SSM Discharged Plasma Purifies Aqueous Solutions, Also Used as Ion Source

Scientists at Taras Shevchenko Kiev University, Kiev, Ukraine, and the Institute of General and Inorganic Chemistry of Ukrainian Academy of Sciences, Kiev, Ukraine, headed by Valeriy Ya. Chernyak and Pavel N. Tsybulev, developed a method to extract metal from different aqueous solutions including waste water. In the sets of experiments they used a semi self-maintained (SSM) discharge stimulated by a plasma stream for plasma column stabilization and also for increasing the contact area between plasma and liquid. The aim of the experiments was to understand the nature of physical and chemical processes associated with the interaction of an SSM discharge and liquid. The researchers investigated axial and radial distributions of the potential in the plasma and in the liquid, elucidating the influence of alkaline and salt aqueous solution concentrations on these distributions. They also investigated the spectral composition of SSM discharge-plasma radiation and the influence of steam pressure on this composition, the chemical modification of zinc nitrate and aluminium nitrate aqueous solutions under the influence of plasma contact, and the chemical composition of aqueous sediments.

The scientists used analysis with absorbed atoms, the titration of solutions, and thermo-differential analysis to obtain chemical information about the solutions and sediments. Distillate water and the aqueous solutions of KOH, NaCl, Na_2SO_4, $ZnNO_3$, and Al_2NO_3 were used as the initial solutions. The investigations were carried out at steam pressure varied from 1 to 340 Torr.

The quantity of metal extracted from nitrate solutions was measured for the plasma-chemical process and compared to the quantity calculated by Faraday's law for electrochemical processing. From this comparison it was determined that

- compared to using electrochemical methods, metal was more effectively extracted from aqueous solutions (about twice as effective in the case of Zn) if plasma-chemical processing was used in the low-pressure region; this increase is due to an increase in the contact area between plasma and liquid; and
- plasma-chemical extraction increased with an increase of pressure in the high-pressure range, depended on the increase in the electron temperature in the plasma (about four times increased effectiveness in the case of Zn).

Chemical analysis of the solution showed that applying plasma-chemical processing to the nitrate metals aqueous solutions caused the metals to precipitate as hydrooxygen combinations.

Researchers at Taras Shevchenko Kiev University also reported the creation and investigation of an effective ion source based on SSM plasma discharge. Development of such a source is important for thermonuclear synthesis, ion implantation, and deposition of thin films for micro- and nanoelectronics.

The investigations employed a mass spectrometrical technique in a hydrogen

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and deuterium SSM discharge stimulated by a plasma stream from an auxiliary discharge source. The gas pressures ranged from 0.07 to 0.54 Torr and the SSM discharge current ranged from 0.5 to 35 mA. The relative maintenance of atomic, diatomic, and triatomic positive ions in the SSM-discharge plasma was determined by mass spectrometry. The estimated disintegration rate for triatomic positive ions was about 4×10^{-11} cm^{-3} s^{-1}. A possibility of the effective control for mass composition of the positive component extracted from the discharge plasma was observed. It was impossible to explain quantitatively such a dependence based only on ion-atom exchange or electron-ion and ion-ion recombination. However, the researchers suggested kinetics of triatomic ions could be defined by dissociative processes.

Numeric investigations of the electron energy distribution function (EEDF) in such an SSM discharge were also carried out. For program testing, EEDF was calculated in a molecular nitrogen plasma under known experimental conditions.

In the range of SSM discharge plasma parameters studied, experimental results showed that the EEDF consists of two "maxwellian" groups with essentially different temperatures ($T_{e1} < 0.8$ eV and $T_{e2} >$ 2.5 eV). The temperature of cold electrons increased from 0.35 to 0.8 eV when the SSM discharge voltage was increased from 0 to 50 V. The density ratio of high-energy electrons was less than 1%. Comparison between measured and calculated EEDF (elastic, Coulomb, inelastic, and superelastic collision with vibrationally excited molecules were encountered) showed good correlation at low energies ($E < 5$ eV). The difference between the results of experimental measurements and calculations at high energies ($E > 5$ eV) may be explained by the existence of a beam of fast electrons that usually occurs in coaxial discharges.

Piezoceramic Disk Provides Base for Smart Vibration Absorber

Researchers at Piezotronics Inc. and The Pennsylvania State University, with support of the National Aeronautics and Space Administration (NASA), have developed a lightweight, smart vibration absorber based on a thin disk of piezoceramic. The piezoceramic disk acts as part of a spring that, when placed between the vibrating structure and a dense mass, can counter with a force that cancels the structural motion.

Christopher L. Davis, a doctoral candidate at Penn State, said, "During operation, the piezoceramic disk changes size by either expanding or contracting. The size change causes the metal disk to which the piezoceramic disk is attached to bend, like the bimetallic strip in a thermostat. A stud attached to the center of the metal disk moves vertically as the piezoceramic is activated."

