New molecules with many branches will help unleash potential of nanotechnology

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Materials science and the pharmaceutical industry could soon be revolutionized by emerging nanotechnologies based on designer molecules with long complex tree-and branch structures. Such molecules offer almost limitless scope for design of bespoke compounds for specific applications in disease therapy, for novel materials such as resins, as well as electronic displays, and energy storage. Almost every field involving design and synthesis of chemical compounds will be transformed by the arrival of technologies allowing nanoscale design of these branched molecules, known as hyperbranched polymers.

The great potential of the field, and corresponding challenges in exploiting it, were discussed at a recent workshop organized by the European Science Foundation (ESF)(Convenor: Dr. K. Karatasos, Co-Convenor: Dr. Alexey Lyulin). The workshop revealed the great scope of hyperbranched polymers and discussed how Europe in particular should respond to the challenges, such as identifying research priorities from the huge range of possibilities.

But the immediate challenge is to develop an underlying research infrastructure for building the technologies required to develop new products, for this is very much an applied field of science. This will require uniting the two sides of the field, those experimenting with these compounds in the laboratory, and theoretical chemists simulating novel hyperbranches molecules on a computer, as Konstantinos Karatasos, the workshop's convenor, pointed out.

"In principle these two communities do not interact at a desirable level," said Karatasos. "This was partly attributed to the fact that there is a lack of a "common language" between the two sides so that information can be exchanged in an efficient manner. It was proposed that this deficiency can be remedied to a certain degree, when people with different backgrounds work in a multidisciplinary environment where contacts between them are realized in a more frequent basis so that familiarization with each other's work and exchange of ideas becomes easier."

Hyperbranched polymers have already been used to develop materials such as resins and wood coatings with improved durability and resistance to abrasion. These exploit the fact that molecules with multiple branches tend to cling together more strongly, making them resistant to wear. But hyperbranched polymers also have other properties, such as low viscosity, which makes them suitable for applications such as flexible electronic displays.

But perhaps the most exciting property of hyperbranched polymers is the sheer range of compounds that can be made by manipulating the terminal side chains of the molecule to change its chemical character. This is now being exploited in a new generation of vaccines and other compounds designed to give people long term protection against infectious disease. At the ESF workshop delegates heard from Dr. Ulrik Boas from the University of Copenhagen how hyperbranched polymers can provide scaffolding for constructing new adjuvants, which are substances that upon injection activate a person's immune system against a particular pathogen. Boas reported that hyperbranched polymers can be used to interact with PAMPs (Pathogen Associated Molecular Patterns), which are motifs on the surface of microbes that can be used by the immune system to identify and then destroy them.

The workshop also revealed industrial applications building on existing work, with Dr. Christopher Plummer from the Ecole Polytechnique Federale de Lausanne in Switzerland explaining that hyperbranched polymers were capable of being tuned to highly specific levels of key attributes such as solubility, miscibility (ability to mix), as well as viscosity. The key point is that the chemical and physical properties of a molecule are determined by the surface characteristics rather than the internal structure, and hyperbranched polymers have large numbers of terminal branch points on the surface capable of being changed. As Plummer pointed out, this brings scope for improving on existing materials, for example designing ultra strong epoxy-resins that can undergo secondary toughening by addition of a hyperbranched polymer compound, whose low viscosity makes the mixing easier.

But the greatest public interest in hyperbranched polymers is being generated by the medical potential, and another exciting application on this front could lie in their use to combat currently incurable diseases involving formation of plaques comprising wrongly folded proteins, such as Alzheimer's and prion diseases like CJD (Creutzfeldt-Jacob) disease. Highly branched molecules called dendrimers have already been shown capable of interacting with the proteins that combine together in plaques to cause these diseases, with evidence that this process can be inhibited, according to Barbara Klajnert from the University of Lodz in Poland in the workshop's first presentation.

Many other topics were discussed, and the workshop set the stage for future collaboration among Europe's leading research groups in this highly promising field. The ESF Exploratory Workshop, Hyperbranched polymers as novel materials for nanoscale applications:insight from experiment, theory and simulations (HYPER-NANO) was held in Fodele in Greece during May 2008.

Source: European Science Foundation