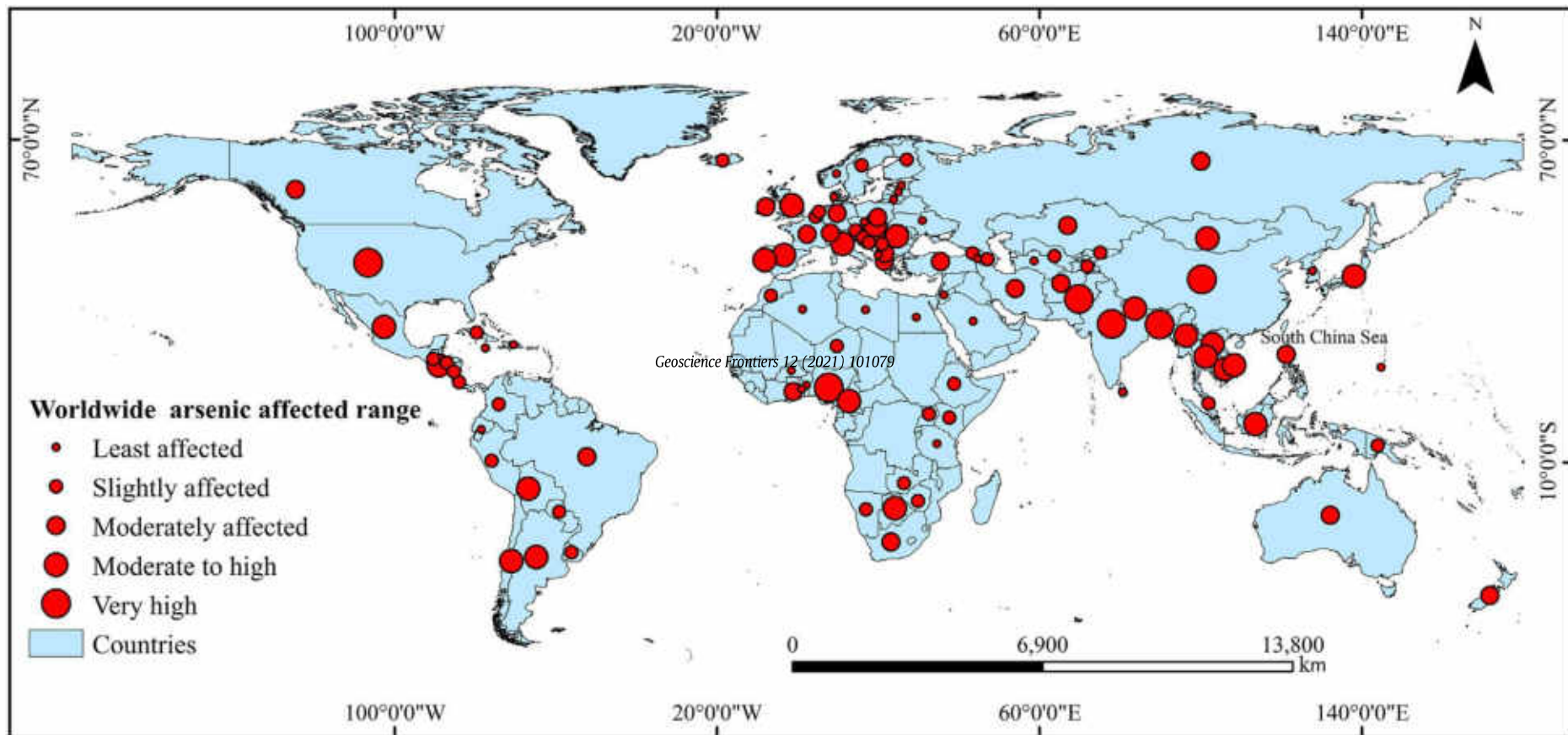
Sensing



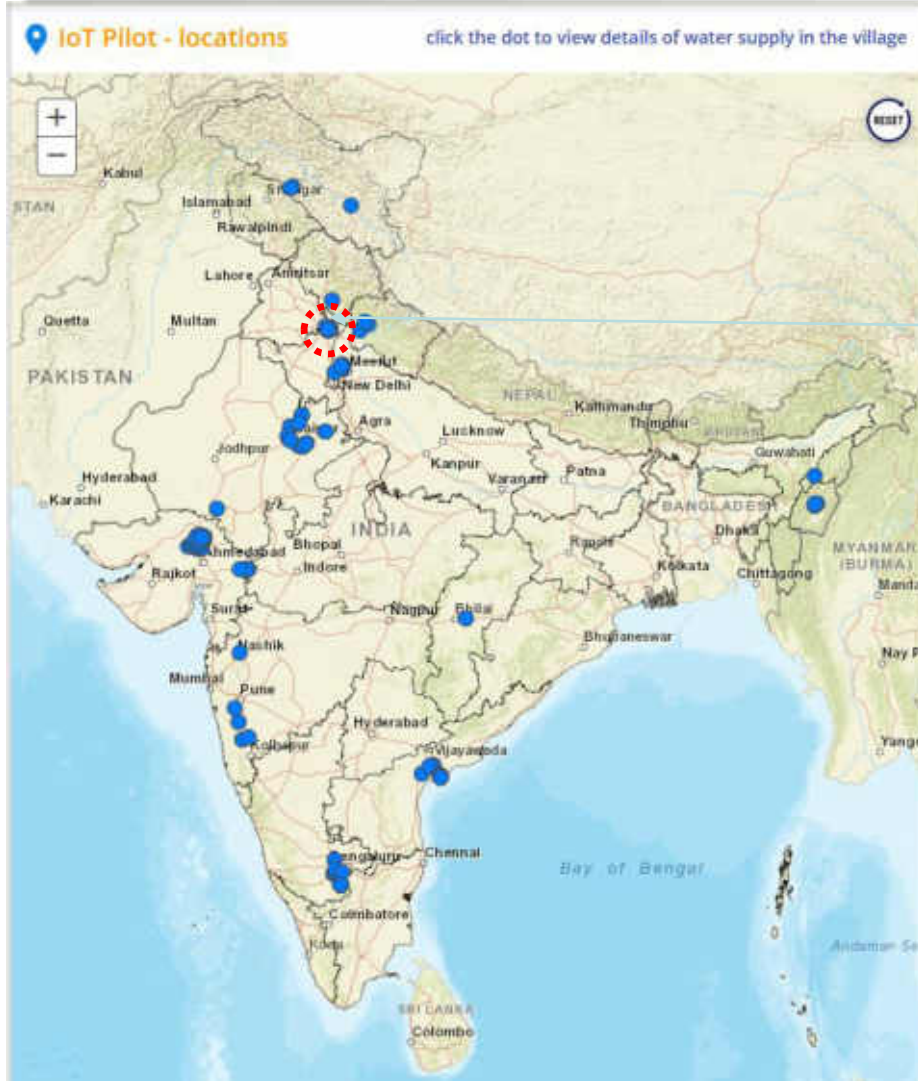
Working electrode



Arsenic poisoning across the world

