

Measurement of normal modes and density of states in a disordered colloidal crystal, where $\Delta a_{ij}/\bar{a}_{ij}$ stands for probability distribution of temporal fluctuations in nearest-neighbor spacing, $\Delta \bar{a}_{ij}/\bar{a}_{ij}$ indicates the probability distribution of nearest-neighbor spacing in the equilibrium configuration, and Δt (s) is change in time in seconds. Reproduced with permission from *Science* **329** (2010) DOI: 10.1126/science.1187988; p.656. © 2010 AAAS.

disordered atomic system have not been experimentally measured because tracking the dynamics of individual atoms directly is experimentally not feasible. Normal modes and the DOS of any material provide a basis for understanding thermal, mechanical, and transport properties.

As reported in the August 6th issue of *Science* (DOI: 0.1126/science.1187988; p. 656), the researchers experimentally measured the normal modes and the energies of the normal modes. From these experiments, they deduced the average particle separations to demonstrate the high degree of geometrical order in their system. The figure shows an average mean squared displacement (MSD) with

a clear plateau which is an indication of solid-like behavior and the absence of diffusion. The team in determining the normal modes observed the spectrum energy eigenvalues converged by 20,000 independent observations of the displacement field. The researchers observed a Debye-like behavior at low energies, with a Boson peak at higher energy.

According to the researchers, this general procedure will be a vital tool to identify the impacts at particle level of different types of disorder on the structure of the normal modes and elasticity that are present in various atomic, molecular, and colloidal crystals and glasses.

Jean L.W. Njoroge

Bio Focus

Graphene serves as trans-electrode membrane for DNA molecules

Researchers S. Garaj, D. Branton, and J.A. Golovchenko of Harvard University, and their colleagues from Harvard and the Massachusetts Institute of Technology have demonstrated that graphene can act as an artificial membrane separating two liquid reservoirs. As reported in the cover story of the September 9th issue of *Nature* (DOI: 10.1038/nature09379; p. 190), by drilling a nanopore in the graphene membrane, the researchers were able to measure exchange of ions through the pore and demonstrated that a long DNA molecule can be pulled through the graphene nanopore just as a thread is pulled through the eye of a needle.

“By measuring the flow of ions passing through a nanopore drilled in graphene we have demonstrated that the thickness of graphene immersed in liquid is less than 1 nm thick, or many times thinner than the very thin membrane which separates a single animal or human cell from its surrounding environment,” said lead author Slaven Garaj, a research associate in the Department of Physics at Harvard. “This makes graphene the thinnest membrane able to separate two liquid compartments

from each other. The thickness of the membrane was determined by its interaction with water molecules and ions.”

Graphene, the strongest material known, has other advantages. Most importantly, it is electrically conductive.

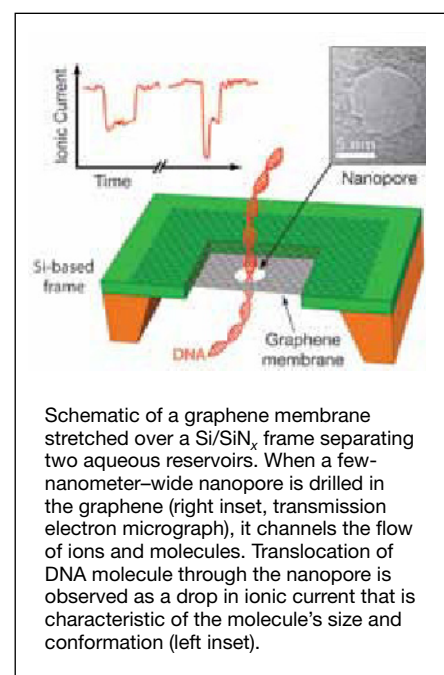
“Although the membrane prevents ions and water from flowing through it, the graphene membrane can attract different ions and other chemicals to its two atomically close surfaces. This affects graphene’s electrical conductivity and could be used for chemical sensing,” said co-author Jene Golovchenko, Rumford Professor of Physics and Gordon McKay Professor of Applied Physics at Harvard, whose pioneering work started the field of artificial nanopores in solid-state membranes.

The researchers stretched the graphene over a silicon-based frame, and inserted it between two separate liquid reservoirs. An electrical voltage applied between the reservoirs pushed the ions toward the graphene membrane. When the researchers drilled a nanopore through the membrane, this voltage channeled the flow of ions through the pore and registered as an electrical current signal.

When the research team added long DNA chains in the liquid, they were electrically pulled one by one through the graphene nanopore. As the DNA molecule threads the nanopore, it blocks the

flow of ions, resulting in a characteristic electrical signal that reflects the size and conformation of the DNA molecule.

