Spectral Observation of Interstellar FeD_2 Molecule Accomplished with Far-Infrared Laser Magnetic Resonance

Scientists from the National Institute of Standards and Technology (NIST) Time and Frequency Division, Oxford University, and the University of Bonn have made spectral observations of the iron deuteride (FeD_2) molecule near 6.9 terahertz using laser magnetic resonance (LMR) spectroscopy. These are the highest frequency far-infrared (FIR) LMR observations recorded and the first FIR observations of a vibrational bending spectrum made using LMR spectroscopy.

The research team modified a spectrometer so that it allows measurements at frequencies as high as 9 terahertz, just about the same as the upper limit for radio astronomy measurements. This expanded range of LMR measurement now covers fine-structure transitions in a number of atoms and molecules, providing the potential for making the exacting laboratory frequency measurements needed to support searches for these species in space.

The FeD_2 observations provide accurate spectral information for researchers to search for iron in the interstellar medium—an existence that has yet to be documented. Additionally, the development of the technology used to make the observations opens significant opportunities for measurements in radio astronomy and upper-atmospheric research.

Closer to Earth, the researchers soon may use their new ability to assess the level of chlorine oxide (ClO), an important molecule in the upper atmosphere. ClO has a fine structure transition at 8.2 terahertz, which should be detectable by the improved LMR spectroscopy. This data would provide needed information on atmospheric chemistry relating to depletion of the ozone layer.

Chemically Modified Soy Oil Replaces Conventional Resins in Composite Manufacturing Processes

A patent disclosure filed October 27, 1997, by University of Delaware scientists describes a technique for using soybean oil, rather than petroleum-derived resins, to produce inexpensive, lightweight, and potentially biodegradable composites for tractors, bridges, and military vehicles. The technique involves chemically modifying soy oil, a commodity that is 50% cheaper than the polyester, epoxy, and vinyl ester resins commonly used in composite manufacturing processes, said Richard P. Wool, professor of chemical engineering and director of the ACRES (Affordable Composites from Renewable Sources) project at the university. Soy-based resin and reinforcing fibers such as glass may then be injected into a mold where the liquid solidifies to form the composite, Wool said.

The scientists unveiled a door-sized sample of the environmentally friendly material during the John Deere New Millennium Plastics Expo, which took place September 16–17, 1997, in Moline, Illinois. Featuring a foam core encased on both sides by a glass-reinforced, soy-based composite, the 8-by-3-foot prototype weighed 25 pounds, making it up to four times lighter than a comparable metal bailer part. Although the prototype contained preservatives, Wool said, subsequent formulations could easily be made to biodegrade under certain conditions. Ultimately, he said, natural straw or hay fibers might replace the reinforcing glass matrix within the soy-based composite.

"This first test part would replace standard metal sheeting materials," Wool said. "It would not corrode or rust, and it was made using a low-energy procedure that is far more benign than metal casting systems. Moreover, it is structurally comparable to metal, but at lower cost, while its lower weight provides better fuel efficiency."

The use of soybeans in composite materials has thus far been limited primarily to surface coatings such as varnish, "but none of these applications require any structural strength from the resulting material," Wool said. By comparison, he said, his process strengthens soy oil by chemically modifying its structure, resulting in more highly cross-linked, and therefore inherently stronger molecules. More than a dozen different chemical reactions have been developed and are currently being patented by the university.

The researchers have achieved composite stiffness, strength, and toughness comparable to that of commercial vinyl-ester-based composites, said doctoral candidate Shrikant Khot. Wool said that genetically engineered soybeans now make it possible to produce a consistently reliable product, thereby avoiding problems such as seasonable variations in the chemical composition of the natural oil.

Stone-Age Use of Collagen Discovered Near the Dead Sea

Research at the Weizmann Institute of Science in Israel reveals that in the stone age, people were putting collagen to use. Arie Nissenbaum, the Institute's Academic Secretary, discovered an 8,000-year-old cache of collagen used as glue during the Neolithic period in the area of the Dead Sea.

"No one knows who these people were and where they came from, but by stone-age standards they surely had mastered at least one type of advanced technology," said Nissenbaum. According to Nissenbaum, production of collagen glue placed the stone-age inhabitants several thousand years ahead of the ancient Egyptians, a surprising technological feat for a group that had not yet mastered pottery.

