# Viscous nanopores collapse according to universal law

December 2 2015

Viscous nanopores, tiny holes punctured in fluid membranes, collapse according to a universal law, a Purdue University study shows. The finding could improve the design of nanopores for fast, inexpensive DNA analysis and sheds light on the biology of pores in cell membranes.

Typically just big enough to allow a single strand of DNA to pass through, viscous nanopores are powerful sensors of molecules and have applications in many areas of technology. Small pores often contract to minimize surface energy, a behavior that plays a key role in nature and technology. But visualizing how nanopores shrink and collapse is difficult after their radius contracts smaller than 10 nanometers, thousands of times smaller than a red blood cell.

Carlos Corvalan, associate professor of food science, and his team used high-fidelity computer simulations to get an inside look at the physics that govern the closing of nanopores. The simulations showed that nanopores collapse following a universal law that scales according to the pore radius.

"With this knowledge, we could design better and cheaper ways of making nanopores that will speed up DNA analysis," Corvalan said. "This could also open the door to understanding how pores in cell membranes behave."

Nanopores drilled through a sheet of silicon provide a quick, cost-effective way to analyze DNA, RNA and proteins, which are "read" as they pass through the pore.

One challenge of this technology, however, is that nanopores are too small to be made. Instead, researchers make a larger hole and gradually shrink it, stopping when it reaches the desired size. This process could be optimized if the physics that controls the collapse of nanopores was clearly understood.

Corvalan's team used a Purdue supercomputer to uncover the nanoscale details of what happens inside the pore as it closes. Using data such as initial pore radius, shape and the thickness of the membrane allowed the computer to simulate a pore's collapse and showed the team the physics underpinning the process.

"Computer simulations help complement what we can't measure," he said. "Some things that happen at the surface can be measured, and if we can reproduce those, we are more confident that the other things we see in the simulation will be correct."

To the team's surprise, collapse of a pore follows a universal law based on the pore's initial radius. This law describes the collapse of any viscous nanopore regardless of its shape - spherical, cylindrical, triangular - or the thickness of the fluid sheet encompassing it.

"The beauty of the universal law is that after a brief transition at the beginning, everything collapses according to a constant rate," said Corvalan, who is also a courtesy associate professor of agricultural and biological engineering.

The finding offers researchers the ability to fine-tune the process of creating pores as nanosensors and could also help biologists understand how nanopores in cell membranes function. Nanopores serve as cells' connection to the outside world, enabling the exchange of materials between a cell and its exterior.

One method of destroying harmful microorganisms such as food pathogens is to make holes in bacterial membranes, a process known as electroporation. If the hole is too small, however, it may collapse and heal rather than open wider, killing the pathogen.

What makes a nanopore collapse? The answer lies in a basic principle of physics: Unless outside forces are at work, everything tries to use as little energy as possible. If a pore is small enough, it will collapse due to surface tension. If it's too large, then opening wider requires less energy than closing.

"That's why when you puncture a bubble, it will break," Corvalan said. "And that's why if the pore in a bacterial cell membrane is large enough, the cell will die."

Jiakai Lu, a postdoctoral researcher in food science, and Jiayun Yu, a biological engineering undergraduate, also co-authored the study.

The paper was published in the *Journal of the American Chemical Society* and is available to journal subscribers and on-campus readers at pubs.acs.org/doi/abs/10.1021/acs.langmuir.5b01484

**More information:** Universal scaling law for the collapse of viscous nanopores, *Journal of the American Chemical Society*, pubs.acs.org/doi/abs/10.1021/acs.langmuir.5b01484

Provided by Purdue University