ISAS INDIA Newsletter

Volume 22 , No. 2 *April-June, 2022*

From Editor's Desk

It gives me immense pleasure and boundless joy in bringing the second issue of the year. On this auspicious occasion of आजादी का अमृत महोत्सव, DAE family remembers its legendary founder, great visionary, father of India's Nuclear Power Programme, Dr. Jenhgir Homi Bhabha.

Homi Bhabha Park at Anushaktinagar, Trombay has been dedicated to sweet memories of Bhabha Ji. The park was inaugurated on 5^{th} June, 2022 by Dr. R. Chidambaram (Ex chairman AEC) in presence of Shri K.N. Vyas Chairman AEC, Dr. A. K. Mohanty and Shri B. K. Jain, Director, DCSEM. Bhabha was a great nature lover and nice coincidence that Homi Bhabha Park was inaugurated on world environment day. In park the sweet memories of Bhabha's legendary work and life are expressed through beautiful stone paintings, some of them are included in the newsletter. Many interesting, informative science news items have been compiled. Slightly old news, but quite interesting, US is planning to install a nuclear reactor on moon, which will benefit future human exploration and robotic missions to the moon as well as Mars. Question ," from where life originated on earth" has been matter of curiosity among scientists since ages. All the bases in DNA and RNA have been found in meteorites, pointing towards outer space for origin of life's precursors. New US Lab is geared to create many versions of atoms, never recorded on earth before.

Facility for Rare Isotope Beams (FRIB) at Michigan State University, will produce new isotopes by accelerating a beam of atomic nuclei to half the speed of light. Atomic clouds using strontium atoms have been stabilized to measure dilation of time as postulated by Einstien's theory of relativity. Researchers at the University of California at Santa Barbara in the US have reconstructed a representation of the electron's wave nature – its Bloch wavefunction – in a laboratory experiment for the first time. In our neighboring country Bangladesh, a nuclear reactor construction has begun with collaboration with Russia. In a tiny, lab-grown garden, the first seeds ever sown in Lunar dirt from Apollo missions have sprouted. One small stem for a plant, one giant leap for plant science. Carbon nanotubes have shown tremendous promise in the design and structure of atomic force microscopy (AFM) tips and probes. Novel theory of entropy may solve materials design issue as theory is capable of predicting the change of volume as a function of temperature at a multiscale level.

Dr. Pradeep Kumar
Chief Editor, ISAS Newsletter
and Vice President, ISAS

Message from President ISAS.

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Happy to note that the ISAS News Letter for April-June 2022 is ready for issue.

Thanks to Editor and hope that this issue will be received with good interest by the Members.

We look forward to execute activities that meet the interests of our Members.

I take this opportunity to request all Members of ISAS to regularly visit ISAS Website, isasbharat.in, and keep abreast with the latest activities of ISAS.

I convey my best wishes for a Healthy and Successful Life to all Members of ISAS and their families.

With best regards,

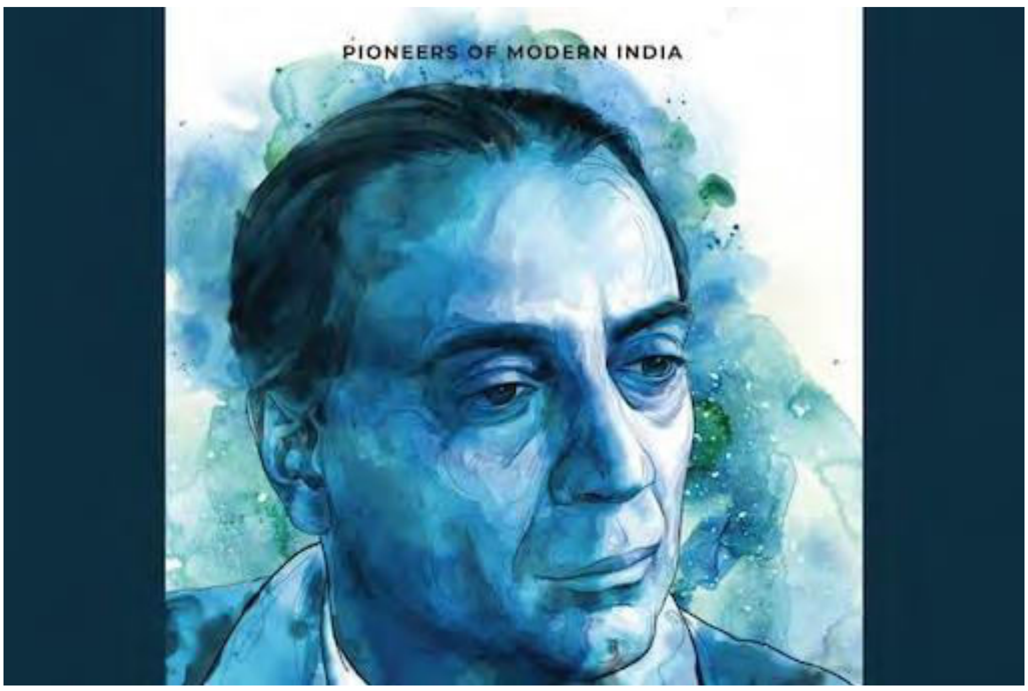
(Dr. P. P. Chandrachoodan)
President, ISAS.

Homi Bhabha had shown the Seeds for Making Inia a Nuclear Power

06 March, 2022 | by Biman Nath

Source website links: https://www.news18.com/news/opinion/even-before-independence-homi-bhabha-had-sown-the-seeds-for-making-indiaa-nuclear-power-4840274.html

Although India did not have much of uranium, which was a fissile material, its thorium reserve, which was among the largest in the world, gave India an advantage.



In the aftermath of the atomic bombs dropped on Japan, many countries began to develop the techniques of nuclear technology. There was a tremendous amount of secrecy around these developments as each country wanted to safeguard their interests for the military use of the nuclear bomb. For Indian scientists, this was a new opportunity that they did not want to miss. They had realized that the UK was out of the American plans of nuclear activities, and that the UK and Soviet Union were trying to develop their own nuclear reactors. All these countries had formed atomic energy commissions for themselves. The then British government in India did not object and interfere in the Indian scientists‘ activities regarding nuclear power, partly because they were more worried about the looming independence, and perhaps also because they thought Indian scientists would not go far.

They were aware of the developments in India though. Patrick Blackett met (Homi) Bhabha and Nehru in early 1947 and briefed the viceroy about the _atomic energy setup in India‘. In February 1947, D.N. Wadia, a geologist, reported to the committee about a thorium reserve in India. It was reported that the beaches of Kerala contained a large quantity of monazite, a mineral that had thorium. Although India did not have much of uranium, which was a fissile material, its thorium reserve, which was among the largest in the world, gave India an advantage. However, one cannot build a nuclear reactor using thorium (232) alone because of its physical properties. It has to be converted to uranium (233) in a reactor before it can be used as a fuel.

Bhabha asked the National Research Council of Canada in June 1947 for a ton of crude uranium oxide, so that he could start experimenting with nuclear fuel. An understanding was reached between the USA, UK and Canada regarding this, and Canada shipped uranium, perhaps hoping that this would gain them access to the Indian thorium supply in the future. Here, too, Bhabha‘s old Cambridge network helped him. W.B. Lewis, the head of the Atomic Energy of Canada Limited, was one of Bhabha‘s friends in Cambridge, and both had been in the rowing teams. Bhabha went to Ottawa to meet Lewis to ensure the shipment, and that too in secret, of uranium to India. Within a few days of India‘s independence, a Board of Research on Atomic Energy was set up on 26 August 1947, with Bhabha as chairman. Subsequently, Nehru opened a debate in the Constituent Assembly in April 1948. He introduced a legislation that was drafted by him, Bhabha and Shanti Swarup Bhatnagar, and which ultimately led to the formation of the Atomic Energy Commission (AEC) in India. This legislation was closely modelled after the British and American bills on atomic energy. Nehru stressed on the need for secrecy around nuclear research, that the government should have complete monopoly on its research, and why India needed to act without delay. It was however clear to parliamentarians that there was a link between peaceful application of nuclear energy and military uses. In the ensuing debate, one member criticized the question of state control, which he argued would signal India‘s military intentions. Another member suggested that India should not shy away from military applications.

Nehru in his reply did not deny…that the Indian nuclear programme has a military component from the moment of inception‘ (Nucleus and Nation). Nehru also defended the secrecy clause in a speech in 1954 while laying the foundation stone of TIFR, stating that although science does not flourish in secrecy, India‘s association with other countries in nuclear physics context demanded it: Those other countries are more advanced than we are, and if we have any association with them in regard to this work, they want us to keep it secret, even if we do not.‘ (Ibid.) There was fierce criticism from Meghnad Saha, who had been gradually side-lined by the powers that be and by the trio of Nehru, Bhabha and Bhatnagar, because of his outspoken nature. He had from the beginning criticized the idea of concentrating the nuclear research in one institution, or one umbrella organization, and especially the choice of Bombay as the centre of nuclear research in India, a place which he argued as being dangerous because of its coastal location.

In a letter to Shyamaprasad Mukherjee, Saha wrote on 10 April 1947, that ‗…there is a very dangerous clause in the speech of Pt Nehru in introducing the Atomic Energy Bill that all research would be more or less concentrated. I believe that he has done so under the influence of Bhabha and Bhatnagar' (Abinash Meghnad Saha). By late 1947, the tension between Saha and Bhabha had become more than apparent, when Bhabha reacted negatively to Saha's application for funds for his institute to UNESCO, a reaction that Saha took as a sign of malice.

In 1948, Bhabha became one of the examiners of the PhD thesis of a student of Saha. While Bhabha thought it was unpublishable, other examiners including Bruno Rossi, a pioneer in the studies of cosmic rays, praised the thesis. Saha's point was that elsewhere in the world, nuclear research was being planned to be conducted under their atomic energy bills at several universities and institutes, with a few selected leaders in the field. He gave the example of the UK, where under their atomic energy bill, six universities had been selected, under the supervision of six scientists: Oxford (Lindeman), Cambridge (Frisch), Liverpool (Chadwick), Birmingham (Oliphant), Glasgow (Dee) and Edinburgh (Feather).

However, in India, all nuclear research was going to be concentrated in one institute in Bombay under Bhabha's leadership. Saha feared that his nuclear research would be pushed to become an irrelevant exercise. He was already facing a problem of getting the grant money from CSIR transferred to his institute, although it had been officially sanctioned by Bhatnagar. Saha's model was to build up the capability of nuclear research from bottom up—by teaching nuclear physics in universities, and training the best among students. In contrast, Bhabha's model was more top-down, with a centralized structure and concentrated at one place. Saha's view was that ‗India first needed to grow an independent industrial strength and also to train personnel in nuclear physics in universities' (Nucleus and Nation). He felt that neither Bhabha nor Bhatnagar were in universities, and building research institutes separated from the centres of learning would only produce ivory towers. Some of these concerns have proved to be right, in hindsight, but he was either not persuasive enough at that time, or the policy makers considered him a lone dissenter and marginalized him.

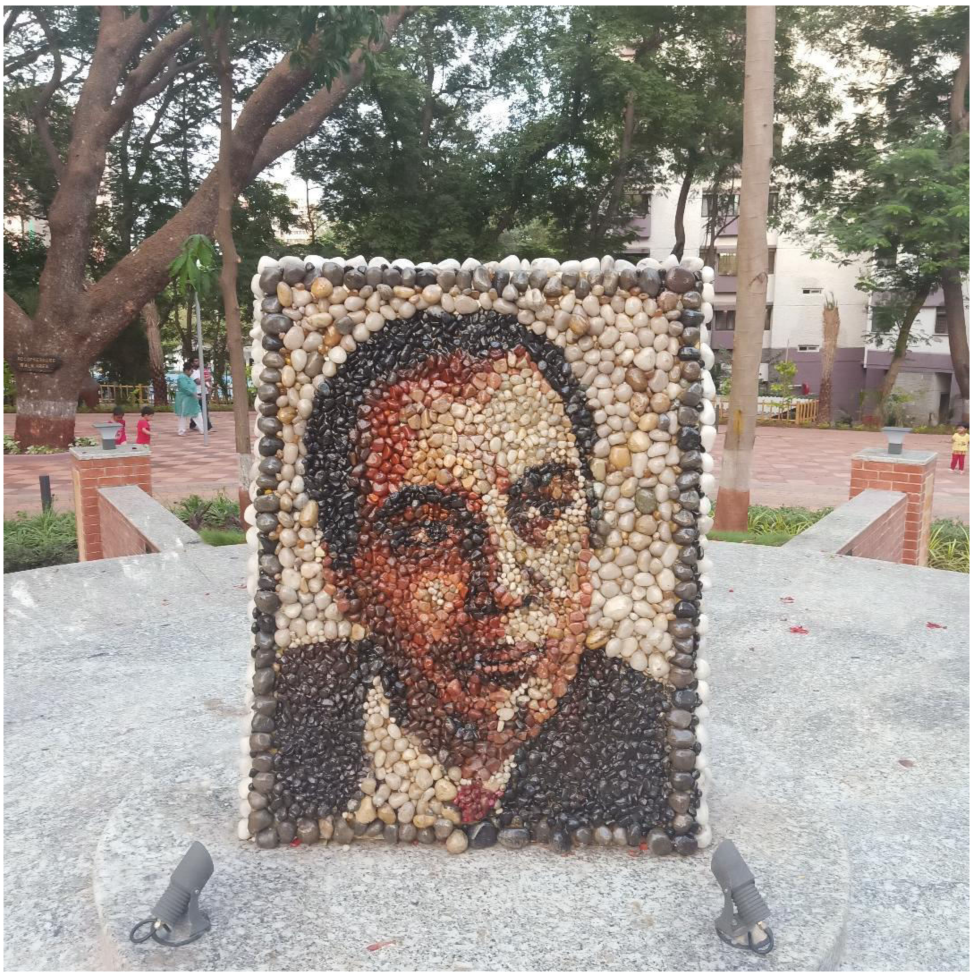
This excerpt from Biman Nath's Homi J. Bhabha: A Renaissance Man among Scientists has been published with the permission of Niyogi Books