As reported in *Archeologia Umada'ei Hateva*, Nissenbaum studied findings from the Nahal Hemar cave, which, Nissenbaum said, was probably used for cult purposes by ancient humans. According to Nissenbaum, this cave, located on a cliff near the Dead Sea northwest of Mt. Sedom, has provided some of the most important regional findings from the Neolithic period. One of the striking features of the excavated objects is the use of a black substance originally believed to be asphalt. It was applied as a protective lining on rope baskets, contain-

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ers, and embroidered fabrics, as a criss-cross-patterned decoration on tops of sculptured skulls, and as an adhesive holding together tools and utensils.

When Nissenbaum, who studied asphalt from different archaeological digs, conducted a chemical analysis of the material, he discovered it was not asphalt but rather collagen, the most common fibrous protein in living organisms and a major component of skin, sinews, and cartilage. Its chemical composition, as well as an electron microscope analysis of its structure, suggested it was derived from animal skin.

Carbon-14 dating established that the collagen was about 8,100 years old, which coincided with the period when the cave was first used. Although collagen normally quickly converts into gelatin, according to the report, the Nahal Hemar specimens were exceptionally well preserved due to the region's extremely dry climate.

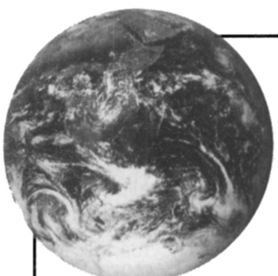
Natural glues from animal and plant sources were extensively used from antiquity up to the early 20th century. According to Nissenbaum, with the Middle East's scarcity of trees, a common source of resin adhesives in ancient Europe, it is hardly surprising that people during the Neolithic period turned to collagen as a glue. What is surprising, though, is that this use of collagen is older than that previously known that the ancient Egyptians used in its gelatinous form as the basis for the "carpenter's glue" that held together furniture.

Nissenbaum said that while the Egyptians apparently produced "carpenter's glue" through heating and alkaline solution treatment of animal skins, it remains unclear how the Neolithic inhabitants near the Dead Sea manufactured theirs. Clearly, however, the stone-age artisans supplemented the glue with plant-tissue additives, evidently in order to endow it with the appropriate texture.

Laser Process Purifies MG-Silicon

Researchers at Central China Normal University and Hauzhong University of Science and Technology in China have developed a laser technique for processing metallurgical grade silicon (MG-Si). The researchers used MG-Si powder which was about 97% purified. The researchers applied a multimode 5 kW continuous wave (cw) carbon dioxide laser. The silicon sample had been treated by a laser beam with irradiation intensity about 2 kW/cm^2 for 0.5–1 minute in a gas environment of 95% Ar^+ and 5% HCl. The silicon sample was melted by the laser beam. Violent reactions between the molecules of silicon and the impurities in the silicon sample and the molecules of hydrogen chloride occurred on the surface of the silicon sample under high temperature and infrared laser photon irradiation.

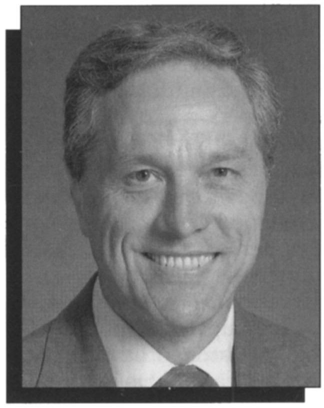
After the laser process, the silicon sample was purified. In the middle section of the smelted sample, in particular, the densities of the impurities had decreased by about one order of magnitude. The densities of fermium and aluminum had been decreased by about two orders of magnitude. In the top section of the smelted sample, the densities of the impurities were slightly higher than in



the middle section, while purification of the silicon in the bottom section changed only a little.

According to Zhao Ning of the Department of Physics in Central China Normal University, the infrared laser beam can easily heat the sample to a high temperature. The infrared laser photons excite molecules of hydrogen chloride, which accelerate the reactions' velocity between the molecules of impurities in the silicon sample and the molecules of HCl. Ning said that the process of laser smelting is simple, achieving a high production efficiency.

