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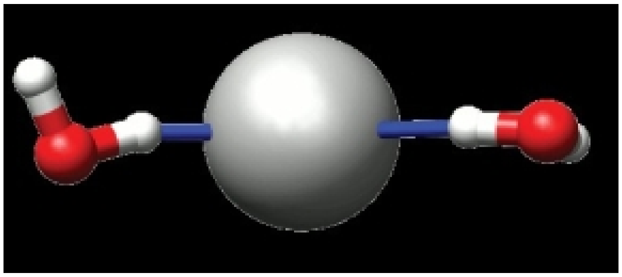
Probing nanoscale physical processes with nanopores

Pores of just a nanometer in diameter can cause ions to dehydrate as they pass through, giving rise to signature features in the ionic conductance versus the nanopore radius.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Nanopores are holes of nanoscale dimensions in a membrane. They can be made of biological or solid-state materials. At first glance, they may seem to have little to offer. Solid-state pores have no moving parts nor do they have intricate designs; they really are just holes. Construct a nanopore in a membrane that separates two solutions, however, and interesting possibilities open up for developing new technologies. By applying an electric bias across the membrane, ions are pulled through the pore and generate an ionic current. Charged molecules, such as DNA, can even be pulled into and through pores. Thus, nanopores give the opportunity to localize molecules into a small region of space. By monitoring changes in the ionic current or embedding additional sensors (such as electrodes that generate a tunneling current), for example, the properties of molecules can be interrogated as they make their way through the pore. As a result of this feature, nanopores have attracted a widespread interest from the scientific and technology communities as a foundation for ultra-rapid, low-cost DNA sequencing and molecular sensing. Less explored, however, is the potential to use them to probe physical processes occurring at the nanoscale.

In *J. Phys.: Condens. Matter* **22** 454126 (http://iopscience.iop.org/0953-8984/22/45/454126) , the authors have developed a theory of quantized ionic conductance using a combination of molecular dynamics simulations and modeling. Ions in solution are surrounded by tightly bound layers of water—so-called hydration layers. When the pore has a diameter of around one nanometer the hydration layers can be prevented from entering as the ions attempt to go through the nanopore. Thus, the ion has to 'dehydrate' or shed these strongly bound water molecules (see the figure), paying a substantial energy penalty to enter the pore in the absence of localized or surface charges. The authors predicted that dehydration of successive layers should give rise to discrete drops in the ionic conductance versus the nanopore radius, as well as enhancing the noise in the ionic current when the pore radius is tuned to a hydration layer radius.

The present work thus shows that, in addition to their potential in technologies for sequencing and detection, nanopores open up new avenues for probing physical processes at the interface between solids, liquids, and biomolecules.

About the author

Michael Zwolak is currently a Feynman Fellow at Los Alamos National Laboratory. His research interests focus on the structural transitions and the dynamics of biological molecules. More can be found at Mike Zwolak. James Wilson is a graduate student working on nanoscale electronics in the Department of Physics at the University of California, San Diego. Massimiliano Di Ventra is a professor of physics at UCSD. His interests are in the electronic and transport properties of nanoscale systems. More details can be found at Massimiliano Di Ventra (http://www-physics.ucsd.edu/~diventra/) . University of California, San Diego.

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