Glimps from Homi Bhabha Park at Anushakti Nagar, Mumbai

(Inaugurated on 5th June, 2022 by Dr. R. Chidambaram (Ex chairman AEC) in presence of Shri K.N. Vyas Chairman AEC, Dr.A.K.Mohanty and Shri B. K. Jain, Director, DCSEM)

(by Dr. Pradeep Kumar, Vice President ISAS and Chief Editor ISAS

Senior scientist at Bhabha Atomic Research Centre, Trombay)



Homi Jehangir Bhabha ,

The Great Visionary, Father of Indian Nuclear Power Programme

Bhabha with great scientists, Enistien, Yukawa, Wheeler

Bhabha Graduated in Mechanical Engineering from Cambridge

Bhabha Inspecting Construction work at BARC, TROMBAY

Bhabha Conducting balloon Flight experiment at IISc

Bhabha engrossed in discussion with JRD Tata

Bhabha with Dr. Vikram Sarabhai discussing on space reeasrch programme

Bhabha in front of 1MeV Particle Accelerator

Bhabha had great Love for Music

Bhabha loved Paining. His paining of Dr.C.V.Raman

US government paves way for the first nuclear reactor on moon

Source website links: https://www.jagranjosh.com/current-affairs/us-government-paves-way-for-the-first-nuclear-reactor-on-moon-1609317715-1

The nuclear reactor or the fission power system will benefit future human exploration and robotic missions to the moon as well as Mars

The plan of the United States to have the first nuclear reactor on the moon by the end of the year 2026 got a push from the recent directive from the White House. For the nuclear reactor plan, the US Department of Energy in collaboration with the National Aeronautics and Space Administration intends on soliciting the industry design proposal in early 2021. In the latest directive by the White House, Donald Trump, the outgoing US President issued the 'National Strategy for the Space Nuclear Power and Propulsion'. Under it, NASA has been asked to initiate the fission power project for the moon surface demonstration by 2027. It will have the scalability to a power range of 40 kW-electric and higher to provide support to a sustained presence on the moon and exploration of the planet Mars.

What does the order from the White House states?

The order by the United States government emphasizes the need of developing uranium fuel processing capabilities that will enable the production of suitable for the planetary and lunar surface. The development of uranium fuel processing capabilities is significant as the ability to use the propulsion systems and space nuclear power securely, safely, and sustainably is important for maintaining and advancing the United States leadership and dominance in space

Significance of having a nuclear reactor in space:

NASA aims at establishing a flight hardware system that will be ready for integration with the lunar lander by the end of 2026. The nuclear reactor or the fission power system will benefit future human exploration and robotic missions to the moon as well as Mars. The availability of efficient, safe, and readily available power is crucial to the missions and the fission surface power system meets those requirements.

Development of Fission Surface Power System

•The Fission surface power system as the nuclear reactor is called will be assembled and completely manufactured on Earth and will be integrated on a lander as a payload.

• The system will be designed to operate and deploy from the payload platform after the lander arrives on the moon's surface.

• The system will be consisting of four major subsystems- a nuclear reactor, heat rejection array, an electric power conversion unit, and power management and distribution system. It will be designed and developed to operate for up to the time period of 10 years.

• All the safety requirements will be strictly followed. The fission process will be initiated only after the nuclear system lands on the moon on a command from the supervision on Earth.

• The Region of the moon where the reactor will be placed has been worked out.

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All of the bases in DNA and RNA have now been found in meteorites

By Liz Kruesi

April 26, 2022 at 11:00 am, Science News

The discovery adds to evidence that suggests life's precursors came from space

More of the ingredients for life have been found in meteorites.

Space rocks that fell to Earth within the last century contain the five bases that store information in DNA and RNA, scientists report April 26 in Nature Communications.

These "nucleobases" — adenine, guanine, cytosine, thymine and uracil — combine with sugars and phosphates to make up the genetic code of all life on Earth. Whether these basic ingredients for life first came from space or instead formed in a warm soup of earthly chemistry is still not known (SN: 9/24/20). But the discovery adds to evidence that suggests life's precursors originally came from space, the researchers say.

Scientists have detected bits of adenine, guanine and other organic compounds in meteorites since the 1960s (SN: 8/10/11, SN: 12/4/20). Researchers have also seen hints of uracil, but cytosine and thymine remained elusive, until now.

"We've completed the set of all the bases found in DNA and RNA and life on Earth, and they're present in meteorites," says astrochemist Daniel Glavin of NASA's Goddard Space Flight Center in Greenbelt, Md.

A few years ago, geochemist Yasuhiro Oba of Hokkaido University in Sapporo, Japan, and colleagues came up with a technique to gently extract and separate different chemical compounds in liquified meteorite dust and then analyze them.

Our detection method has orders of magnitude higher sensitivity than that applied in previous studies," Oba says. Three years ago, the researchers used this same technique to discover ribose, a sugar needed for life, in three meteorites (SN: 11/22/19).

In the new study, Oba and colleagues combined forces with astrochemists at NASA to analyze one of those three meteorite samples and three additional ones, looking for another type of crucial ingredient for life: nucleobases.The researchers think their milder extraction technique, which uses cold water instead of the usual acid, keeps the compounds intact. "We're finding this extraction approach is very amenable for these fragile nucleobases," Glavin says. "It's more like a cold brew, rather than making hot tea." With this technique, Glavin, Oba and their colleagues measured the abundances of the bases and other compounds related to life in four samples from meteorites that fell decades ago in Australia, Kentucky and British Columbia. In all four, the team detected and measured adenine, guanine, cytosine, uracil, thymine, several compounds related to those bases and a few amino acids.

Using the same technique, the team also measured chemical abundances within soil collected from the Australia site and then compared the measured meteorite values with that of the soil. For some detected compounds, the meteorite values were greater than the surrounding soil, which suggests that the compounds came to Earth in these rocks.

But for other detected compounds, including cytosine and uracil, the soil abundances are as much as 20 times as high as in the meteorites. That could point to earthly contamination, says cosmochemist Michael Callahan of Boise State University in Idaho. "I think [the researchers] positively identified these compounds," Callahan says. But "they didn't present enough compelling data to convince me that they're truly extraterrestrial." Callahan previously worked at NASA and collaborated with Glavin and others to measure organic materials in meteorites.

But Glavin and his colleagues point to a few specific detected chemicals to support the hypothesis of an interplanetary origin. In the new analysis, the researchers measured more than a dozen other life-related compounds, including isomers of the nucleobases, Glavin says. Isomers have the same chemical formulas as their associated bases, but their ingredients are organized differently. The team found some of those isomers in the meteorites but not in the soil. "If there had been contamination from the soil, we should have seen those isomers in the soil as well. And we didn't," he says.

Going directly to the source of such meteorites — pristine asteroids — could clear up the matter. Oba and colleagues are already using their extraction technique on pieces from the surface of the asteroid Ryugu, which Japan's Hayabusa2 mission brought to

Earth in late 2020 (SN: 12/7/20). NASA's OSIRIS-REx mission is expected to return in September 2023 with similar samples from the asteroid Bennu (SN: 1/15/19).

"We're really excited about what stories those materials have to tell," Glavin says.
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New US Lab to Create Versions of Atoms Never Recorded on Earth

Source website links: https://www.theguardian.com/science/2022/may/16/new-us-lab-aims-create-versions-atoms-never-recorded-on-earth

From carbon to uranium, oxygen to iron, chemical elements are the building blocks of the world around us and the wider universe. Now, physicists are hoping to gain an unprecedented glimpse into their origins, with the opening of a new facility that will create thousands of peculiar and unstable versions of atoms never before recorded on Earth.

By studying these versions, known as isotopes, they hope to gain new insights into the reactions that created the elements within exploding stars, as well as testing theories about the ―strong force – one of the four fundamental forces in nature, which binds protons and neutrons together in an atom's nucleus. The facility could also yield new isotopes for medical use. Atoms are composed of protons, neutrons and electrons. The number of protons dictates an atom's chemical behaviour and which element it is – eg carbon always has six protons, and gold 79 – whereas atoms of the same element containing different numbers of neutrons are called isotopes. Because many isotopes are unstable and decay quickly –sometimes within fractions of a second – scientists have only studied a small proportion of those thought to exist.―There are 285 isotopes of elements that exist on Earth, but we think that there are ***potentially 10,000 isotopes*** for the elements up to uranium, said Prof Bradley Sherrill, the scientific director of the Facility for Rare Isotope Beams (FRIB) at Michigan State University, which officially opened on 2 May. ―The goal of FRIB is to provide as

Researchers at the Facility for Rare Isotope Beams. Photograph: Mel Russell III/FRIB

wide of an access to this vast landscape of other isotopes as technology allows.

Some of these ―rare isotopes may drive reactions crucial to the formation of elements, so by studying them physicists hope to gain a better understanding of the chemical history of the universe – including how we got here. The vast majority of elements are thought to have been created within exploding stars, but ―in many cases we don't know which stars created which elements, because these reactions involve unstable isotopes – things we couldn't readily get our hands on, said Prof Gavin Lotay, a nuclear physicist at the University of Surrey, who plans to use the new facility to investigate common explosions called X-ray bursts within neutron stars. Another goal is to understand atomic nuclei well enough to develop a comprehensive model of them, which could provide fresh insights into the role they play in the creation of energy for stars, or the reactions occurring within nuclear power plants. The facility could also yield medically useful isotopes. Already, doctors use radioactive isotopes in eg Pet scans and some types of radiotherapy, but the discovery of additional ones could help improve diagnostic imaging, or provide new ways of seeking out and destroying tumours.

To generate these isotopes, FRIB will accelerate a beam of atomic nuclei to **half the speed of light** and send them shooting down a 450-metre pipe, before crashing them into a target that causes some of the atoms to fragment into smaller combinations of protons and neutrons. A series of magnets will then filter out the desired isotopes and direct them into experimental chambers for further study. ―Within a millionth of a second, we can select a particular isotope and deliver it to an experiment where [scientists] may catch it and watch for its radioactive decay, or we may use it to induce another nuclear reaction and use those reaction products to tell us something about the structure of the isotope, Sherrill said. The first experiments will involve making the heaviest possible isotopes of fluorine, aluminium, magnesium and neon, and comparing their rates of radioactive decay with those predicted by existing models. —The surprise will be if our observations agree with what we expected, Sherrill said. —Most likely they won't agree, and then we'll use that disagreement to refine our models. Approximately a month later, FRIB researchers plan to measure the radioactive decay of isotopes thought to exist within neutron stars – some of the densest objects in the universe, formed when a massive star runs out of fuel and collapses – to better understand their behaviour. —Finally we have the tools to enable people to do research that they've been waiting 30 years to do, said Sherrill. —It's like having a new, bigger telescope that can see further into the universe than ever before – only we'll be seeing further in the nuclear landscape than we've ever been able to look before. Whenever you have a new tool like that, there's the potential for discovery.

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Atomic Clouds Stabilized to Measure Dilation of Time

NEWS AND VIEWS

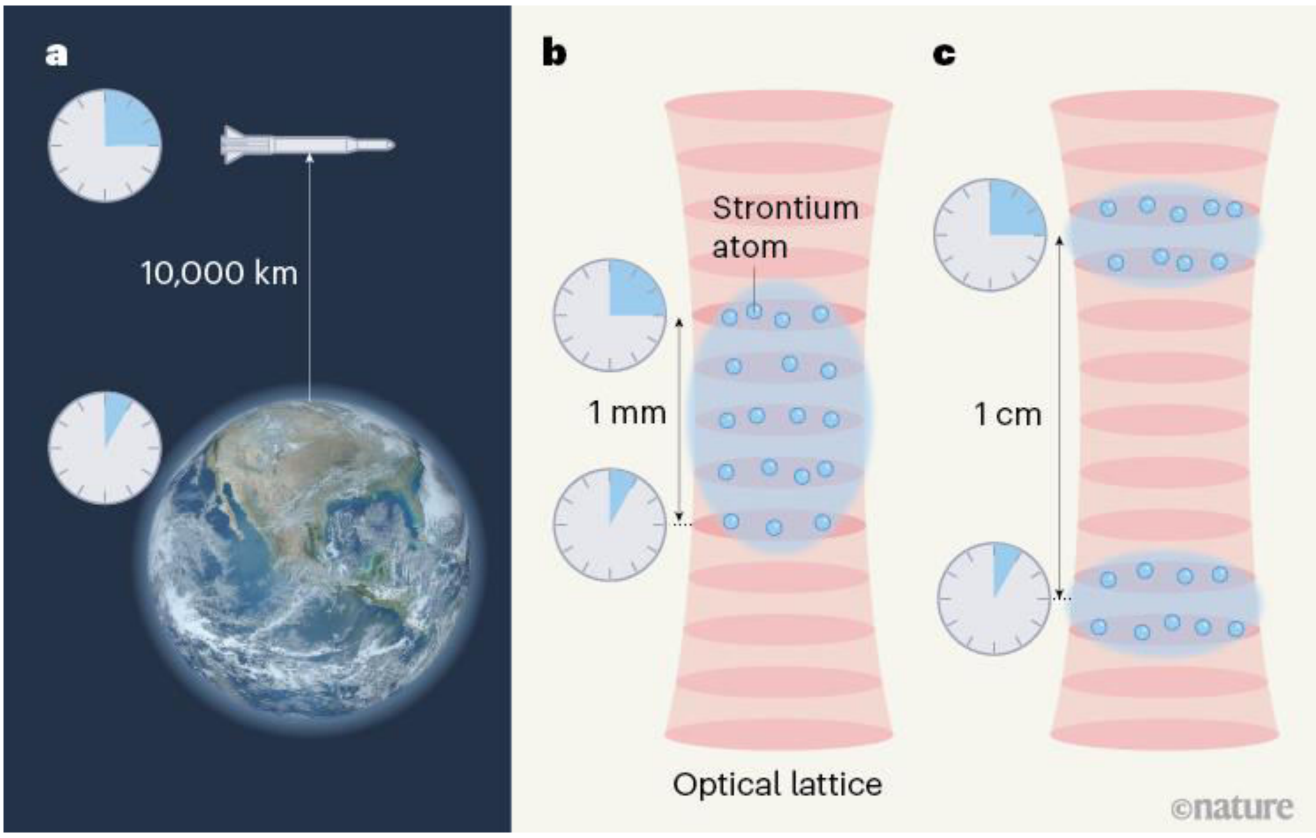
16 February 2022 , Nature 602, 391-392 (2022)

Tests of relativity once required accurate clocks separated by thousands of kilometres. Optical techniques have now made such tests possible in an atomic cluster measuring no more than one millimetre in size.