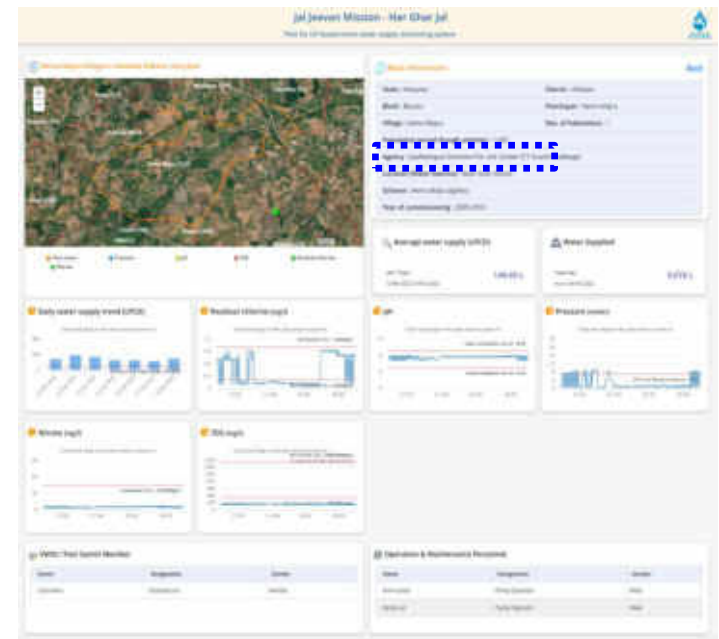


India's water is being monitored



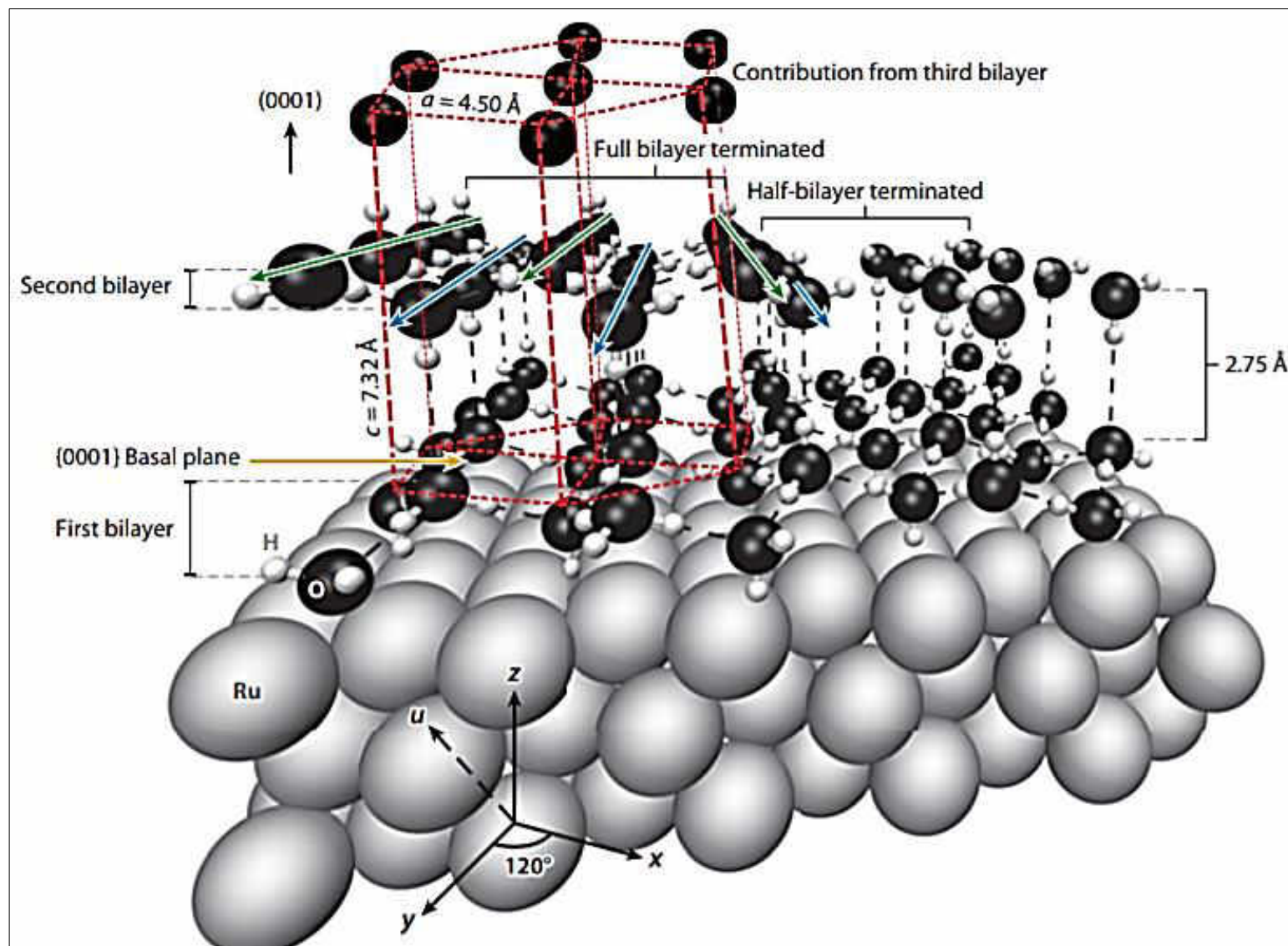
IITM/IISc

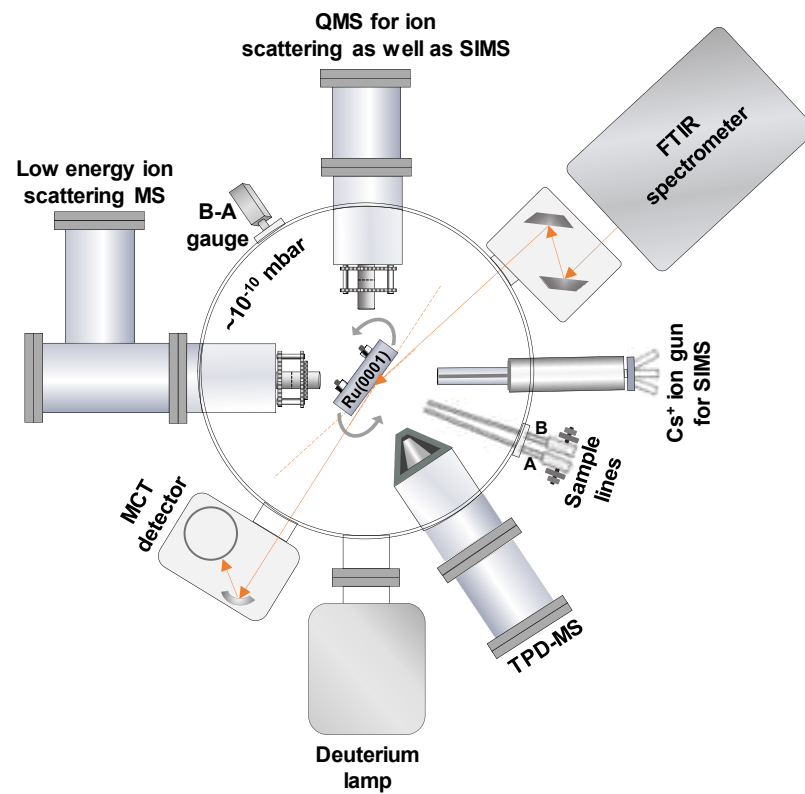