Harper Receives John A. Thornton Memorial Award and Lecture from AVS



James M.E. Harper

The American Vacuum Society has presented the John A. Thornton Memorial Award and Lecture to James M.E. Harper of IBM T.J. Watson Research Center on October 22, 1997, during AVS's 44th National Symposium held in San Jose, for Harper's "pioneering research on ion beam deposition and sputtered thin films." Harper's research is focused on the materials science of interconnections and interfaces for advanced microelectronics, with the goal of introducing improved materials and processes into semiconductor manufacturing. He has recently researched compound formation, phase transformations, and thermomechanical stability of aluminum, copper, tungsten and metal silicides in submicrometer dimensions, with an emphasis on rapid turnaround measurements of important materials properties.

Harper received his PhD degree in applied physics from Stanford University. He has co-authored five book chapters, about 130 technical papers, and 25 patents. He was chosen AVS Fellow in 1995. He has served as a councillor of the Materials Research Society and chair of the MRS Subcommittee on Meetings Quality.

The AVS award consists of a cash prize, a commemorative plaque stating the nature of the award, and an honorary lectureship at a regular session of the AVS National Symposium.

Single-Energy X-Ray Source Produces Sharply Defined Images

A team of scientists from the University of North Carolina at Chapel Hill, the Illinois Institute of Technology in Chicago, Brookhaven National Laboratory, and North Carolina State University in Raleigh are developing an imaging method using a single-energy x-ray source to produce sharply defined pictures. The research team physician Etta Pisano, also mammography chief and associate professor of radiology at the UNC-CH School of Medicine, said, "Mammography presents difficult imaging problems because the densities of the tissues are similar, and the lack of contrast often masks tumors. With our new method, which we call diffraction-enhanced imaging, or DEI, we have produced images showing improved detail of cancerous tumors in human breast tissue."

With synchrotron radiation, the DEI method employs a single-energy fan beam of x-rays instead of the broad-energy beam of conventional radiography. The beam is passed through the object under study.

Dean Chapman, director of the IIT's Center for Synchrotron Research and Instrumentation, said, "This method of line-scan imaging reduces scatter and helps us visualize low-contrast areas that otherwise would be lost. The key to the new method is an analyzer crystal placed in the beam of x-rays that has passed through the object on its way to the imaging plate detector."

According to a report published in the November 1997 issue of *Physics in Medicine and Biology*, the analyzer can differentiate angle differences much less than one microradian. The refraction image shows changes in x-ray refraction as it passes through a target and highlights the edges of structures in that target. Objects having little absorption contrast may have strong refraction properties, which the image will highlight. An example is the fine, thread-like fibers extending from some malignant tumors. Normally difficult or impossible to detect, they are clearly visible in the refraction image.

https://doi.org/10.1557/S0883769400031377 Published online by Cambridge University Press

The second of two images DEI creates—the apparent absorption image—appears similar to a normal x-ray of the object but shows improved contrast due to the scatter-free method. In studies of the American College of Radiology test object used for quality control in mammography, researchers have observed better than 25-fold contrast enhancements.

Chapman said, "During recent experiments at the Advanced Photon Source, we also showed that our method is energy independent for the refraction image. Imaging breast tissue samples at 30 keV produced the same high-quality images as at 18 keV, which is the energy used in conventional mammography. Imaging at a higher energy means less dose or absorbed radiation for the patient."

If the DEI method works as well in the future as current studies suggest it could, it might be used clinically within a decade, Pisano said.

Early studies looking at defects in airplane parts also have produced significantly better pictures than conventional x-rays. Other possible applications include nondestructive materials testing, airline baggage screening, and defense.

Hand-Held Biosensor Developed for Diagnostics

A portable, hand-held biosensor capable of detecting a wide range of chemical compounds has been created by a team of researchers from The Scripps Research Institute (TSRI) of La Jolla, California and the University of California—San Diego. The biosensor, which changes colors to signal the presence of specific molecules, may represent a new type of practical and affordable device for a variety of medical applications. Potential uses range from the screening of chemicals for drugs to diagnosing illness at the bedside without having to send samples to the laboratory.

As reported in the October 30, 1997, issue of *Science*, the new biosensor is able to detect many of the classic biological reactions that involve the recognition and binding of one molecule to another partner molecule. In the researchers' tests, for example, the biosensor was able to match tiny concentrations of specific DNA sequences to its complementary strand, suggesting a potential role for a variety of genetic studies and tests, including DNA fingerprinting for clinical and forensic applications. Another biosensor proved sensitive to the binding of certain antibodies, manufactured by the body's immune system, to small amounts of their specific antigens—a class of molecules produced by invading organisms that include viruses, bacteria, in addition to toxins and allergens.