Previously, co-author Daniel Branton, Higgins Professor of Biology, Emeritus at Harvard, together with his colleague David Deamer at the University of California, suggested that nanopores might be used to quickly read the genetic code, much as one reads the data from a ticker-tape machine. As a DNA chain passes through the nanopore, the nucleobases,



Schematic of a graphene membrane stretched over a Si/SiN_x frame separating two aqueous reservoirs. When a few-nanometer-wide nanopore is drilled in the graphene (right inset, transmission electron micrograph), it channels the flow of ions and molecules. Translocation of DNA molecule through the nanopore is observed as a drop in ionic current that is characteristic of the molecule’s size and conformation (left inset).

which are the letters of the genetic code, can be identified. But a nanopore in graphene is the first nanopore short enough to distinguish between two closely neigh-

boring nucleobases.

Several challenges still remain to be overcome before a nanopore can do such reading, including controlling the speed

with which DNA threads through the nanopore.

Other co-authors are W. Hubbard of Harvard, and A. Reina and J. Kong of MIT.

Nano Focus

Ultracompact self-wound nanomembranes exhibit exceptional supercapacitance

Designing ultracompact supercapacitors is a critical challenge for the development of next-generation compact electronic gadgets such as implantable biomedical devices. Currently available supercapacitors are too bulky for use in such small gadgets. Using nanoscale self-assembly techniques, C.C. Bof Bufon and O.G. Schmidt from Chemnitz University of Technology and IFW Dresden in Germany, and their colleagues have developed a method to fabricate self-wound ultracompact hybrid nanomembranes that are two orders of magnitude smaller than their flat counterparts with exceptionally high capacitance per footprint area.

As reported in the July 14th issue of *Nano Letters* (DOI: 10.1021/nl1010367;

p. 2506), the research team deposited strained multilayered nanomembranes by sequential depositions of metal and dielectric thin films on a sacrificial layer. Selective etching of the sacrificial layer initiated self-rolling of the nanomembranes into cylinders. The compactness of the cylinders was reproducibly tuned by careful control of the processing parameters. Hundreds of self-rolled cylinders can be prepared in parallel on a single chip which can be reused repeatedly. Furthermore, the research team demonstrated that organic monolayers may be introduced in the inorganic films of the nanomembranes to reduce leakage currents. In addition, these organic monolayers could be potentially leveraged for biological and chemical functionalization of these electronic elements with organic molecules. This self-rolling process can occur in aqueous media at physiological pH and is thus compatible for incorporation of biomolecules.



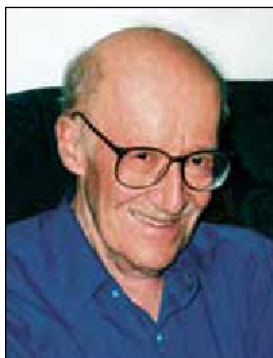
Self-rolled nanomembrane supercapacitor showing the hybrid layer sequence of self-assembled monolayer-oxide-metal. Reproduced with permission from *Nano Lett.* **10** (7) (2010) DOI: 10.1021/nl1010367; p. 2506. © 2010 American Chemical Society.

The researchers believe that these ultracompact capacitors could be used to reduce size of energy storage elements, filters and signal converters in a variety of applications such as implantable biomedical devices and novel devices for energy harvesting.

Kaushik Chatterjee

In Memoriam:

Arthur Stanley Nowick



Arthur Stanley Nowick died on July 20 at age 86 of heart arrhythmia while swimming near his home in Newport Beach, Calif. He was a pioneer in the field of internal friction, anelasticity, and crystal defects.

He is the author of more than 200 publications in a wide range of fields in materials science and solid-state physics. His 1972 book *Anelastic Relaxation in Crystalline Solids* (Academic Press), co-authored with Brian S. Berry, is widely recognized as the definitive treatise on internal friction and anelasticity. He is author of the 1995 book *Crystal Properties via Group Theory* (Cambridge University Press). He is co-editor of two additional books on diffusion in solids. He was also an advisor to nearly 30 PhD students.

Nowick was the 1994 recipient of the David Turnbull Lectureship, bestowed by the Materials Research Society in recognition of career contributions to the fundamental understanding of the science of materials. The award cited his "pioneering work in anelastic and dielectric behavior in fast ion conductors, and

in amorphous alloys," his "profound contributions to the understanding of grain boundary motion, morphological stability, the structure of surfaces and interfaces, and flow and diffusion as stochastic phenomena," and "his excellence in teaching and writing." His Turnbull Award Lecture, titled, "The Golden Age of Crystal Defects," elucidated the emergence of an understanding of crystal defects and explained his seminal contributions and those of his collaborators.

Nowick also received the Achievement Award from the American Society for Metals (1963), the A. Frank Golick Lectureship from the University of Missouri, Rolla (1970), and the Gold Medal from the 9th International Conference on Internal Friction and Ultrasonic Attenuation in Solids (1989). He was a fellow of the American Physical Society and of the Metallurgical Society of AIME. In