Installations made by four companies





International Centre for Clean Water





Formation and Transformation of Clathrate Hydrates under Interstellar Conditions

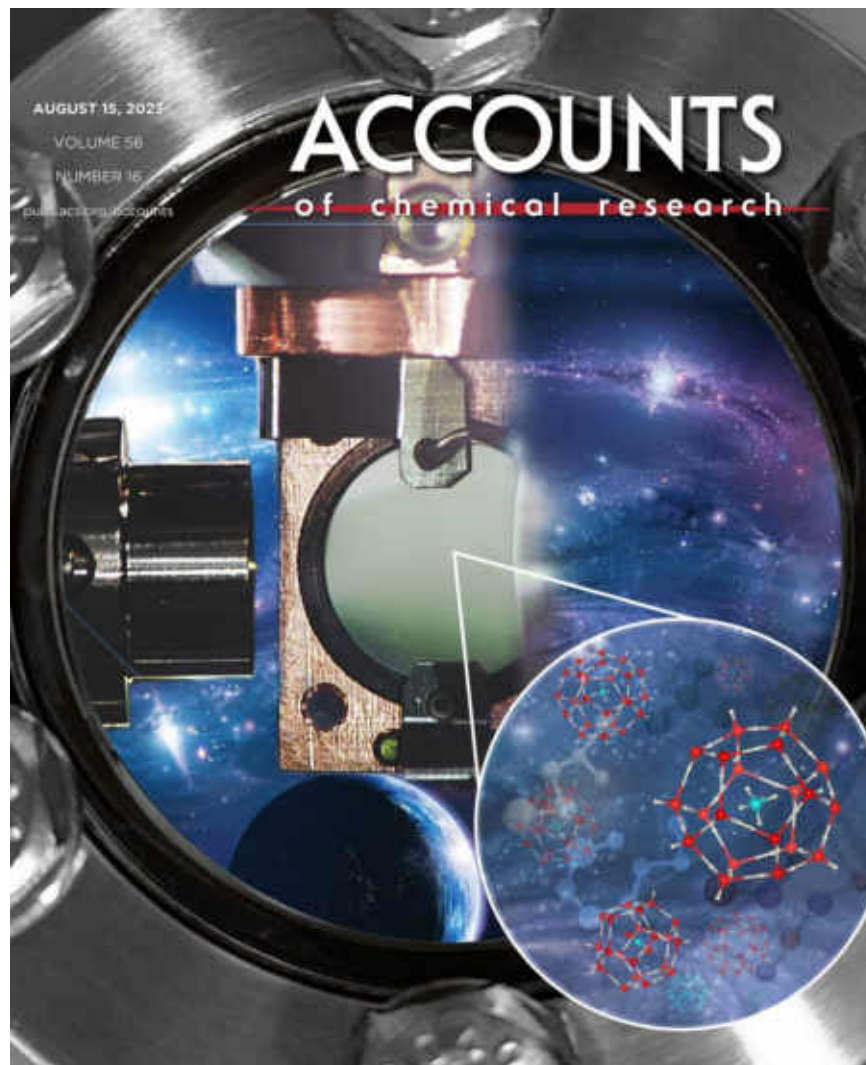
Jyotirmoy Ghosh, Gaurav Vishwakarma, Rajnish Kumar,* and Thalappil Pradeep*