In the research described at the SPIE Smart Structures and Materials Conference in San Diego, California on March 3, the team showed that providing an adjustable path through which electricity can flow enables tuning of the piezoceramic absorber so that it can drive the mass efficiently at different frequencies. Experiments using the off-the-shelf device showed that the natural frequency of the piezoceramic absorber could be predictably shifted by more than 5%.

Davis said that passive vibration absorbers currently used aboard planes can only be effective at one frequency. If the noise or structural motion changes frequency, becomes faster or more high pitched, the passive absorber cannot change with it to counter it.

With the piezoceramic absorber, George A. Lesieutre, associate professor of aerospace engineering at Penn State, said, "It is enough to accommodate typical variations in aircraft engine speeds during cruise. Furthermore, it should be possible to modify the design of the basic device to increase the frequency range over which it can be tuned."

Polyatomic Ion Landing Padded by Fluorocarbon Matrix on Surface

Scientists at Purdue University have developed a technique to gently trap ions projected at a surface so they can be studied later. As reported in the March 7 issue of *Science*, researchers deposited ions onto gold surfaces covered with a single layer of organic molecules. The self-assembled fluorocarbon matrix stands vertically from the surface while remaining strongly bonded to the gold, acting as a cushion to capture polyatomic molecules bombarding the surface. While this primarily is useful for capturing and studying interesting molecules, the authors suggest it opens the door to preparing surfaces with "unusual electronic and magnetic properties," potentially even for storing information at a nanoscale level.

According to R. Graham Cooks, the Henry Bohn Hass Distinguished Professor of Chemistry at Purdue University, silyl and pyridinium cations can safely land on the surface without reacting with it.

Bulky groups of trimethylsilicon molecules were attached to the end of each ion to slow its landing and ensure that it did not hit the gold surface. Instead, the ions wedged between the fluorocarbon structures. Once the ions landed, the fluorocarbons served as shields to keep the chemically reactive particles from interacting with the gold surface or with molecules in the air.

"This experiment allows virtually any chemical species to be generated in a mass spectrometer as an ion, and injected into a surface," Cooks said.

According to Cooks, the method allows scientists to trap undamaged ions on a surface for days at a time, then release them back into the mass spectrometer by sputtering or thermal desorption for further study.

Traditional methods of surface modification rely on a limited range of chemicals that react after they are deposited on the surface, Cooks said. His approach is done with molecular ions, which can be selected on the basis of mass, allowing for a higher degree of chemical selection. Though mass spectrometers make it possible to study ions, the particles are only stable while in flight. When they hit a surface, crash landings take a toll on the tiny structures, making it impossible to preserve them or deposit them onto a surface without destroying them, he said.

He said, "Our study shows that polyatomic ions can be transferred from the gas phase to a surface and held there for periods of days." This technique enables the study of ions at relative leisure outside a mass spectrometer.

Toroidal Carbon Nanotubes Observed

A Rice University team of nanotube researchers has observed circular formations of laser-grown single-walled carbon nanotubes in each nanotube batch they created. Single-walled carbon nanotube ropes consisted of 10–100 individual nanotubes aligned over their entire length, packed in a two-dimensional crystalline array. While the researchers thought the formations could be coils that circled around as the nanotube grew, they did not see any overlap or step that would come from the start or the end of the coil. The researchers called the formations "crop circles" to reflect their skepticism that what they were seeing were actually seamless toroidal nanotubes.

"We are now convinced some of them [crop circles] are perfect 'doughnuts,'" said Daniel Colbert, Welch Postdoctoral Fellow and co-author of an article in the February 27 issue of *Nature*.

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The group can find the doughnut-shaped nanotubes on a regular basis, but Colbert said they exist in relatively low abundance. The researchers estimate that between 0.01% and 1% of ropes were of this circular type. Diameters typically ranged between 300 and 500 nm, and rope widths were similar to those of ordinary ropes: 5–15 nm.

Because nanotubes conduct electricity, the toroidal nanotubes are of interest in studying basic fundamental issues of electron transport. This discovery gives scientists the opportunity to study how electrons move in loops on the nanometer scale, and to understand the physics of nanoscale conductivity. The nanoscale crop circles could prove to help in designing electronic nanomachines.

Laser-Induced Wavepackets Used to Separate Isotopes

Ilya Averbukh of the Chemical Physics Department at Weizmann Institute of Science in Rehovot, Israel has designed a wavepacket technique to distinguish different isotopes. According to quantum theory, different quantum states of a particle—each of which can be visualized as a wave—can be combined to form a "wavepacket." When the waves in the packet come together to form a single peak, for a certain time interval this packet behaves like a classical electron, atom, or molecule that obeys the laws of Newtonian mechanics.

Averbukh, as reported in *Physical Review Letters* 77 (1996), applied an extremely short laser pulse to a mixture of different isotopes, exciting them and causing them to form wavepackets. At the moment when the wavepackets of the two isotopes are identifiably different, the research team applied a second laser pulse to ionize one isotope but not the other. The ionized isotopes are then pulled out of the mixture using an electric field. This method, in effect, creates an isotope separation "machine" operating at the level of a single molecule or atom. The wavepacket approach was applied in a laser laboratory to separate two different isotopes of bromine. □

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