As Albert Einstein predicted in his theory of general relativity, the gravitational field of a massive object distorts space-time, which causes time to move more slowly as one gets closer to the object. This phenomenon is known as gravitational time dilation, and it is measurable — particularly in the vicinity of a very massive object such as Earth. The measurement requires a sufficiently accurate clock, and, today, the most accurate timekeepers are atomic clocks, which keep time by detecting the transition energy between two electronic states in an atom. Bothwell et al.1 and Zheng et al. now report astounding progress in the stability of atomic clocks using ensembles of ultracold strontium atoms. Bothwell and colleagues even managed to measure the degree to which time is dilated by gravity — a quantity known as gravitational redshift — in a single atomic cloud.

Gravity Probe A was the first such experiment sensitive enough to measure gravitational redshift. In 1976, a spacecraft carrying a maser (the microwave equivalent of a laser) reached a height of 10,000 kilometres above Earth's surface (Fig. 1a). At this height, the highly accurate signal produced by the maser, which acts as a clock, was expected to be faster than an equivalent clock on Earth by around one second every 73 years. The Gravity Probe A team found that the clock on the spacecraft differed from the one on

Earth by the predicted amount to an accuracy of 70 parts per million. Although this might seem a very small difference, an error of this magnitude would cause a GPS navigation system to calculate the wrong coordinates, so the GPS clocks on satellites flying 20,000 kilometres above Earth are corrected for the gravitational redshift.

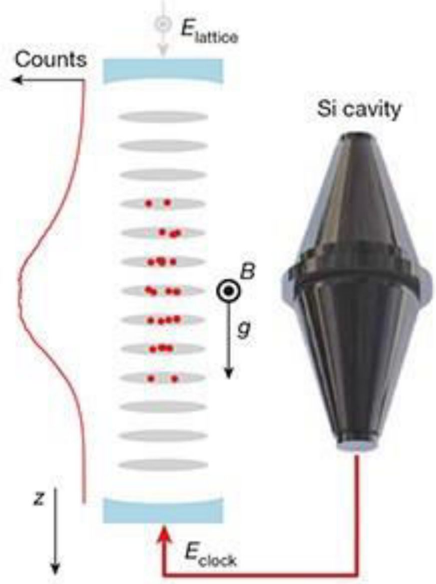


Measuring time differences in vertically separated clocks. a, The Gravity Probe A experiment3 measured gravitational redshift (a metric for how gravity changes time) using two clocks separated by a vertical distance of 10,000 kilometres — one was on a spacecraft and the other remained on Earth's surface. The clock on the spacecraft ran faster than the clock on Earth. b, Bothwell et al.1 showed that it is possible to measure gravitational redshift even on the submillimetre scale, by probing the timing of electronic transitions in a single cloud of strontium atoms trapped in an optical lattice (formed by the interference pattern of lasers). This required the team to measure an effect that was 20 billion times less pronounced than that detected in the Gravity Probe A experiment. c, Zheng et al.2 demonstrated a similar set-up for such measurements using clouds of strontium atoms separated by one centimetre.

The transitions between two electronic states in an atom that are the basis for an atomic clock are known as clock transitions, and they are typically induced by the oscillating light wave of a laser. In the case of neutral atomic clocks, a large ensemble of atoms is trapped in the interference patterns of oppositely propagating laser light, known as an optical lattice. The atoms are then exposed to a laser that is generating electromagnetic waves with an ultrastable frequency. State-of-the-art optical clocks can achieve a performance corresponding to an error of less than one second over the lifetime of the Universe4.

Such accuracy has become possible through exquisite control of experimental conditions, effectively extending the time over which the quantum behaviour of the atomic ensemble can be predicted, which is known as the quantum coherence time. The longer the coherence time, the more stable and accurate the clock. Pioneering research in 2010 showed that a comparison of two atomic clocks separated in height enables the gravitational redshift to be measured on a scale of less than one metre5. The advance reported by Zheng et al. improves on this approach — and Bothwell and co-workers even bring it below the millimetre scale — with the help of record coherence times in ensembles of ultracold strontium atoms

Bothwell and colleagues trapped strontium atoms in an optical lattice, forming a millimetre-scale atomic sample that was oriented along the direction of gravity (Fig. 1b). The authors succeeded in imaging the entire atomic ensemble in situ, with layer-by-layer spectroscopy that resulted in a resolution of 6 micrometres, corresponding to approximately 15 lattice sites. This approach allowed them to mitigate experimental errors and construct a map of atomic-transition frequencies across the cloud. The measured frequency gradient was consistent with the gravitational redshift predicted for two identical clocks separated vertically near Earth's surface.



To detect the redshift in a single atomic sample measuring only one millimetre in size, Bothwell and colleagues needed to measure an effect that was 20 billion times less pronounced than the gravity-induced frequency shift that the Gravity Probe A team had discerned. This is also a remarkable leap beyond previous measurements in ytterbium optical lattice clocks on a subcentimetre scale6.

Zheng et al. also used strontium atomic ensembles trapped in an optical lattice, but in this case the clouds were vertically separated by one centimetre (Fig. 1c). They showed that up to six strontium atomic ensembles can be compared at the same time. Even more remarkably, they found that the ensembles can consist of different isotopes. The work is a feat of engineering, presenting a multiplexed optical-lattice-clock configuration that enables record quantum coherence times of up to 26 seconds — providing extraordinary clock stability. The authors minimized the effects of noise associated with the phase and amplitude of the laser by inducing and measuring transitions simultaneously.

Although Zheng et al. achieved excellent quantum coherence times and clock stability, factors preventing accurate measurement of gravitational redshift still need to be assessed before the authors' multiplexed optical-lattice clock can offer subcentimetre-scale precision. For example, the behaviour of different strontium isotopes can vary, even if the conditions are held constant. The conditions in Zheng and co-workers' set-up differ across the lattice, and it can be difficult to control the effect that this has on the behaviour of the isotopes.

These two papers show that progress in the stability and accuracy of atomic clocks has not stopped since Gravity Probe A first launched more than 40 years ago. The reported improvements in measurement precision offer new opportunities for the development of clock-based detectors and extremely sensitive quantum sensors.

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Time Dilation and Hindu Mythology

(Dr. Pradeep Kumar, Vice President ISAS and Chief Editor ISAS
Senior scientist at Bhabha Atomic Research Centre, Trombay)

In Hindu mythology the concept of time dilation seems to be expressed in coded language in terms of stories. During my graduation, when the Einstien's Special Theory of Relativity was taught to us, obviously it was difficult to digest how time can vary. Our professor told us that when Einstein put forward his theory, only four persons all over the world were able to understand. Suddenly some storied flashed into my mind.

Perhaps "maya" in scriptures is related to time variation. We often come across term "Krishna ki Maya". Krishna is called owner of Kal or time. Krishna is said to be beyond space and time i.e. Krishna transcend space and time. There is a story in Mahabharat that Yudhistra insisted Lord Krishna to reveal his Maya. Lord Krishna asked Yudhishtra to take bath in the river. Yudhishtra dove into river, he finds himself that he had born in chandal family. His brothers snatched his property and kicked out from house. With broken heart he marched towards city in search of some job. On the reaching city gate, the sainiks welcomed him and made him King of that country. The king of that country had died and pundit told that first person entering the city should be made King. He ruled the country for 25 years, got married and had children. One day one of his brother visited the city and recognised him. On truth revelation, people of the country got terribly annoyed and started throughing stones, swords on him. He ran away to save his life. When Yudhishtra raised his head, he found Krishna smiling in front of him. On diving he saw people running after him to kill him. Suddenly one person appeared in front of theme and told that he was coming from very distant country where a chandal ruled the country for 25 years and afterward his identity got revealed. People are searching the person to punish him.

In one story in Bhagvatam, Bal gavals were very close to Krishna and treated him like normal cowherd boy. Brahma got annoyed that the very simple boys in very close company of Lord Krishna. Brahma took all the cows and the boys with him

Brahma Loka. Krishna expanded himself in the form of the boys, cows and calves in exactly same shape. Krishna went back to Gokula, pretending as if nothing had happened. No one could doubt that these were not the original cows and boys.

After one day, Brahma returned the cows and boys. But mean while on earth one year has passed. This incidence shows that time is different in different dimensions.

One more story is flashing my mind, some where I heard on TV discourse. Once Guru Nanak ji visited one country and the king of the country welcomed him with uttermost devotion. Nanak and his disciple Mardana were served delicious food and nice stay in his Palace. King had dream that he had taken birth in chanadal and lead very poor and hard life. King inquired Nanak ji that why he had such a nightmare in spite of serving pious saga like him. Nanak ji told that according to laws of karma , king had take birth in Chandal life. Due to service to saint, his chandal birth had been spent in dream and he no longer actually realise. In dream state time moves faster. One person takes birth, grows, gets elder and dies.

There is another story. One king went to meet brhma at Bhrham lok. Song was going on so he waited for song to complete. On his return to earth many generations had passes.

All these stories shows that time passes differently in different dimensions.

In western philosophy time is linear. In Hindi mythology time is non linear and cyclic in nature. Einstien's theory also predicts curved space-time plane.

Einstien famous quote is "matter tells space-time how to curve, and curved space-time tells matter how to move".

Some believe that so called time is :non -existence entity. Time is conceptual phenomenon. Time is out come of happening of two events. Time is some thing which is necessary to move the universe. If events are happening fast the time passes fast if events are happening slow time passes slowly. In dream state time passes fast, Nanak Story.

Aurobindo says " Space and Time are our names for this self-extension of the one Reality." – "Space would be Brahman extended for the holding together of forms and objects; Time would be Brahman self-extended for the deployment of the movement of self- power carrying forms and objects; the two would then be a dual aspect of one and the same self- extension of the cosmic Eternal."

Yogi Aurobindo Ji in epic SAVITRI finds 'Space' as 'a vast experiment of the soul, the soul which is a portion of the Divine in the constitution of the being of man, more to say, the individual poise of the Supreme Divine at the centre of the being of man.

Interestingly on earth itself, various biological species have different life cycles.

Some bacteria have life cycle of few hours. Average life of tortoise is nearly 150 years. During man's life cycle, around thousands generations of some species will pass.

In Hindu scriptures, unit of time is as given.

1 Kashta =1/3400 of second, 1 Truti= 1/300 of second, 2 Truti= 1 Lov, 1 Lov= 1 Kshan

30 Kshan = 1 Vipal, 60 Vipal = 1 Pal, 60 Pal =1 Ghadi (24 Minute) ,

2.5 Ghadi = 1 Hora (1 Hour), 3 Hora =1 Prahar, 8 Prahar ==1 Divas(var),

7 Divas= 1 Saptah, 4 Saptah = 1 mas , 2 Mas = 1 Ritu , 6 Ritu = 1 Varsh

10 Varsh = Dashak, 10 Dashk= 1Shatabdi , 10 Shatabdi = 1 Shashtabadi ,

432 Shashtabadi = 1 Yug , 2 Yug =1 Dwapar Yug, 3 Yug = 1 Traita Yug ,

4 Yug= Satyug . 1 Mahayug = Satyug+Traitayug+ Dwaper Yog+Kaliyug

72 Mahayug =1Manvantar ,

1000 Mahayug= 1 Kalp.

1 Mhayug = 1 Nitya Pralya (End of life on earth and Again starting)

1 Naimitika Pralya = 1 Kalp (End of devata and rebirth)

1 Mahalay = 730 Kalp (End of Brahma and Re birth)

According to google information the life of earth is estimated to be 4.54 billion based on radiometry of rocks.

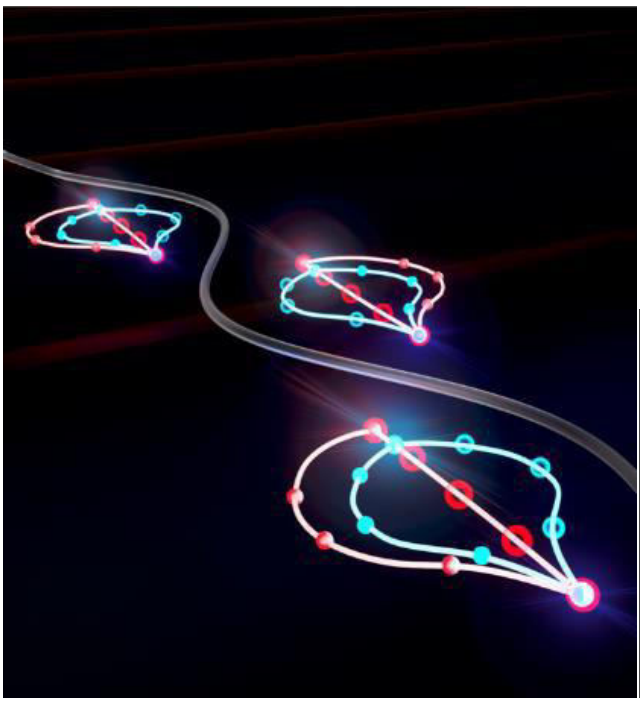
One interesting information , 1 Kalp is 4.32 Billion years. Some what close agreement.

