The airplane and the seashell

André R. Studart
Complex Materials, Department of Materials, ETH Zurich, 8093 Zurich, Switzerland

Composite materials are abundant in nature and are present in an increasing number of man-devised technologies. Interestingly, both natural and synthetic composites often experience similar mechanical loading conditions in their specific environment and application. Since the materials, processing conditions and methods used to obtain composites differ markedly in the natural and the synthetic worlds, the question arises as to how the structures of these materials have evolved to tackle the similar mechanical demands. Seashells and the body of aircrafts provide illustrative examples of the remarkable differences between the structures developed in natural and biological systems (Fig. 1). Modeling and direct characterization of biological materials have been carried out to address this question. Although synthetic composites that resemble the structure of biological materials have also been prepared, their use as model systems to understand the design principles of nature remains largely unexploited. The challenge in this approach is to replicate the intricate structures of natural biomineralized materials using simple synthetic assembly routes. In this talk, I will present the research efforts of our group towards the assembly of bioinspired composite structures with deliberate orientation of reinforcing building blocks. I will show a simple approach to align non-magnetic anisotropic particles coated with minimum concentrations of iron oxide nanoparticles (< 0.1 vol%) using magnetic fields as low as 1 milliTesla. Our ability to control the position and orientation of reinforcing particles within a polymer matrix can lead to heterogeneous structures with unusual out-of-plane stiffness, hardness, wear resistance and tailored local mechanical response. Such bioinspired synthetic composites might help address some of the limitations of current composite technologies and can potentially be used as model systems to investigate the design principles of biological materials.

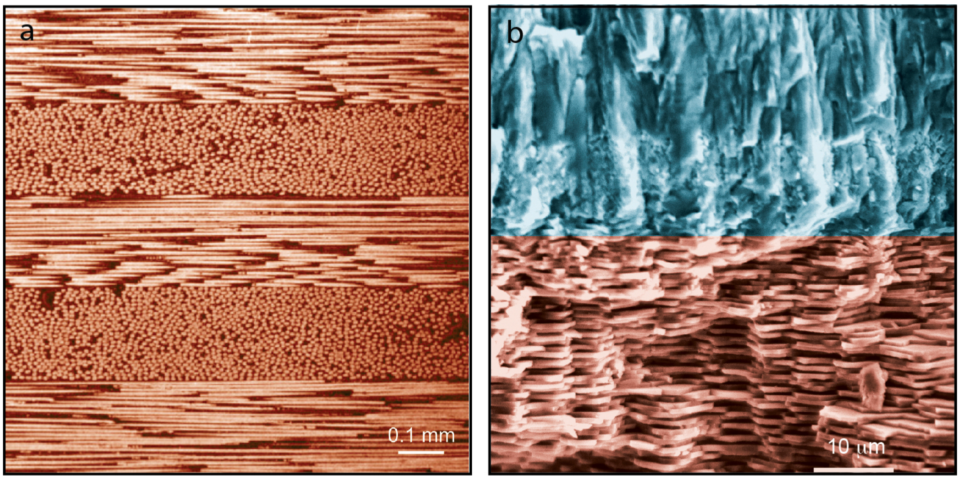

Figure 1. Cross-sections of (a) a fiber-reinforced composite laminate used in the body of aircrafts, [1] and (b) the Californian red abalone shell, *Haliotis rufescens*. [2]

References:

1. Ermanni, P., Lecture notes, ETH Zurich.
2. Qi, H. J.; Bruet, B. J. F.; Palmer, J. S.; Ortiz, C.; Boyce, M. C., Micromechanics and macromechanics of the tensile deformation of nacre. In *Mechanics of Biological Tissues*, Holzapfel, G. A.; Ogden, R. W., Eds. Springer-Verlag: Graz, Austria, 2005.