Self-Assembly of Anisotropic Multi-Nano-Composites

Gero Decher

A major roadblock in materials science lies in the controlled preparation of composites composed of more than two components, so-called multi-composites and this holds especially true for nanoscale multicomposites. This is due to the fact that phase separation phenomena at the micro- and nanoscale often prevent to organize the individual components in a composite with precise distances between them. Over the last 20 years our team has focused on the development of one-dimensional multicomposites, so-called Layer-by-Layer (LbL) assembled films, in which the sequence of different materials and the distances between them are precisely controlled along the layer normal.

An even greater challenge in materials science lies in the preparation of anisotropic materials which possess physical properties, for example optical, electronic or mechanical properties that differ in different directions of space. While materials science has made enormous progress over the last decades, especially with respect to composites and nowadays also nano-composits, the methods available for preparing anisotropic composite materials are still extremely limited.

Particularly interesting components for the preparation of anisotropic multicomponent materials are anisotropic nanoparticles, such as nanofibrils, nanowires or nanorods whose physical properties can easily be tuned by varying their aspect ratio. While the physical properties of such nano-objects are often highly anisotropic at the single particle level, their controlled integration into composites or multicomposites is even more difficult then the integration of their spherical counterparts. This is due to the fact that one does not only have to control the dispersion of the particles in a for example polymeric matrix, but to do so while additionally controlling the anisotropy of the composite. The latter aspect, the anisotropy of the nanocomposite film, will for the present porpose not be brought about by external electrical or magnetic fields nor will it be brought about by surface templating or mechanical stretching since all of these techniques would impose severe restrictions with respect to the requirements for the size and the chemical nature of the materials onto which the composite films can be deposited. For keeping the alignment method as general as possible we have recently developed grazing incidence spraying as a LbL-compatible technique based on liquid shear for aligning anisotropic nanoparticles with moderate to high aspect ratios in the form of LbL-monolayers on surfaces.

Here we discuss the preparation and the anisotropic properties of thin films composed of cellulosic nanofibrils and of silver nanowires. The first materials we made have already shown highly interesting properties. Cellulose nanofibrils allow to prepare biodegradable transparent objects with the tensile strength of steel and silver nanowires allow to challenge some of the plasmonic properties of metallic nanostructures that could previously only be prepared by nanolithography.