Electron’s Wave Nature Constructed in the Lab at Last

Source website links: https://physicsworld.com/a/electrons-wave-nature-constructed-in-the-lab-at-last/

Researchers at the University of California at Santa Barbara in the US have reconstructed a representation of the electron‘s wave nature – its Bloch wavefunction – in a laboratory experiment for the first time. The work could have applications in the design and development of next-generation electronic and optoelectronic devices.

Like all matter, electrons behave as both particles and waves. One of the main goals of condensed-matter physics is to understand how the wavelike motion of electrons through periodically arranged atoms give rise to the electronic and optical properties of crystalline materials. Having such an understanding is especially important when designing devices that take advantage of the electron‘s wavelike nature, explains Joseph Costello, who co-led the UC Santa Barbara team together with Seamus O‘Hara, Mark Sherwin and Qile Wu.



In the lower right, a near-IR laser separates the two electrons (empty circles) from the two kinds of holes (solid circles). The charges are accelerated away from each other by the fluctuating electric field from the terahertz laser (grey wave). The changing field then drags the charges toward each other, at which point they combine and emit two flashes of light. The trajectories are depicted in one dimension of space with time flowing from the bottom right to the top left. (Courtesy: Brian Long)

The electron's wavelike motion is described mathematically by a so-called Bloch wavefunction. Named after the 20th-century physicist Felix Bloch, who was the first to describe the behaviour of electrons in crystalline solids, these wavefunctions are complex –that is, they have both real and imaginary components. For this reason, the value of an electron's Bloch wavefunction cannot be measured directly.

Heavy and light holes

Certain physical properties related to the wavefunction can, however, be observed. The UC Santa Barbara team exploited this fact to calculate a system's Bloch wavefunction from these observable properties. To do this, the researchers used a powerful free-electron laser to create an oscillating electric field within a semiconductor, gallium arsenide (GaAs), while simultaneously using a low-intensity infrared laser to excite its electrons. Whenever an electron is excited, it leaves behind a positively charged ―hole. In GaAs, Sherwin explains that these holes come in two varieties, heavy and light, that behave like particles with different masses. The team found that if they created electrons and holes at the right time relative to the oscillations of the electric field, the components of these quasiparticle pairs (known collectively as excitons) would accelerate away from each other, slow down, stop, and then accelerate towards each other before colliding and recombining. At the point of recombination, they emit a pulse of light, known as a sideband, with a certain characteristic energy. This sideband emission contains information about the wavefunctions of the electrons, including their phases – that is, the degree to which the waves are offset from each other. Because the light and heavy holes accelerate at different rates in the electric field, their respective Bloch wavefunctions acquire different quantum phases before they recombine with the electrons. Thanks to this phase difference, their wavefunctions interfere to produce the final emission, which can then be measured. The interference also determines the polarization of the final sideband, which can be either circular or elliptical (even though the polarization of both lasers is linear to start with

One free parameter

According to Wu, this simple relation between interference and polarization connects fundamental quantum mechanical theory to a real-world experiment via a single free parameter, which is a number with a real value. This parameter fully describes the Bloch wavefunction of the hole they create in the GaAs, O'Hara adds. ―We can acquire this parameter by measuring the sideband polarization and then reconstructing the wavefunctions, which vary based on the angle at which the hole propagates in the crystal, he explains. Before now, researchers have had to rely on theories with many poorly-known parameters, Sherwin adds. ―So, if we can accurately reconstruct Bloch wavefunctions in a variety of materials, then that will inform the design and engineering of all kinds of useful and interesting things like lasers, detectors and even some quantum computing architectures, he says.

VVER Units Take Shape in Russia and Bangladesh

Source website links: https://www.world-nuclear-news.org/Articles/VVER-units-take-shape-in-Russia-and-Bangladesh

Kursk-II unit 2's The inner containment dome is hoisted into place
(Image: Rosenergoatom)

The installation of the dome is a landmark event in the process of construction of Kursk-II, said Oleg Shperle, vice president of Rosatom subsidiary Atomstroyexport and director of the construction project.

The 265-tonne structure was lifted with a large crawler crane on 27 December, forming a sealed dome over the reactor building. Atomstroy export said this creates better conditions for the installation of the reactor system, steam generators and activation of the polar crane, which will now begin. The dome remains to be concreted, a procedure which will begin in March. A further outer dome also remains to be added to complete the double-walled containment building of the reactor unit. The Kursk-II plant is the first of Russia's latest large reactor design, the VVER-TOI, which is optimised in terms of standardisation and digitisation. Rosatom's current export model is its predecessor, the VVER-1200, which itself is an evolution and enlargement of other VVER designs operating in Russia, Eastern Europe, India and China In Bangladesh, two VVER-1200s are under construction by Atomstroyexport at Rooppur. The company reported that it concreted the fifth and final containment ring of Rooppur 2 on 24 December. Atomstroyexport's director of construction at Rooppur, Alexey Deriy, said this was done "much earlier than the deadline." The reactor's inner containment dome is being assembled on site and is slated for lifting and placement in the first half of this year, Atomstroyexport said.

These are the first plants grown in moon dirt

By Maria Temming

May 23, 2022 at 9:00 am

Citations: A-L. Paul, S.M. Elardo and R. Ferl. Plants grown in Apollo lunar regolith present stress-associated transcriptomes that inform prospects for lunar exploration. Communications Biology. Published online May 12, 2022. doi: 10.1038/s42003-022-03334-8.

The small garden shows the promise and potential challenges of farming on the moon

This thale cress seedling sprouted from a seed potted in lunar dirt collected during some of the Apollo missions. Tyler Jones, IFAS/UF

That’s one small stem for a plant, one giant leap for plant science.

In a tiny, lab-grown garden, the first seeds ever sown in lunar dirt have sprouted. This small crop, planted in samples returned by Apollo missions, offers hope that astronauts could someday grow their own food on the moon.

But plants potted in lunar dirt grew more slowly and were scrawnier than others grown in volcanic material from Earth, researchers report May 12 in Communications Biology. That finding suggests that farming on the moon would take a lot more than a green thumb.

“Ah! It’s so cool!” says University of Wisconsin–Madison astrobotanist Richard Barker of the experiment.“Ever since these samples came back, there’s been botanists that wanted to know what would happen if you grew plants in them,” says Barker, who wasn’t involved in the study. “But everyone knows those precious samples … are priceless, and so you can understand why [NASA was] reluctant to release them.”

Now, NASA’s upcoming plans to send astronauts back to the moon as part of its Artemis program have offered a new incentive to examine that precious dirt and explore how lunar resources could support long-term missions (SN: 7/15/19).

The dirt, or regolith, that covers the moon is basically a gardener’s worst nightmare. This fine powder of razor-sharp bits is full of metallic iron, rather than the oxidized kind that is palatable to plants (SN: 9/15/20). It’s also full of tiny glass shards forged by space rocks pelting the moon. What it is not full of is nitrogen, phosphorus or much else plants need to grow. So, even though scientists have gotten pretty good at coaxing plants to grow in fake moon dust made of earthly materials, no one knew whether newborn plants could put down their delicate roots in the real stuff.

To find out, a trio of researchers at the University of Florida in Gainesville ran experiments with thale cress (Arabidopsis thaliana). This well-studied plant is in the same family as mustards and can grow in just a tiny clod of material. That was key because the researchers had only a little bit of the moon to go around.

The team planted seeds in tiny pots that each held about a gram of dirt. Four pots were filled with samples returned by Apollo 11, another four with Apollo 12 samples and a final four with dirt from Apollo 17. Another 16 pots were filled with earthly volcanic material used in past experiments to mimic moon dirt. All were grown under LED lights in the lab and watered with a broth of nutrients

Thale cress plants grown for 16 days in volcanic material from Earth (left) looked starkly different compared with seedlings nourished in moon dirt (right). Plants potted in samples returned by the Apollo 11 mission (right, top) fared worse than those planted in Apollo 12 samples (right, middle) or Apollo 17 samples (right, bottom).Tyler Jones, IFAS/UF

"Nothing really compared to when we first saw the seedlings as they were sprouting in the lunar regolith," says Anna-Lisa Paul, a plant molecular biologist. "That was a moving experience, to be able to say that we're watching the very first terrestrial organisms to grow in extraterrestrial materials, ever. And it was amazing. Just amazing."

Plants grew in all the pots of lunar dirt, but none grew as well as those cultivated in earthly material. "The healthiest ones were just smaller," Paul says. The sickliest moon-grown plants were tiny and had purplish pigmentation — a red flag for plant stress. Plants grown in Apollo 11 samples, which had been exposed on the lunar surface the longest, were most stunted.

Paul and colleagues also inspected the genes in their mini alien Eden. "By seeing what kind of genes are turned on and turned off in response to a stress, that shows you what tools plants are pulling out of their metabolic toolbox to deal with that stress," she says. All plants grown in moon dirt pulled out genetic tools typically seen in plants struggling with stress from salt, metals or reactive oxygen species (SN: 9/8/21).

Apollo 11 seedlings had the most severely stressed genetic profile, offering more evidence that regolith exposed to the lunar surface longer — and therefore littered with more impact glass and metallic iron — is more toxic to plants.

Future space explorers could choose the site for their lunar habitat accordingly. Perhaps lunar dirt could also be modified somehow to make it more comfortable for plants. Or plants could be genetically engineered to feel more at home in alien soil. “We can also choose plants that do better,” Paul says. “Maybe spinach plants, which are very salt-tolerant, would have no trouble growing in lunar regolith.”

Barker isn’t daunted by the challenges promised by this first attempt at lunar gardening. “There’s many, many steps and pieces of technology to be developed before humanity can really engage in lunar agriculture,” he says. “But having this particular dataset is really important for those of us that believe it’s possible and important.”

Carbon Nanotube Applications in Atomic Force Microscopy

18 April, 2022 | By Osama Ali

Source website links: https://www.azonano.com/article.aspx?ArticleID=6090

Atomic force microscopy (AFM) is a standard imaging technique for the structural characterization of surfaces in different fields of materials science, surface science, and biology. Carbon nanotubes have shown tremendous promise in the design and structure of AFM tips and probes.

The tip of an AFM probe is determined by the machine's lateral resolution, which in turn, determines its sensitivity. The radius of curvature at the apex of conventional microfabrication methods is generally less than 10 nm. While developing smaller tips is a priority for AFM researchers, they also aim to develop tips that stay longer, accurately depict complicated surface topographies and are mechanically non-invasive.

Carbon Nanotubes and their Application

Carbon nanotubes (CNTs) have great potential in many research and industrial applications. A single-wall carbon nanotube (SWCNTs) can be defined as a graphite sheet folded into a nanoscale tube or with additional graphene tubes around the core of an SWCNT, which are referred to as multi-walled CNTs (MWCNTs). The diameters of these CNTs range

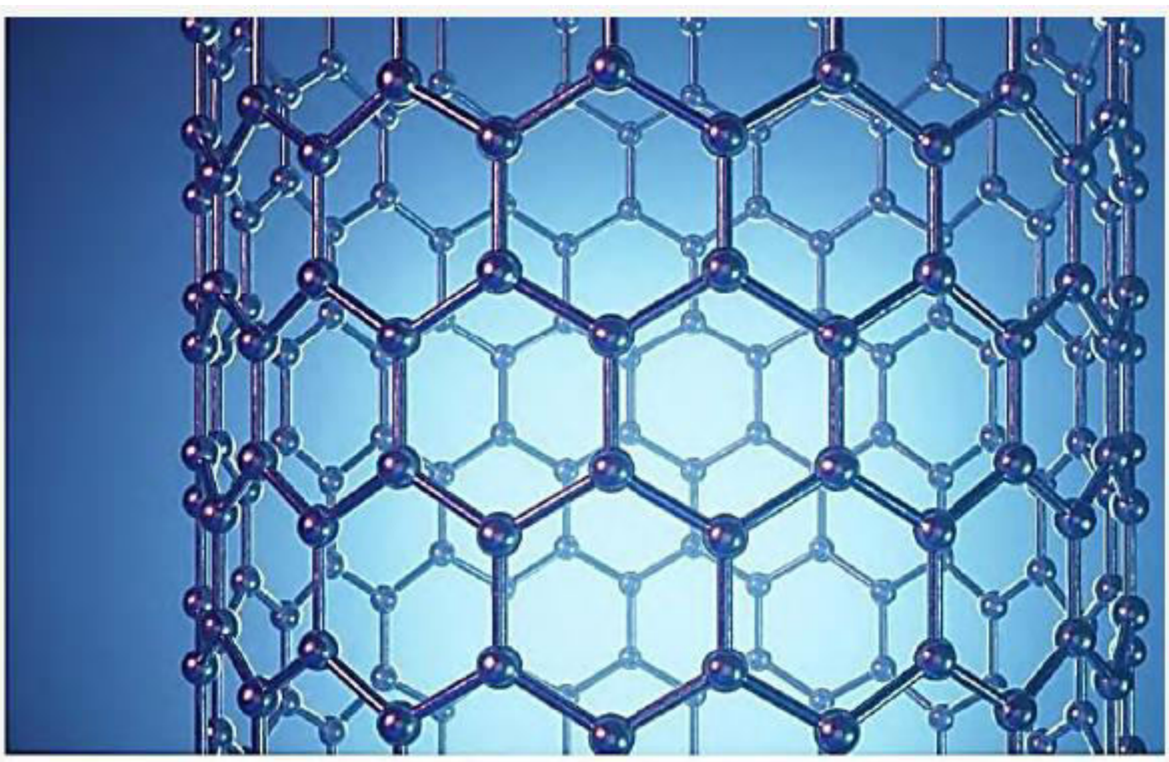
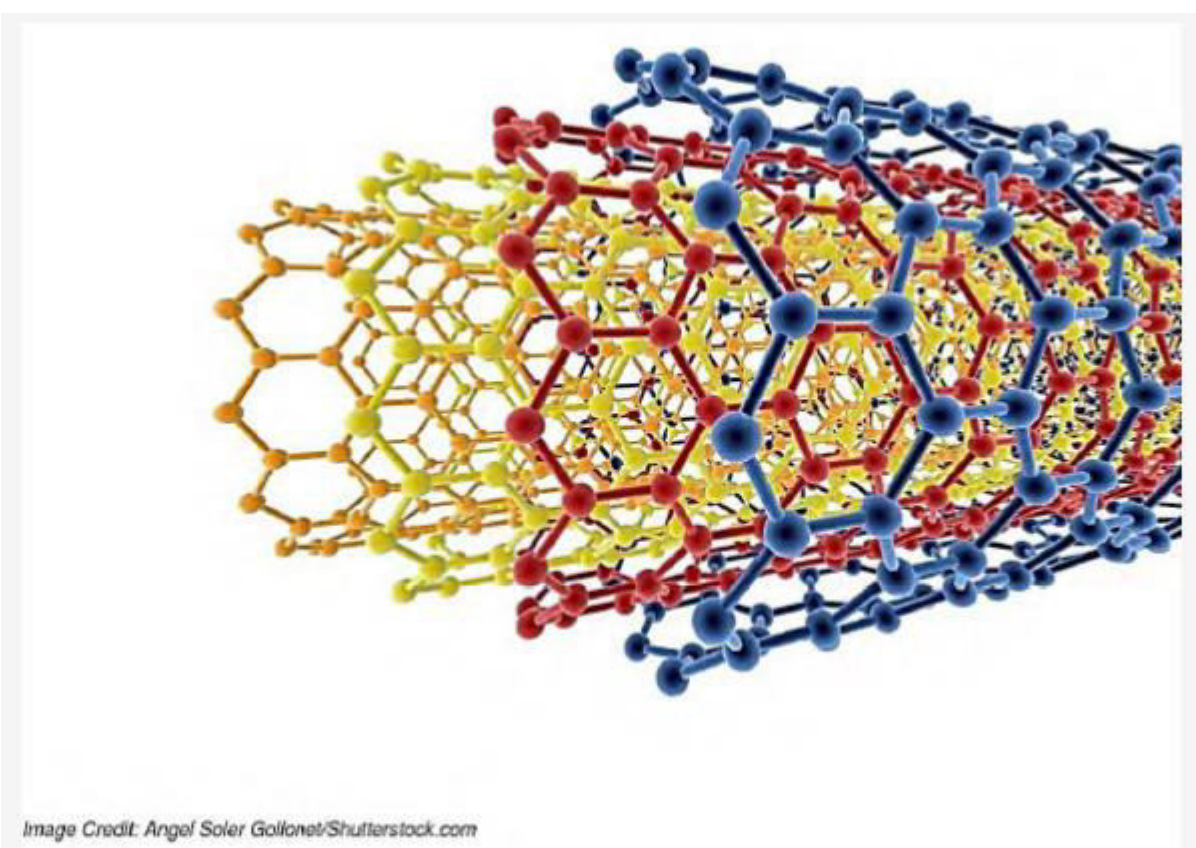


