Dendrimers: Organic Functional Nanoparticles by Design

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Micelles formed by assembly of small or polymeric emulsifiers (amphiphiles) in aqueous or organic solvents constitute miniaturized reaction vessels for various chemical reactions in geometric confinement, and give access to organic and inorganic nanoparticles. Herein, inverse mini-emulsion polymerizations will appear as a particularly useful protocol for making such nanoparticles. A special case is core-shell particles since they allow the combination of diverse chemical, physical and biological properties. Among these are hydrophobized inorganic particles for incorporation into organic matrices, immobilization of metallocene catalysts for polyolefin synthesis, or enzyme induced cleavage of peptide shells for releasing therapeutic drugs. Chemical functionalization, both in the interior and on the surface of nanoparticles, is thus a key process. But there remain uncertainties regarding the size of the particles as well as the number and location of active groups.

Dendrimers, three-dimensional, highly branched polymers, hold promise for better size control and precise nanosite definition of functional units, despite slightly more synthetic effort. However, many dendrimers are made from conformationally flexible bonds and are thus not shape-persistent, and this hampers the desired control over the function of guest molecules. We introduce a unique class of polyphenylene dendrimers (PPDs) which are only made from twisted, tightly packed, interlocked benzene rings. Their advantages are:

- monodisperse, defect free structures in spite of molecular weights up to 1.8 MDa: the perfection arises from the build-up via repetitive Diels-Alder cycloaddition reactions;
- shape-persistence;
- thermal and chemical stability; and
- site-specific chemical functionalization in the core, scaffold and on the surface.

It is this design that yields highly sophisticated functions. We describe light harvesting, catalysis, sensing after uptake of guest molecules and drug release. A particularly exciting case is the formation of polar and unpolar “patches” on the surfaces that enables transfection of an adenovirus.

Klaus Müllen was director at the Max Planck Institute for Polymer Research. He now holds an emeritus position for continuation of his research there and is fellow of the Gutenberg Research College of Mainz University. His broad research interests range from new polymerforming reactions, to the chemistry and physics of single molecules as well as graphenes, dendrimers and biosynthetic hybrids. He published about 1,900 papers. He received the Max Planck Forschungspreis, Philip Morris Forschungsspreis; Nozoe-Award; Science Award of the “Stiftverband”; Innovation Award of the State of North Rhine Westphalia; Nikolaus August Otto Award; Society of Polymer Science Japan International Award; Americal Chemical Society (ACS) Award in Polymer Chemistry; Tsungming Tu Award, Taiwan; BASF-Award for Organic Electronics; Franco-German Award of the Société Chimique de France; Adolf-von-Baeyer-Medal; Utz-Hellmuth-Felcht Award, SGL Group; China Nano Award; Carl Friedrich Gauß-Medal, van’t Hoff Award of the Royal Netherlands Academy of Sciences as well as the Hermann-Staudinger Award and the Award of the Academy of Sciences and Humanities in Hamburg. From 2008-09, he served as president of the German Chemical Society (GDCh). In 2013-14, he was president of the German Association for the Advancement of Science and Medicine. He is member of the American Academy of Arts & Sciences, North-Rhine-Westphalian Academy for Sciences and Art, National Academy Leopoldina, European Academy of Sciences, Braunschweigische Wissenschaftliche Gesellschaft and Academia Europaea. In 2010, he received an Advanced European Research Grant for his work on nanographenes. He is associate editor of the Journal of the American Chemical Society.