Building a smaller, lighter future: Understanding polymer behaviors below one nanometer

October 5 2010

Knowing how to build nanosized assemblies of polymers (long molecular chains) holds the key to improving a broad range of industrial processes, from the production of nanofibers, filters, and new materials to the manufacture of low-energy, nanoscale circuits and devices. A recent paper in *Nature Communications* sheds light on key behaviors of polymers in specially engineered confined spaces, opening the door to a level of control that has previously been impossible.

Scientists in Japan at Kyoto University and Nagoya University have succeeded in manufacturing custom-designed sub-nanometer scale channels, or pores, which can be manipulated to trap polymers and allow researchers to observe how these chains respond to temperature changes. Previously this level of observation was not possible, and hence much about polymer behaviors in subnanometer spaces -- in particular thermal transitions -- was unknown.

The technique uses specially designed substances known as porous coordination polymers (PCPs), which are notable for the high-degree to which their pore sizes and other characteristics can be controlled.

"PCPs allow us to design cages in which to trap specific molecules," explains lead scientist Dr. Takashi Uemura of Kyoto University's Graduate School of Engineering. "In this case, polyethylene glycol molecules -- PEGs -- can be accommodated in the cages similarly to the

way in which sea eels hide in holes. In open water there is no order to their swimming. But in cylindrical pipes, they prefer to arrange themselves linearly in groups. Polymer chains do this as well, becoming orderly assembled in the PCP channels."

In this case, the PCP channels were precisely tuned to control their size and inner surface characteristics, allowing the research team to directly observe how the polymers behaved. This led to the unexpected finding that the transition temperature -- in this case, melting point -- of confined PEGs decreased as their molecular weight -- length in this instance -- increased.

"This was exactly the opposite of what we had observed in bulk, that is, 'free' PEG," elaborates Dr. Susumu Kitagawa, deputy director of Kyoto University's Institute for Integrated Cell-Material Sciences (iCeMS). "We believe this to be the result of destabilization of the PEG chains under confinement. Instability increases together with chain length."

Understanding such minute details of the behaviors of nanoconfined polymers gives rise to the possibility of future breakthroughs in nanoscale manufacturing based on assemblies of small numbers of polymer chains, which may in turn be used to fabricate a wide range of new materials.

More information: The article, "Unveiling thermal transitions of polymers in subnanometre pores" by Takashi Uemura, Nobuhiro Yanai, Satoshi Watanabe, Hideki Tanaka, Ryohei Numaguchi, Minoru T. Miyahara, Yusuke Ohta, Masataka Nagaoka, and Susumu Kitagawa, appears in the October 5, 2010 issue of *Nature Communications*.

Provided by Kyoto University

Citation: Building a smaller, lighter future: Understanding polymer behaviors below one nanometer (2010, October 5) retrieved 26 April 2024 from https://phys.org/news/2010-10-smaller-lighter-future-polymer-behaviors.html

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