Image Credit: Rost9/Shutterstock.com

from fractions of nanometers to tens of nanometers, with lengths ranging from a few centimeters to several centimeters. Chemical nerve agents can be detected by using thin-film transistors made from SWCNTs. They are reversible, detect concentrations as low as parts per billion (ppb), and are innately selective against hydrocarbon vapors and humidity interference signals. In a miniaturized capillary electrophoresis setup, a microdisk electrode made of MWCNTs and epoxy resin was utilized to measure the amperometric activity of bioactive thiols. Carbon nanotubes are several times stronger than steel and other metals in terms of strength and are lighter in weight, making them a viable choice for structural reinforcement. Adding CNTs to cement-based materials has been proven in studies to boost performance considerably. When using CNTs in cementbased products, the ability of CNTs to be spread evenly is critical. CNTs are difficult to spread uniformly in cement-based materials because of their huge surface area, strong van der Waals force, and large aspect ratio. When a single MWCNT is isolated from its filling body, it is referred to as a CNT dispersion. There are two sorts of approaches to dispersion techniques. The first is to use physical means, such as mechanical stirring, ultrasonic, and ball milling, to break down the material.

Carbon nanotube agglomerations can be broken down using ball milling, but the aspect ratio will be reduced, which negatively impacts the carbon nanotube's role in the matrix. Mechanical stirring includes magnetic and manual stirring, which is typically used in conjunction with ultrasonics to reduce the aspect ratio of carbon nanotube. The addition of functional carboxyl and hydroxyl groups and covalent or non-covalent bonds to the CNT's surface improves its wettability, resulting in the chemical dispersion of the CNT.



Benefits of CNTs in Atomic Force Microscopy

Carbon nanotubes have a nanoscale diameter and a high length/diameter ratio, unlike any other tubular structure. CNTs contain special properties such as a high aspect ratio which is used to image narrow and deep features. Furthermore, they elastically buckle rather than break down when a high amount of force is applied to them, and for gentle imaging processes, they have low adhesion in tip-sample. It is possible to employ controlled synthesis to manufacture every nanotube tip with the same structure and resolution because of the well-defined molecular architectures of nanotubes. As in previous structural approaches, a well-defined transfer function might be used to describe nanotube probes if the latter characteristic were achieved. SWNT bundle tips and multi-walled carbon nanotube (MWNT) tips for functionally sensitive imaging are used to get high lateral resolution images.

Nanotubes can have a diameter ranging from a few tens of nanometers to several hundreds of nanometers, depending on the number of concentric carbon shells used. There are several advantages to using carbon nanotubes as atomic force microscope probes, including the fact that they can have a one-nanometer diameter, strong mechanical qualities, and the ability to customize the tip end of the tube with chemical and biological probes.

Carbon Nanotubes in AFM Systems

To physically contact and evaluate a sample surface, atomic force microscopy (AFM) uses an ultra-sharp tip. Using new nanotechnology processes, the technology for making AFM probe tips is rapidly evolving. A new generation of AFM probes is now easily accessible, with increased performance, higher quality, and novel materials.

Probes made of carbon nanotubes offer a new AFM imaging universe, boosting the probe's resolution and endurance, reducing the probe–sample forces, and broadening the AFM application areas.

Nanotechnology, surface engineering, and biotechnology would all benefit from this breakthrough. Using carbon nanotube tips in AFM has various benefits, such as performing gentle imaging and using low tip-sample adhesion. To bend elastically upon severe pressure load rather than breaking. Such properties make use of CNT in AFM systems very much appealing and beneficial.

The CNT-AFM probes were found to be very easy to use for regular imaging in Peak Force Tapping (PFT) mode. Additionally, it has been found that chemical vapor deposition (CVD) nanotube tips offer superior imaging capabilities for biomolecules than commercial tips or manually assembled nanotube tips when used in the same environment.

Challenges Faced During Usage of CNTS in AFM

When using a CNT-AFM probe for AFM imaging, there are a lot of crucial elements that must be regulated efficiently, but possibly the most significant is the applied force. An unstable contact is possible if too much force is exerted on the nanotube.

When it comes to Probe production, the length of the CNT and the orientation are crucial considerations, making these probes particularly challenging. Because of the strong lateral stresses, CNTAFM probes are not suitable for imaging in contact mode for the reasons stated above. As a means of reducing forces (lateral), CNTAFM probes are often used in tapping (mode).

Novel Theory of Entropy May Solve Materials Design Issues

16 March, 2022 | by Penn State

Source website links: https://www.eurekalert.org/news-releases/946699

A challenge in materials design is that in both natural and manmade materials, volume sometimes decreases, or increases, with increasing temperature. While there are mechanical explanations for this phenomenon for some specific materials, a general understanding of why this sometimes happens remains lacking. However, a team of Penn State researchers has come up with a theory to explain and then predict it: Zentropy.

Zentropy is a play on entropy, a concept central to the second law of thermodynamics that expresses the measure of the disorder of a system that occurs over a period of time when there is no energy applied to keep order in the system. Think of a playroom in a preschool; if no energy is put into keeping it tidy, it quickly becomes disordered with toys all over the floor, a state of high entropy. If energy is put in via cleaning up and organizing the room once the children leave, then the room returns to a state of order and low entropy. Zentropy theory notes that the thermodynamic relationship of thermal expansion, when the volume increases due to higher temperature, is equal to the negative derivative of entropy with respect to pressure, i.e., the entropy of most material systems decreases with an increase in pressure. This enables Zentropy theory to be able to predict the change of volume as a function of temperature at a multiscale level, meaning the different scales within a system. Every state of matter has its own entropy, and different parts of a system have their own entropy.

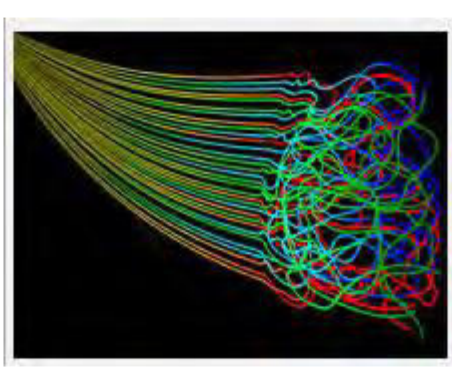


Image: Entropy is the measure of the disorder in a system that occurs over a period of time with no energy put into restoring the order. Zentropy integrates entropy at multiscale levels. Credit: Elizabeth Flores-Gomez Murray/Jennifer M. McCann, Penn State

—When we talk about the configuration entropy (different ways particles rearrange within a system) that entropy is only part of the entropy of the system, said Zi-Kui Liu, Dorothy Pate Enright Professor of Materials Science and Engineering and primary investigator in the study. —So, you have to add the entropy of individual components of that system into the equation, and then you consider the different scales, the universe, the Earth, the people, the materials, these are different scales within different

systems. The authors of the study, published in the Journal of Phase Equilibria and Diffusion, believe that Zentropy may be able to predict anomalies of other physical properties of phases beyond volume. This is because responses of a system to external stimuli are driven by entropy.

Macroscopic functionalities of materials stem from assemblies of microscopic states (microstates) at all scales at and below the scale of the macroscopic state of investigation. These functionalities are challenging to predict because only one or a few microstates can be considered in a typical computational approach such as the predictive "from the beginning" calculations, which help determine the fundamental properties of materials.—This challenge becomes acute in materials with multiple phase transitions, which are processes that convert matter from one state to another, such as vaporization of a liquid, Liu said. —This is often where the most transformative functionalities exist, such as superconductivity and giant electromechanical response.

Zentropy theory —stacks these different scales into an entropy theory that encompasses the different elements of an entire system, presenting a nested formula for the entropy of complex multiscale systems, according to Liu.

"You have these different scales and you can stack them up with Zentropy theory, Liu said. —For example, atoms as a vibrational property, that's low scale, then you have electronic interaction, that even lower scale. So now how do you stack them together to cover the entire system? So that is what the Zentropy equation is about, stacking them together. It creates a partition function that is the sum of all the entropy scales.

This approach has been something Liu‘s lab has worked on for more than 10 years and five different published studies. —The idea actually became very simple after we studied it and understood it, Liu said.

Zentropy has potential to change the way materials are designed, especially those that are part of systems that are exposed to higher temperatures. These temperatures, given thermal expansion, could cause issues if the materials expand.

—This has the potential to enable the fundamental understanding and design of materials with emergent properties, such as new superconductors and new ferroelectric materials that could potentially lead to new classes of electronics, Liu said. —Also, other applications such as designing better structural materials that withstand higher temperatures are also possible. While there are benefits for society in general, researchers could apply Zentropy to multiple fields. This is because of how entropy is present in all systems. "The Zentropy theory has the potential to be applied to larger systems because entropy drives changes in all systems whether they are black holes, planets, societies or forests, Liu said. Along with Liu, other authors of the study include Yi Wang, research professor in materials science and engineering, and Shun- Li Zhang, research professor in materials science and engineering. The work was supported by the National Science Foundation, the Department of Energy and the Department of Defense.

A Rare Earths Roadmap for India: Seeking Atma Nirbharta in Indian Technology

Controlling the supply chains of strategic minerals is an exercise in consolidating power over critical technologies Representational Image. American Geosciences Institute

India‘s growth trajectory is witnessing a potential inflection point. After posting strong, broad-based GDP growth numbers signalling a roaring recovery, the foundations of a new economy are emerging. India has been witnessing a massive solar energy push, an Electric Vehicle (EV) ecosystem, and a speciality chemicals sector that is becoming a global hub. Clearly, India is moving towards a greener, cleaner, and technologically enhanced economy. In the same vein, India‘s defence ecosystem is modernising and becoming a technologicallydriven force with a slew of futuristic defence projects underwaystealth surface vessels, nuclear attack submarines, Unmanned Aerial Vehicles, stealth aircraft, and continuing its greatly successful missile program. However, the technology which is essential to enable all of the foregoing is dependent upon a slew of strategic minerals as inputs. From a phone to a nuclear reactor, these strategic minerals are inescapable to make it all happen.

Representational Image. American Geosciences Institute

Controlling the supply chains of strategic minerals is an exercise in consolidating power over critical technologies. Within the broad category of strategic minerals, a particular set of elements occupy a privileged position. These are rare earths- a group of 17 elements-fifteen lanthanides along with scandium and yttrium. Each of these elements has very specific properties, and substituting one rare earth with another is often not possible. The principal cause of concern is that rare earths face a monopolistic supplier in China- the vast majority of the rare earths supply chains have slowly fallen to Chinese dominion. The dangers of this fact were illustrated most starkly in 2010 and 2011, where China placed an embargo of rare earths on Japan following a flare-up in the Senkaku islands dispute. By throttling rare earth supplies, countries' industrial and military capacities can be crippled while stunting future technological growth. With rare earths being an Within the broad category of strategic minerals, a particular set of elements occupy a privileged position. These are rare earths- a group of 17 elements-fifteen lanthanides along with scandium and yttrium. Each of these elements has very specific properties, and substituting one rare earth with another is often not possible.

