Polymer characterization 'tweezers' turn Nobel theory into benchtop tool

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Researchers at UC Santa Barbara have developed a new and highly efficient way to characterize the structure of polymers at the nanoscale – effectively designing a routine analytical tool that could be used by industries that rely on polymer science to innovate new products, from drug delivery gels to renewable bio-materials.

Professor Omar Saleh and graduate student Andrew Dittmore of the UCSB Materials department have successfully measured the structure and other critical parameters of a long, string-like polymer molecule – polyethylene glycol, or PEG – by stretching it with an instrument called magnetic tweezers.

"We attach one end of the PEG molecule to a surface, and the other to a tiny magnetic bead, then pull on the bead by applying a magnetic field," explained Saleh. "The significance is that we're able to perform the elastic measurements – force vs. length measurement – to see aspects of polymer structure that are hard to see in any other way, and we can do it within minutes on a benchtop apparatus."

Their research to characterize this particular polymer will lay the groundwork for developing a screening tool that could be used by a number of industries, according to Saleh's research team.

"Our measurements of PEG can be used as a baseline for comparison to other polymers, including biomolecules such as DNA, RNA and proteins, which display more complex physics," said Dittmore. "We chose to study PEG because it is an inert polymer that is biocompatible, soluble in water, and used for many technological purposes. The protocols we developed will be useful for future work with a variety of polymers, greatly expanding the versatility of the magnetic tweezers technique."

PEG is one of the most frequently used polymers in creams, cosmetics, adhesives and medicines, but its application goes beyond everyday household products. As a coating, PEG can shield against an unwanted immune response to give a medicine a stealth-like quality. To this end, it is used to enhance the effectiveness of anticancer drugs by increasing the circulation time in the body. PEG repels other molecules and is often used as a nonfouling coating for biomedical implants and biosensors that detect the presence of drugs or antibodies in blood.

In 1974, Paul Flory won the Nobel Prize in Chemistry for his theories regarding polymer structure in a solvent. Inspired by the work of Flory, and theories put forth decades earlier by UCSB materials and physics professor Philip Pincus, Saleh and Dittmore set out to develop an experiment that would validate their theories.

"Flory and de Gennes taught us that the structure of a polymer in solution depends on both the quality of solvent and also the length of the chain. Pincus extended upon this theory, and brought force into the picture as an important experimental variable," said Dittmore. "Now we have a method to directly test these ideas at the single-molecule level, using a powerful and quantitative technique."

"Until now, the most general method to obtain comparable data is to use neutron or x-ray diffraction which involves expensive national facilities such as nuclear reactors or particle accelerators. Thus, this research opens up a broad area of research that can be carried out at academic and industrial laboratories with modest resources," commented Professor

Philip Pincus, Chair of Biomolecular Science and Engineering at UCSB.

The findings of Dittmore et al. were published in the journal *Physical Review Letters* in September. The paper establishes a framework for comparing biomolecules and synthetic polymers based on chain structure that could be further refined and translated into a laboratory tool for industry.

"Many companies are looking to replace the petroleum-based polymers they use in consumer products with polymers made from biomass, such as sugar cane or cellulose," said Professor Glenn Fredrickson, Chair of Functional Materials and Founding Director of the Mitsubishi Chemical Center for Advanced Materials at UCSB. "If their methods could be made into a compact and inexpensive screening tool for polymer properties in an industrial setting, it could be important in affecting industry transformation to producing polymers from renewable resources.

Their research was made possible by support from the National Science Foundation and was carried out at the Materials Research Laboratory: an NSF MRSEC facility at UC Santa Barbara.

"This is an excellent example of high-risk, transformative research that breaks down conventional wisdom," said Craig Hawker, Director of the Materials Research Laboratory at UCSB. "The MRL is proud to have contributed to the success of this project through a Seed program designed to fund research that will revolutionize existing fields. By establishing this technique as a powerful, new strategy for characterizing synthetic polymers, countless future studies are now possible."

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