Cite This: <https://doi.org/10.1021/acs.accounts.3c00117>

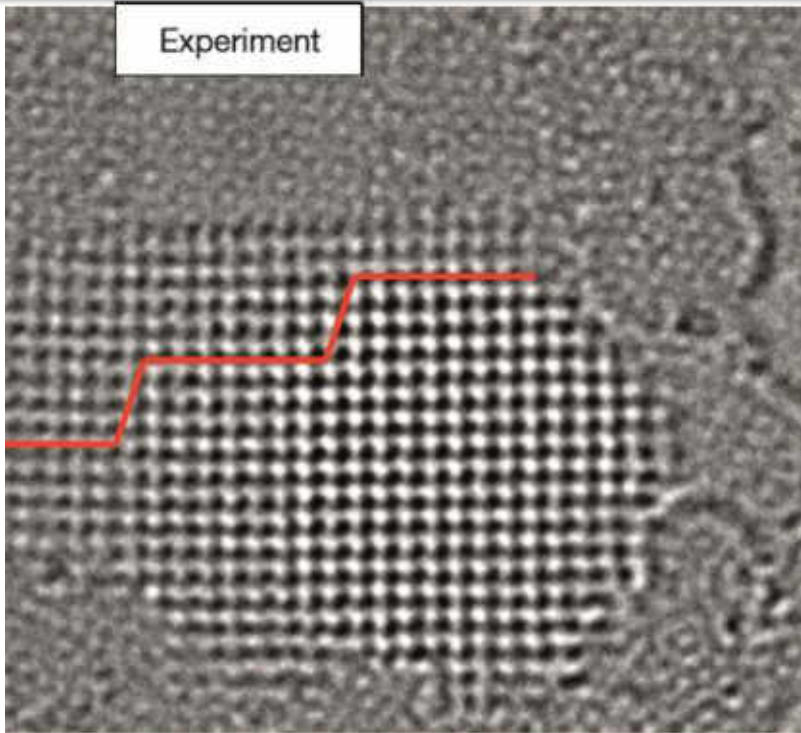


Read Online

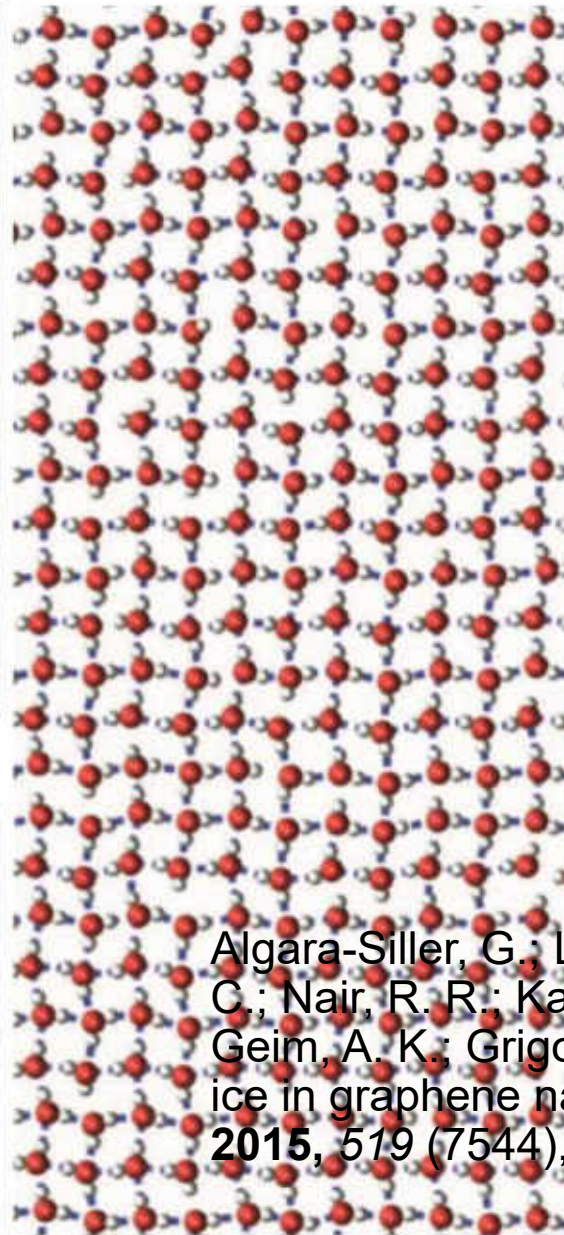
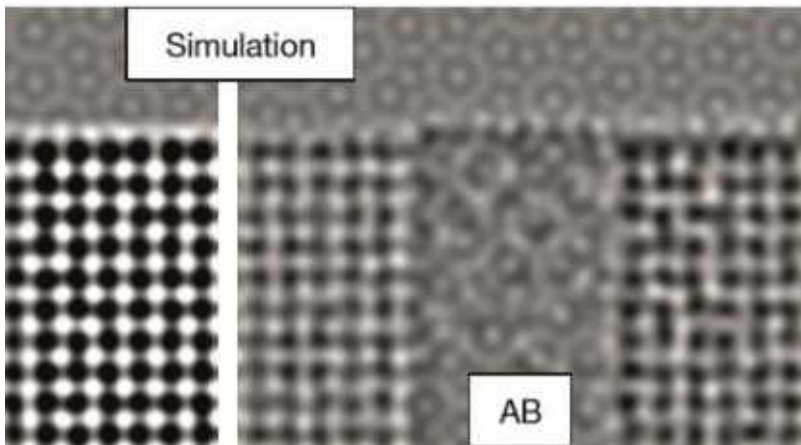




Observing clathrate hydrates?



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.



IIT Madras Research Park

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Tomas Base



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Olli Ikkala



Horst Hahn



Biswarup Pathak



K. V. Adarsh



G. U. Kulkarni



Vivek Polshettiwar



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Avula Anil Kumar, Chennu Sudhakar, Sritama Mukherjee, Anshup, and Mohan Udhaya Sankar

Funding: Department of Science and Technology, Government of India

Start-ups and partners:

PhD Theses: Bindhu Varughese, M. R. Resmi, M. Venkataramanan, N. Sandhyarani, R. Selvan, A. Sreekumaran Nair, M. J. Rosemary, Renjis T. Tom, C. Subramaniam, Jobin Cyriac, V. R. Rajeev Kumar, D. M. David Jeba Singh, Akshaya Kumar Samal, E. S. Shibu, M. A. Habeeb