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1. How China Monopolised Rare Earths

—You don't control your destiny — if the price goes up, China can still bring it down‖.- CEO of Geomega Resources Inc., Kiril Mugerman

China is a country blessed with mineral resources, and its reserves of Rare Earths is no exception. However, while it has just above a third of the world's known reserves, it has an iron grip over around 58% of the global rare earth production. While this is a significant reduction from its earlier 90% share, China's control over the global market remains a pain point for all involved.

China's present pole position is not sui generis, but an outcome of a very long and consistent strategic effort. The —863 Program‖ to develop advanced technologies was inaugurated in 1986 and included a focus on —New Materials, the scope of which was subsequently expanded over the years. A long term view and consistent support from the Chinese government has cemented its present dominance in the field. In the 1980s itself, China branded rare earth minerals as a strategic commodity and used a wide variety of economic tools to nurture the industry through the decades. Added to this are the usual Chinese inflictions of market manipulation, intellectual property theft, capital restrictions, export restrictions, and subsidies. Two more underhanded methods further boost Chinese capabilities- complete disregard for environmental concerns, and strategic acquisition of foreign firms for their technical know-how, after bankrupting them by crashing prices. These methods are not unique to the rare earth market- moving up the value chain and acquiring strategic know-how through all means necessary is a thinly veiled Chinese objective

So why is China so keen on rare earths? The answer is obvious, albeit multifaceted:

Vertical integration: secure control over raw materials as well as downstream industries to secure Chinese economic interests. China has built up a formidable, integrated ecosystem in rare earths from mining to end-product manufacturing which acts as a competitive moat for other players to enter. Sunrise technologies currently being developed are rare earth intensive, and controlling their supply chains can secure China‛s future as the advanced systems manufacturing hub of the world- similar to China‛s present hegemony over solar panel production. China‛s redoubtable rare earth mining and processing prowess subsidise China‛s domestic industry and military while making the rest of the world dependent on Chinese whims.

Civil-Military Fusion: China‛s ultimate strategic imperative of having the most technologically advanced armed forces in the world demands removing distinctions between civil and military industries. As long back as 1997, China had codified the ―16 Character Strategy‖ which, when translated, reads- ―Combine the military and civil; Combine peace and war; Give priority to military products; Let the civil support the military. Vertically integrated industries within a context of weak intellectual property rights and the lack of rule of law provide an attractive means of accreting strategic technologies.

Suppressing strategic competitors‛ technological advances:

The concentration of rare earth materials value chains, from ore to finished product in China, ensures a relative advantage in research, simply because of access and control over the entire ecosystem. By disrupting the formation of such ecosystems in other countries, China maintains a scientific advantage. New-age technologies, particularly those related to green energy and communications, are essential for China‛s global ambitions. Controlling these technologies ranks high in Chinese strategic calculus.

Under the Made in China 2025 initiative, China has continued to focus on ‗New Materials‛, which include permanent magnets, to be one of the 10 industries which will receive focused State support. Therefore, the entire rare earth industrial ecosystem remains a priority for China. China possesses the industrial repertoire from mining to advanced applications, all backed by a robust research system geared towards both military and industrial advances. Rare earths will thus play a key role in China‛s envisioned economic future- greener, smarter, and based on high value-added products targeted towards domestic consumption rather than exports. China‘s monopolistic position in the world‘s rare earth supply has important ramifications, which smothers competition and severely limits other countries‘ strategic choices. These impacts can be broadly clubbed under the following heads.

Dump and Pump

China is notorious for dumping all sorts of goods in the global market so as to wipe out the competition. This is achieved through a number of methods in concert- off-the-book reserves, maintaining overcapacity, export quotas, and State funding. India has had to repeatedly impose anti-dumping duties so as to save its industries from waves of Chinese dumping, ranging from products such as steel to chemicals. The motivation behind such actions is rather obvious. By flooding markets with artificially cheap products from time to time, depresses market prices and turns firms based in other countries uneconomical, driving them out of business. In industries involving heavy capital expenditure, long gestation periods, or super specialised expertise, it is not possible to reopen or re-enter the markets in a short time when prices increase again.

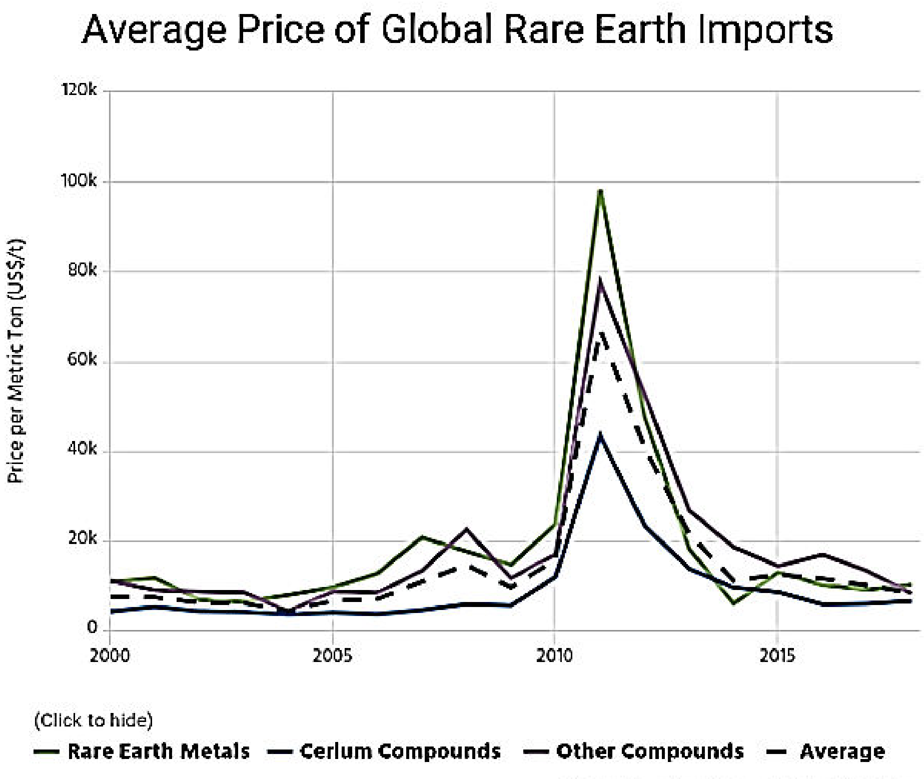
Thus, China reaps supernormal profits in the years after dumping as it can charge inflated premiums in markets devoid of competition. The Rare Earth industry is a perfect case of such unbridled mercantilism by China, where a relatively demand inelastic market ensures handsome gains for the Chinese Communist Party (CCP).

Downstream Support to Industries

During periods of extreme export restrictions, such as in 2010-11, the entire world was left scurrying to fend for Rare Earths supplies. China‘s strategic imposition of export quotas on its rare earth exports led to a more than 700% jump in global prices, crippling downstream industries dependent on rare earths worldwide. Such blatant market manipulation led to a windfall for Chinese domiciled firms, as the supply glut enabled them to produce key components such as magnets cheaper than ever before. Indeed, such export restrictions created a favourable glut of raw material for manufacturers, enabling them to effectively scale up. Thus, China cornered the global market for key rare earths products as well. The Chinese have three interrelated, vertically integrated monopolies- mining, processing, and production, which act as a strategic choke on the rest of the world while being an implicit subsidy for its strategic industries. Systems of global commercial governance proved moribund- it took the WTO four years to rule against China for its export quota move, long after the crisis had passed.

“Unrestricted Warfare”

In 2010, China and Japan witnessed rising diplomatic tensions due to a resurfacing of the Senkaku islands dispute.



A Chinese ―fishing boat‖, which is more than likely a grey zone actor belonging to the Chinese Maritime Militia, collided with Japanese patrol boats, and was captured. In retaliation, China proceeded to illegally impose an embargo on rare earth exports to Japan. The same year, it used this very technique against the United States when it began to investigate Chinese firms' trade practices for illegalities. Such behaviour fits perfectly with the well-established Chinese doctrine of ―unrestricted warfare‖- where pressure is built on one sphere of interstate relations so as to gain concessions in another Essentially, China weaponises all interstate relations and has no qualms in using relations of all kinds either to build dependency by others or to steal strategic knowledge. In Japan's case, China used its rare earth monopoly as a means of bullying concerning an issue rooted in a territorial dispute. The same could very well be inflicted on any other country in the future, which would leave long term dents on its electronics and strategic capacities. Of key importance to China is the acquisition, assimilation, and perfection of dual-use technologies (i.e. having both industrial and military uses). In the rare earths field as well, China has been proactive in its efforts. In 1997, Magnaquench was sold to a Chinese State-Owned consortium headed by Deng Xiaoping's sonin-law. Magnaquench was a market leader in neodymium magnets, having applications across data storage, automotive, and critical weaponry.

Despite a Mitigating Agreement' preventing Magnaquench's new Chinese owners to moving production and jobs to China for a period of ten years, an ex-employee stated that its top of the line neodymium-iron-boron magnet production line was "duplicated in China" and that, after the Chinese "made sure that it worked, they shut down" the U.S. production in Indiana. The employee added, "I believe the Chinese entity wanted to shut the plant down from the beginning. They are rapidly pursuing this technology".

Magnaquench was the United States' only source of neodymiumiron- boron magnets, which has irreplaceable uses in weaponry.

State Administration for Science, Technology and Industry for National Defence (SASTIND), China's counterpart to the UnitedStates' DARPA, is known to be monitoring foreign technologies,including all those imported into China through joint ventures.China thus engages in extensive oversight of imported dual-usetechnology. This effort is the stepping stone to translating foreigntechnical data, analysing it, and assimilating it for industrial andmilitary programs.

India's Position and Problems

India's rapidly growing economy currently has two massive input deficiencies which threaten its stability- oil, and rare earths. The two constraints are closely related to each other- rare earth minerals are essential for green energy generation as well as for green technologies like LEDs and Electric Vehicles. Energy security aside, the broader umbrella of strategic minerals (which contains rare earth minerals) has a litany of critical applications- chemicals, electronics, and defence.

India has many key rare earth minerals' reserves already identified. Furthermore, explorations in this field have only recently commenced in a big way- the discovery of more reserves is a foregone conclusion since the occurrence of rare earths is largely a function of a country's area. Rather ironically, India was one of the pioneers in the rare earth industry. The Public Sector Undertaking (PSU), Indian Rare Earths Limited (IREL), has been up and running since 1949, implying decades of industry work. It remains as India's largest producer and exporter, and that's where the problems begin.

India's Policy Structure

India's present underperformance is a direct consequence of a policy error that has continued unabated for decades. One would notice that IREL, the PSU monopolist in the rare earths mining space (save for Kerala Mines and Minerals Limited, a government of Kerala undertaking), is owned by the Department of Atomic Energy (DAE), India's apex civil nuclear agency. This was primarily because of India's nuclear energy program espousing the long term aim of using Thorium as a nuclear fuel, and unfortunately, Thorium is prevalent in the same beach sands where other rare earth minerals also occur. The consequence of this circumstance was that these mineral-rich beach sands were brought under the ambit of ―prescribed substances‖ in the Atomic Energy Act, 1962, granting the Central Government a monopoly. This self-imposed restriction has been extended further under the Atomic Mineral Concession Rules, 2016, which flow from the 2015 Amendments to the Mines and Minerals (Development and Regulation) Act, 1957. The two read together to make the picture much clearer: ranging from Beryllium and Lithium, rare earths such as Titanium and Niobium have also been handed over to India's atomic agencies. Such essential materials being turned into government monopolies only exacerbates pre-existing bottlenecks. Though reports exist on the Government thinking of partial privatisation, that in and of itself won't improve the situation significantly. In fact, IREL exports low-value rare earth ores, often to Chinese processors, due to a lack of impetus on building complicated and costly processing facilities. One-off initiatives such as the upcoming Samarium-Cobalt Permanent Magnet plant in Visakhapatnam cannot substitute for a lab-to-product ecosystem, which necessarily has to be centred around strategic needs and commercialisation.

Expertise Mismatch

One of the most vexing problems arising from India's policy structure is that rare earths with super specialised uses but across multiple industries become vested within just one domain- atomic energy. Thus, the present system ends up separating the rare earths ecosystem from other R&D ecosystems like electronics or metallurgy. This severely impacts the overall umbrella of strategic research, undercutting the interdisciplinary and integrative nature of modern, solution-oriented research work. The situation is similarly balkanized with regards to exploration, whereby the Geological Survey of India (GSI), Mineral Exploration Corporation Limited (MECL) and Atomic Minerals Directorate for Exploration and Research (AMD) operate in overlapping spheres while being in siloes.

Incentive Mismatch

Betraying its name, IREL's primary source of revenues is not rare earths at all. Most of its income comes from the production and marketing of other minerals contained in beach sands- ilmenite, sillimanite, and zircon. With access to lucrative beach sands with easily recoverable minerals, IREL has little need to produce and research just as much as demanded by India's assorted government research establishments. Thus, IREL has poor incentives to refocus itself as a globally competitive rare earth extracting and processing firm. This has restricted India to continue as a low-cost exporter of rare earth oxides instead of higher value-added products, unconnected to India's strategic needs and those of industrial users. Value addition is the crux of not just strategic self-reliance but to move up Global Value Chains, whereby India can supply intermediate and finished products instead of exporting cheap raw material. Furthermore, it suffers from the same Byzantine bureaucratic restrictions and low innovation incentives which infest India's Public Sector firms.

Linkage Mismatch

There exist gaping disconnects between all components of India's rare earth ecosystems. Research on rare earths is dominated by the DAE and the Bhabha Atomic Research Centre (BARC), with little, piecemeal representation from the State-owned Council for Scientific and Industrial Research (CSIR) laboratories or Defence Research and Development Organisation (DRDO).

The participation of universities is also minimal. Conspicuously, industry and the private sector have a nigh absence in the field, reflective of absent linkages. Not only is the volume of research low, but collaborations between these research stakeholders is alsosorely lacking.