The biosensor was able to detect DNA concentrations at levels of down to 9 fg/mm^2. By comparison, current technologies detect amounts about 100–1,000 times greater than the new biosensor.

M. Reza Ghadiri of TSRI said, "The results show that we can sense very small molecules that in other systems do not produce a very big change. In our system, we see a huge change."

The new biosensor is based on work conducted during the past few years in professor of chemistry and biochemistry Michael Sailor's laboratory with porous silicon, small chips of silicon sculpted through a chemical etching process into a forest of tiny trees. When 1 cm^2 of this sili-

Jens Lindhard, professor emeritus at Aarhus University, passed away on October 16, 1997. Jens was the leading figure in particle-solid interactions for almost 40 years, and his scientific horizon reached far beyond this field. His paper on the properties of a gas of charged particles, introducing what is now called the Lindhard function, has become a landmark in physics. He contributed pioneering work on channeling, on ion penetration (LSS theory), and on particle stopping. He also made contributions to nuclear physics, thermodynamics, and relativity. As a theoretician he was interested in and contributed to new experimental developments throughout his career. Lindhard seldom wrote more than one paper on a topic that he became interested in, but most of those papers became central for further development, in which he always kept an active interest. His latest published paper, on the relativistic theory of stopping of heavy ions, combines two of his lifelong interests, particle stopping and relativity. Lindhard's scientific activity remained undiminished throughout his life. In later years much of his interest was devoted to the theory of gravitation.

Lindhard, born in 1922, studied physics at the University of Copenhagen and in Stockholm. He had received a MSc degree and a gold medal from the University of Copenhagen. His move to Aarhus to a new chair in theoretical physics was the first and decisive step to establish his institute as a leading research laboratory in the physics community. From 1982 to 1988 Lindhard served as president of the Royal Danish Academy of Sciences and Letters. He received honorary degrees from Odense University in 1996 and from Fudan University in Shanghai in 1997. He retired from Aarhus University in 1992 but continued to work in his office almost every day.

Edited from *Ion Beam Resources News Update.*

https://doi.org/10.1557/S0883769400031377 Published online by Cambridge University Press

con forest is stretched out, its surface area would be about as large as a standard desktop. Though not fully understood, the scientists speculate that the binding of molecules to the surface significantly alters the refractive index of the silicon matrix itself, resulting in a major increase in sensitivity.

"It's as if the color of the film itself is changing because we induce this change in the silicon nanoparticles," said Sailor.

Nonbiological Molecule Self-Assembles into Helical Structure

Chemists at the University of Illinois at Urbana-Champaign have synthesized a nonbiological molecule that self-assembles into a structure similar to that found in living matter. As reported in the September 19, 1997 issue of *Science*, the molecule consists of a flexible polymer chain that can be wound or unwound by either solvent or temperature changes, and may offer insights into the biological folding process. Jeffrey Moore, a professor of chemistry and a researcher at the university's Beckman Institute for Advanced Science and Technology, said that proteins function as they do because they fold into specific three-dimensional structures.

Moore said, "By applying the principles of polymer physics, we designed an all-carbon backbone that spontaneously folds into a compact helical structure. The polymer backbone consists of a string of up to 20 benzene rings held together with covalent bonds. The molecule is guided through its folding transition by nondirectional interactions and local constraints due to the covalent structure of the backbone. Weak, attractive forces between the rings cause them to rotate and stack one upon another."

The resulting helical structure has a tubular cavity that could be used to bind a variety of metals, small molecules, and reactive species, said Peter Wolynes, who holds the James R. Eiszner Chair in chemistry at the University. "The cavity could hold things in specific orientations to perform selective chemistry—for example, to catalyze reactions. In fact, the folding of linear polymers may provide a synthetically simple means of generating new three-dimensional molecules that could potentially equal the biopolymers in their complexity and functionality."

As with proteins, the folding process of the synthesized molecule is reversible, Moore said. Unlike proteins, however, the molecule has no hydrogen bonds to help drive the transition.

According to Wolynes, the importance of hydrogen bonds in determining the shapes of protein molecules has been highly debated. By eliminating the hydrogen-bond factor from their polymer backbone, the chemists have shown that nonspecific forces alone can guide intramolecular self-organization. □

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