Muhammed, P. R. Sajanlal, T. S. Sreeprasad, J. Purushothaman, T. Udayabhaskararao, M. S. Bootharaju, Soumabha Bag, Robin John, Kamalesh Chaudhari, Ammu Mathew, Indranath Chakraborty, Radha Gobinda Bhuin, Ananya Baksi, Amitava Srimony, Anirban Som, Rabin Rajan Methikkalam, K. R. Krishnadas, Soujit Sengupta, Depanjan Sarkar, Atanu Ghosh, Rahul Narayanan, Avijit Baidya, Shridevi Bhat, Papri Chakraborty, Swathy Jakka Ravindran, C. K. Manju, Abhijit Nag, S. Vidhya, Jyoti Sarita Mohanty, Debasmita Ghosh, Jyotirmoy Ghosh, Md. Bodiuzzaman, Biswajit Mondal, Tripti Ahuja, Esma Khatun, Krishnan Swaminathan, K. S. Sugi, Amrita Chakraborty, Sudhakar Chennu, Sritama Mukherjee, Madhuri Jash, Sandeep Bose, Md. Rabiul Islam, Pallab Basuri, Mohd Azhardin Ganayee, Tanvi Gupte

>25 Post-doctoral fellows, >200 masters students and visitors





Indian Institute of Technology Madras



Associate Editor

ACS
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Chemistry & Engineering

Bhaskar Ramamurthi/V. Kamakoti