This fragmented, siloed, and severely inefficient research system is a far cry from developing end-user and strategic technologies, and ultimately commercialising the same. In toto, India simply lacks anecosystem where effective research can take place, and ultimately be converted into products. While a good deal of such sorry status quo is due to the policy structure adopted, the fact of the matter is that there doesn‘t exist an institutionally collaborative focus on rare earths, and poorly organised research initiatives are working in isolation.

A similar break-in linkage exists between miners and processors on one end and the end-user on another. It is imperative to realise that the supply and demand of rare earth minerals require careful analysis and information flow owing to long timelines and high costs. Until the mining and manufacturing ecosystems do not have a reliable dialogue on the quality and quantity of demands, preparing a coherent strategy will be difficult. This exchange of expectations is a necessary precursor to coordinated research and production efforts, which any nascent industrial ecosystem requires. Currently, there exists no broad strategic direction whereby a concerted, joint effort can be made in conjunction withthe end-user's requirements.

License- Permit Raj

India‘s 1991 Economic Liberalisation was not a uniform process, and the reform momentum has been glacial when it comes to certain sectors. Thus, sectors such as agriculture and mining continue to have a very restrictive and elaborate regulatory regime governing them, with clearances coming in costly and time consuming.

A few illustrations of India‘s kafkaesque regulatory regime are as follows.

Regulatory Risk: On 20 February 2019, the Central Government amended the Atomic Minerals Concessions Rules, 2016, whereby threshold values for a range of minerals were drastically reduced. This decision effectively nationalised beach sands containing any monazite overnight, forcing a multitude of private players out of business. Many beach sand players which were exploiting sands for materials having no nuclear use were severely impacted. Such volatile regulatory guidance in a sector demanding long gestation and cost-recovery periods is a disincentive in all but name.

Investment Risk: The Japanese owned firm Toyota Tsusho Rare Earths India (TREI), established in 2009, could not begin production of rare earth oxides until 2016 despite India and Japan issuing a joint declaration in 2010 on rare earths, followed by an MoU in 2012. Even now, the firm basically ships ores, oxides, and slurries to Japan for processing, followed by Japanese firms capitalising on the finished products.The sheer difficulty of getting all adequate licenses and clearances (particularly those relating to land acquisition and environment) ensure minimal private sector involvement.

Judicial Risk: Building public opposition to key projects using foreign-funded NGOs has emerged as the chosen modus operandi of India's strategic competitors. Whether the issue is supposed environmental concerns, or public health, the judiciary and the government have tended to be overcautious against targeted facilities. It should thus come as no surprise when India's National Security Advisor, Ajit Doval, characterises civil society to be —the new frontiers of war. The Sterlite Copper Plant in Thoothukudi, Tamil Nadu, is still reeling under an adverse court order despite independent studies showing the plant was not in breach of environmental norms. This occurred in the wake of protests whipped up by elements having dubious antecedents. The net result has been disastrous- India's copper production dropped by around 45%, and India was forced to become a net importer of a key metal which it used to be an exporter of. Similarly, Chinese involvement is suspected of stoking labour unrest in Foxconn's Chennai factory as a part of a broader effort to impede India from becoming a competing manufacturing hub.

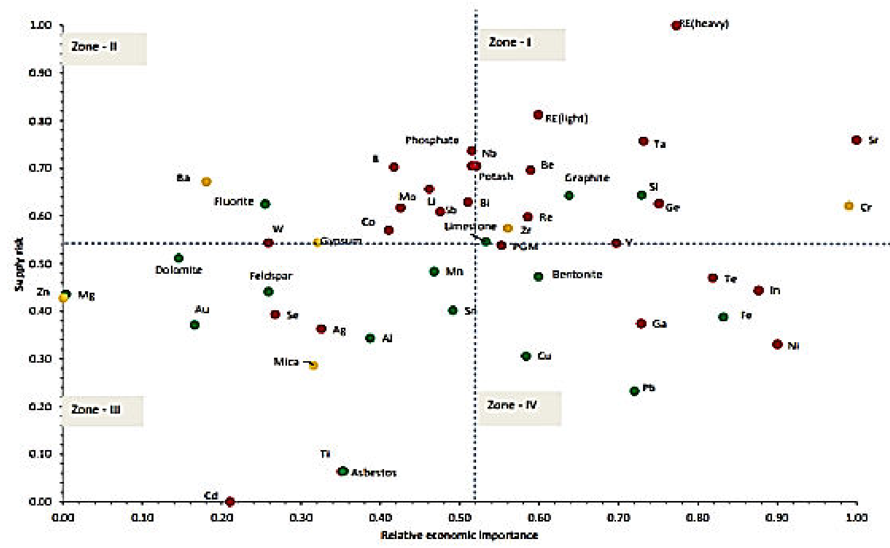
1. Solutions

Focus

An inordinate strategic error has been made and perpetuated by placing all rare earths under the Department of Atomic Energy's ambit. The lack of focus on developing rare earth chemistry and application as a priority in and of itself hinders progress. The time is ripe for a specific focus set being adopted for rare earths as a whole, independent of minerals used exclusively in the nuclear space.

Mineral Selection: Based on availability and criticality of rare earths, the Ministry of Mining has conducted an analysis for prioritising efforts in both exploration and foreign acquisition. India has an established relative abundance of Light Rare Earths: elements from Lanthanum to Samarium, making them an obvious starting point. Neodymium is a core requirement for permanent magnets in both civilian and military uses, which is another mineral to have a keen eye on. In addition, India has begun discovering Lithium deposits as well, which offer much promise. In line with foreign acquisition needs, India has been showing proactiveness. A joint venture of three PSUs, named Khanij India Bidesh Limited (KABIL), has been slowly entering into long-term contracts for India's critical mineral needs. Thus, the few key minerals thus identified should occupy maximum attention, whereby strategic efforts move step by step in acquiring key capabilities

FIGURE 18: PRIORITISATION OF ACTION IN DEVELOPING LONG TERM TRADE AGREEMENTS WITH GLOBAL SUPPLIERS



Red = immediate attention; **Orange** = medium term; **Green** = Long term

Source: CEEW analysis

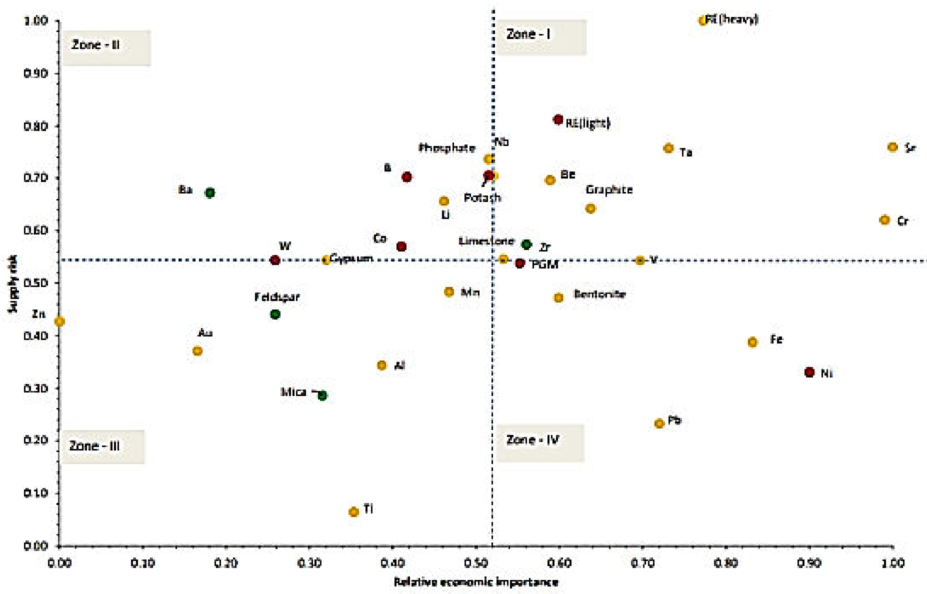
Nodal: Creating a Department of Rare Earths (DRE) within the Ministry of Mines can be an important first step, so as to have a nodal agency to coordinate and plan India‘s efforts. The principal responsibility for the Department would be liaison with government agencies, PSUs, and industry. The Department can, as its strengths increase, be used to set up Special Purpose Vehicles and new PSUs along the lines of ISRO under an overseeing Strategic Minerals Commission.

IREL Demerger: IREL should be demerged into two different entities with appropriate amendments to the Atomic Energy Act‘s Schedule- one focusing exclusively on Thorium extraction and retained under the Department of Atomic Energy, while the remaining entity (having KMML merged with itself, ideally) specialising in other available rare earth processing which would come under the proposed DRE.

The DRE‘s corporation can be provided with an exception to mine and process beach sands specifically for rare earths.These two entities must have a suitable Materials Sourcing Agreement in place, whereby the two will swap or supply each other their products, processed affluents and other waste products so as to ensure there is no inadvertent competition for the raw material i.e. beach sands.

Exploration: A consolidation in the exploration of rare earths is necessary. The National Mineral Exploration Policy of 2016 had a proposal to set up the National Centre for Mineral Targeting (NCMT) to replace the present system of having committees within the Geological Programming Board of the Geological Survey of India. The proposal is yet to fructify into reality. Giving life to the proposal for the

FIGURE 15 : PRIORITISATION OF EXPLORATION ACTIVITY ASSOCIATED WITH MINERALS



Red = immediate attention; Orange = medium term; Green = Long term

Source: CEEW analysis

NCMT and ensuring the presence of all agencies currently involved in the exploration process (including PSUs) will be necessary for optimal exploration efforts.

Exports and Imports: India‘s current practice of exporting away low valorisation ores when such resources are critical to its economy and defence is an absurdity. Rather than repeating TREI‘s underwhelming results, India must rather focus on domestic value addition using a combination of technology transfers as well as indigenous research. Friendly nations‘ governments and firms can be invited and incentivised to open export-oriented facilities in Public Private Partnership mode- joint ventures with IREL‘s DRE entity, and with technology transfers. Similarly, a calibrated and dynamic import duty policy is in order. In case of minerals where India is trying to build a domestic supply chain, long-term import duties may prove crucial to incentivise industry efforts.

Downstream Liberalisation: Private industry must be incentivised and enabled to set up processing capabilities beyond the extraction and oxidation phase. Such a move will be crucial for higher value added products having robust domestic supply chains. Furthermore, this is an unavoidable precondition to having a diversified and competent rare earths sector which can drive India‘s economic and defence initiatives. The importance of private players for innovation and competition cannot be overstated, and their presence is irreplaceable in India‘s overall industrialisation owing to synergies which will emerge especially in the context of agreen economy.

Regulatory and Judicial Risk Mitigation: A statutory blanket of protection to strategic minerals‘ facilities, much like how facilities which handle nuclear materials, should be extended to insulate them sufficiently from regulatory and judicial risks. Similarly, owing to the fact that these minerals generally tend to have _dirty‘ chemistry with environmental ramifications and unique economics, a separate regulator should be instituted for the space.

Linkage and Integration

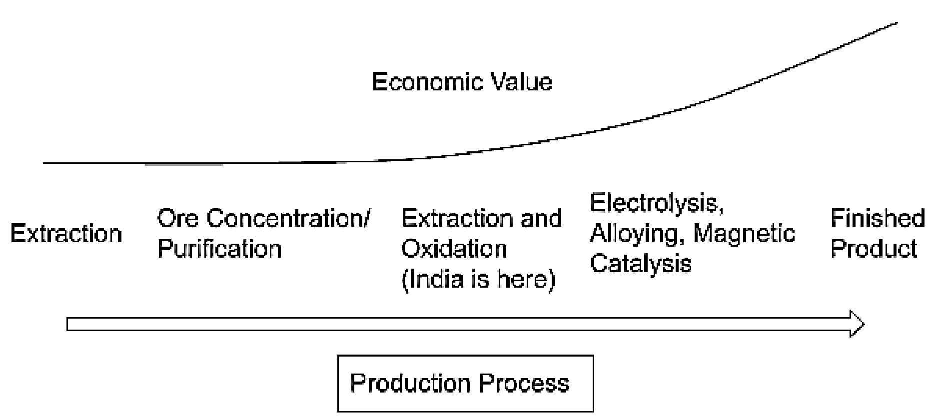
The process of building a strategic minerals ecosystem suffers from a chicken and egg problem- one wouldn't invest in downstream industries if upstream facilities are not established; upstream industries would have no impetus to expand if there are no downstream buyers.

Ensuring a balanced expansion of these two ends is the key to a sustainable industry ecosystem. Overcoming this economic hurdle requires a concerted strategic approach.

Advance Market Commitments (AMCs): AMCs are basically binding pre-orders i.e. the Government has a clear advance commitment of purchasing a certain good at a particular price. Providing AMCs to a capital intensive and nascent industry will provide stability to demand guidance for interested players and ensure adequate capabilities are set up by the private sector.

Strategic Reserves: India has been scaling up and accumulating petroleum reserves for emergencies in the recent past. The logic there applies equally to rare earthsthey' re both essential commodities over which India is import dependent. Having Rare Earth Strategic Reserves can help provide a consistent demand environment, as well as a fallback at times of global squeezes caused by Chinese actions.

Financial Incentives: Access to cheaper capital, tax concessions, a timed exemption from District Mineral Foundation donation requirements, and providing a sovereign guarantee to corporate bonds floated for strategic mineral facilities can channelise much needed investment into the sector. Another very effective means of incentivising industry is through the use of Viability Gap Funding (VGF) to firms willing to enter the space. Furthermore, exemptions and commercial headwinds already being experienced by key related sectors such as green energy, electric vehicles, specialty chemicals and technology intensive products in India will have a positive ripple effect onto the strategic minerals space if private players enter the fray.



Adapted from Mancheri, 2015[42]

The expansion of the Production Linked Incentive (PLI) scheme to semiconductors shows the way- it places incentives across the semiconductor supply chain. Fabrication, assembly, testing, and packaging are all eligible. A well-drawn out PLI scheme for strategic minerals, building on the insights from the PLIsemiconductor experience, can be a game changer.

- **Information Fusion:** The Indian Bureau of Mines (IBM) operates as the principal data collector and disseminator in the space. The agency has long experience and the competency to be transformed into a real-time data fusion centre, allowing for instant access to key demand and supply indicators across the value chain. IBM can become the missing link between the demands of the mining sector and the prospects for mines and processors. Using predictive tools and modern data analytics can set the grounds for a transparent and efficient industrial space. The IBM could ultimately be subsumed in the proposed NCMT.
- **R&D:** The country lacks specialised R&D in rare earths, and this can seriously stymie domestic industrial efforts. Therefore, the twin strategies of setting up domestic R&D centres of excellence along with the acquisition of foreign data and talent are necessary. Concentrating efforts in a handful of highly ranked universities, access to mines, industrial linkages, tie-ups with foreign research endeavours, and onboarding former national and international faculty on short tenures is a prudent way forward.
- **Recycling, Green Chemistry, and Substitution:** India‘s chemistry-intensive heavy manufacturing sector has, of recent, seen enhanced investor interest. This comes on the back of a slow buildup in India‘s commercial chemistry skills and R&D efforts, which has set up a veritable industrial base. Augmenting these efforts with public policy and research for an outcome focussed outlook in the following three heads can be transformative:
- Recycling: India‘s e-waste processing sector has seen burgeoning growth and sophistication. Some of the rare earths present in global e-waste can be extracted and recycled this way, ameliorating supply chain efforts.Apart from e-waste, rare earth recovery from the waste products or residues from the processing of other, more frequently found minerals too should be activelyexplored.
- Substitution: Finding innovative means of subsidising more critical elements with less, more readily available ones has been a particular concern for the west for a few years. India too should focus on reducing its dependence on minerals where domestic and friendly supply sources

are scarce.

- Green Chemistry: As mentioned above, rare earth chemistry tends to be dirty i.e. polluting and hazardous. However, a concerted research effort into greener, cleaner chemistry (which already exists in some pockets of the Indian chemical industry space) can enable India to secure its resource needs while simultaneously emerging as a processor of choice.
- **Blue Economy:** India's high skilled chemistry labour, low costs, and policy push can enable India to open processing facilities using predominantly imported ores. This will be particularly true for Indian acquired mines in Africa and Latin America, which are essential sources of Heavy Rare Earths. Plus, most of the present reserves are in beach sands. Therefore, setting up of these facilities near the coastline, with fast access to ports is vital. Further, India can stay future ready for possibilities such as deep ocean mining, which it is known to be pursuing. Further, India has rich deposits in its Exclusive Economic Zone within the Indian Ocean; as India's Deep Ocean Mission progresses and extraction technologies mature, having facilities onshore will be an exercise in future-proofing.

Rare Earth Quad

The Quad grouping of India, USA, Australia, and Japan have been known to have set up a ‗Critical and Emerging Technology' working group, which subsumes critical minerals' supply chain security. Recently, these countries have been signing bilateral agreements on the matter, and a consensus seems to be emerging. This development can foster a meaningful change for India. All the above countries were either producers of rare earths, or processors, or both. Economic diplomacy can rope in more like minded countries, bringing important capabilities to the table- France, UK, Germany, etc. Their combined efforts and willingness to collaborate can counter China's present monopoly in two important ways- by diluting the monopoly itself as production comes online, and by forming a monopsony (a big buying bloc having a large proportion of global demand). This will not only increase all parties' bargaining power, but allow for a slow decoupling from Chinese dependence. Reducing Chinese dependence on emerging and strategic technologies will provide a great fillip to Indian ambitions economic and military. The use of import-export and capital white lists with such friendly countries, joint ventures with transfer of technology, willingness to participate in decentralised processing, and getting investment (both financial and scientific) into India‘s critical materials sector will leverage India‘s attempts to their fullest potential.

Conclusion

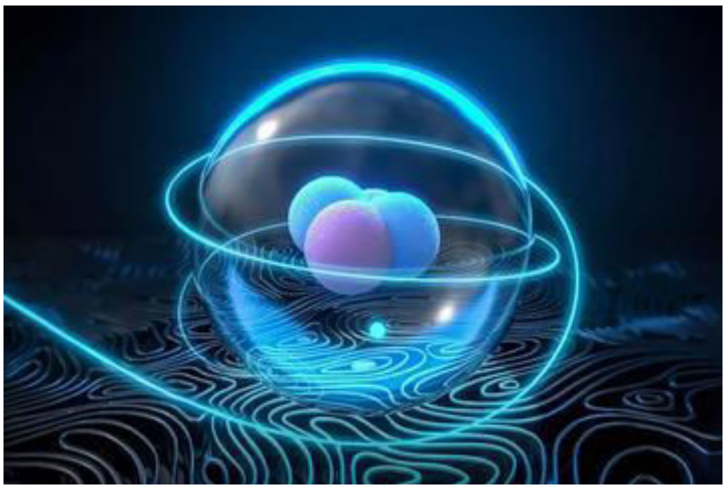
India‘s economy and military not only need to be insulated from external shocks, but their intrinsic strength needs to be developed to the fullest. The fragility of global supply chains, as well as Chinese disregard for a rules based global order, have forced India to recalibrate its modus vivendi. This crisis, however, is an opportunity for India to consolidate its future as an economic, military, and scientific power. There is much that is possible in this space, which begins with unshackling self-imposed policy shibboleths. If a careful and consistent effort on rare earths is made, India‘s prospects won‘t only be secured- they‘ll be empowered.

Special thanks to Professor Gautam Desiraju from the Indian Institute of Science (IISc), Bengaluru, for his guidance.

Antiprotons in Superfluid: Hybrid Antimatter-Matter Atom Behaves in Unexpected Way

Source website links: https://scitechdaily.com/antiprotons-in-superfluid-hybrid-antimatter-matter-atom-behaves-in-unexpected-way/

A team of scientists at CERN led by MPQ physicist Masaki Hori discovered that a hybrid antimatter-matter atom behaves in an unexpected way when immersed in superfluid helium. The result may open a new way for antimatter to be used to investigate the properties of condensed matter, or to search for antimatter in cosmic rays. When peering into the shadowy world of antimatter, researchers have to rely on elaborate technical tricks to keep their samples of antimatter from coming into contact with the normal matter that surrounds us.



Antiprotonic helium atom suspended in liquid helium in the superfluid state. The antiproton is protected by the electron shell of the helium atom and so avoids immediate annihilation. Credit: Christoph Hohmann (LMU München / MCQST)

This isolation is critically important because antimatter and matter immediately destroy each other on contact. An international team of scientists led by the Max Planck Institute of Quantum Optics (MPQ) in Garching has nevertheless combined matter and antimatter into curious hybrid atoms of helium that remain stable for short periods of time. Now the researchers from Italy, Hungary, and Germany have submerged the bizarre atoms into liquid helium and cooled it down to temperatures close to absolute zero where the helium changes into a so-called superfluid state.

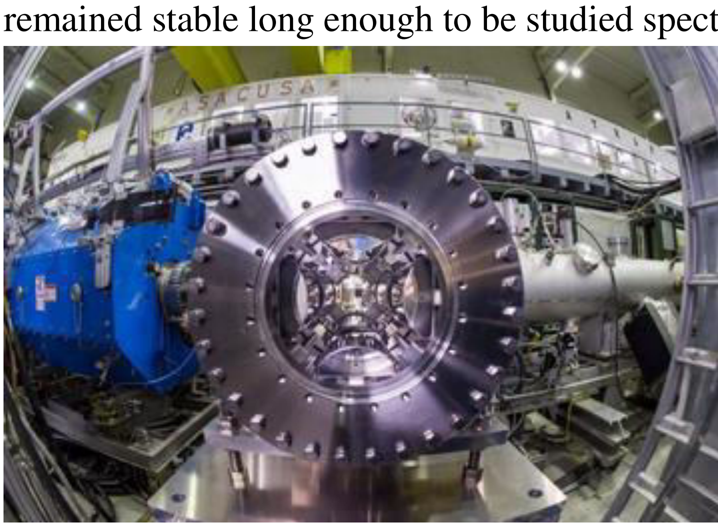
The results of the experiments carried out at the European Organization for Nuclear Research (CERN) in Geneva, Switzerland surprised the scientists because of the precise and sensitive way that the antimatter-matter hybrid atoms reacted to laser light despite the dense liquid that surrounded the atoms. ―Experiments on antimatter are particularly exciting with regards to the fundamental laws of physics, says Masaki Hori, the team leader. For example, the Standard Model of particle physics — the basis of scientists' current understanding of the structure of the universe and the forces acting within it — requires that particles and their antiparticles differ in the sign of their electric charge.An antiproton — the counterpart of the positively charged proton, a building block of atomic nuclei — carries a negative charge. According to the Standard Model the other properties are identical. ―In our past experiments, we have found no evidence that the masses of protons and antiprotons differ in the slightest, notes Hori. ―If any such difference could be detected, however small, it would shake the foundations of our current view of the world.

Research leader Masaki Hori at the ASACUSA experiment in CERN. Credit: CERN

But perhaps the available experimental methods are just not sensitive enough to detect any subtle differences that might exist? —We canot rule that out before actually measuring, says Hori. That‘s why scientists around the world are fine-tuning various techniques to scrutinize the characteristics of antiparticles with ever greater precision. —To do this, atoms of antimatter have been magnetically levitated in vacuum chambers for spectroscopic measurements. Other experiments have confined antiprotons in ion traps made of electric and magnetic fields, Hori explains.—Our team has previously used this hybrid helium atom to precisely compare the masses of antiprotons and electrons.With his team‘s latest findings, however, the Garching physicist has paved the way for a different application of antimatter by optical spectroscopy of antiprotonic helium atoms in a superfluid environment.

Electron out, antiproton in

To create the exotic helium atoms containing antiprotons, the researchers used the Antiproton Decelerator at CERN — a globally unique facility that slows down the antimatter particles created in collisions of energetic protons. The slow velocity of the antiprotons makes them ideal for experiments such as those conducted by Hori‘s team. The researchers mixed the slow antiprotons with liquid helium cooled to a temperature of a few degrees above absolute zero, or minus 273 degrees Celsius, trapping a small part of the antiprotons in atoms of helium. The antiproton replaced one of the two electrons that normally surround a helium atomic nucleus — forming a structure that remained stable long enough to be studied spectroscopically.



Photograph of the quadrupole triplet lens used to focus the antiproton beam into a helium target. Credit: CERN

―Until now, it was thought that antimatter atoms embedded in liquids could not be investigated by high-resolution spectroscopy using laser beams,‖ Hori reports. This is because the intense interactions between the densely packed atoms or molecules of the liquid lead to a strong broadening of the spectral lines. These lines are images of resonances in which the energy absorbed from the laser beam excites the atoms. They are thus a kind of fingerprint that identifies each atom. The exact position of the resonance line on the frequency scale as well as the shape reveal the properties of the atom under investigation — and the forces acting on the antiparticle. But the broadening of the lines obscures this information because it is virtually smeared. Hori and his team have now succeeded for the first time in preventing the ―smearing‖ of the spectral lines in a liquid.

Surprisingly slim line at 2.2 Kelvin

In a series of experiments, the scientists took a spectroscopic look at the antiprotonic helium atoms at different temperatures. To do this, they irradiated the liquid helium with light from a titanium sapphire laser, which excited two characteristic resonances of the antiprotonic atoms at two different frequencies. The surprising discovery: ―If the temperature dropped below the critical temperature of 2.2 Kelvin – 2.2 degrees Celsius above absolute zero — at which helium enters a superfluid state, the shape of the spectral lines suddenly changed, reports Anna Sótér,who was the principal PhD student of the MPQ team in this project and recently promoted as assistant professor of ETH Zürich. ―The lines that were very broad at higher temperatures became narrow. The superfluid phase is a special liquid state that is characterized, among other things, by the absence of internal friction. The quantum physical phenomenon is typical of helium at extremely low temperatures. ―How the striking change in the spectral lines of the antiproton comes about in such an environment and what happens physically in the process is something we don't know yet,says Hori. ―We were surprised by it ourselves.But the possibilities offered by the effect are far-reaching. This is because the narrowing of the resonance lines is so drastic that when excited with light, the so-called hyperfine structure can be resolved, the scientists report in a publication in Nature. The hyperfine structure is a consequence of the mutual influence of the electron and the antiproton in the atom. This indicates that researchers could create in superfluid helium other hybrid helium atoms with different antimatter and exotic particles to study in detail their response to laser light and measure their masses. An example of this is pionic helium atoms that were recently studied by laser spectroscopy at the 590 megaelectron volt cyclotron facility of Paul Scherrer Institute in Villingen, Switzerland.

Searching for particles in cosmic radiation

The sharp spectral lines could also be helpful in detecting antiprotons and antideuterons in cosmic radiation. Researchers have been on the trail of these for years, for example with experiments on board the International Space Station (ISS). Soon, scientists will also launch a test balloon over Antarctica — with an instrument on board that can detect antiprotons and antideuterons that may exist at very high altitudes in the atmosphere.

Masaki Hori speculates: ―Detectors with superfluid helium may support future experiments and may be suitable for capturing and analyzing antiparticles from space. Numerous technical challenges must be overcome, however, before such methods become complementary to existing ones.

This would possibly help solve another great mystery: the question of the nature of dark matter — an ominous and hitherto unknown form of matter that is invisible but apparently accounts for a large part of the mass in the universe. In some theories, it is believed that when dark matter interacts in the halo of our Galaxy, antiprotons and antideuterons may be produced that could then be transported to the earth. Antimatter, of all things, could shed light on this darkness.

Reference: "High-resolution laser resonances of antiprotonic helium in superfluid 4He" by Anna Sótér, Hossein Aghai-Khozani, Dániel Barna, Andreas Dax, Luca Venturelli and Masaki Hori, 16 March 2022, Nature. DOI: 10.1038/s41586-022-04440-7