Fall 11-10-2015

Design and fabrication of microstructured composites using mechanical and magnetic stimuli

Rafael Libaroni
ETH, libanori@mat.ethz.ch

Randall Erb
Northeastern University

Andre Studart
ETH

Recommended Citation

[1] R. M. Erb, R. Libanori, N. Rothfuchs, A. R. Studart; Science 335, 199-204 (Jan 13, 2012). [2] R. Libanori, R. M. Erb, A. R. Studart; ACS Applied Materials & Interfaces 2013, 5 (21), 10794-10805.

DESIGN AND FABRICATION OF MICROSTRUCTURED COMPOSITES USING MECHANICAL AND MAGNETIC STIMULI

Rafael Libanori, Complex Materials – ETH Zurich
E-mail: libanori@mat.ethz.ch
Randall M. Erb, Northeastern University, Boston, USA.
André R. Studart, Complex Materials – ETH Zurich

Keywords: bio-inspired composites; platelet-reinforced composites; magnetic assembly; tailored microstructures; structure-properties relationship

Combining soft and hard building blocks is a widely used approach to fabricate composite materials exhibiting mechanical properties that are not achievable by their single components alone. Remarkably, the design strategies applied in engineering and biological processes lead to striking differences in the nano/microstructure and mechanical performance of such composite materials. While nature is able to grow composites with deliberate control over the orientation and spatial distribution of anisotropic reinforcing particles, the use of intricate and tailored architectures to optimize the mechanical and functional properties remains largely unexplored in synthetic materials. Although magnetic manipulation has been successfully applied as a strategy to remotely control the orientation of magnetized alumina platelets, steric interactions between adjacent reinforcing platelets limit both the maximum alignment degree and the volume fraction of platelets that can be achieved within a continuous polymer matrix. [1] In this talk, we show that bulk platelet-reinforced composites with tailored microstructures can be designed and fabricated via a directed-assembly route combining magnetic and mechanical stimuli. As depicted in Figure 1, the application of mechanical vibrations with amplitudes of 3 mm at a frequency of 50 Hz during the magnetic alignment process increases significantly the degree of platelet alignment in the resulting composite. [2]

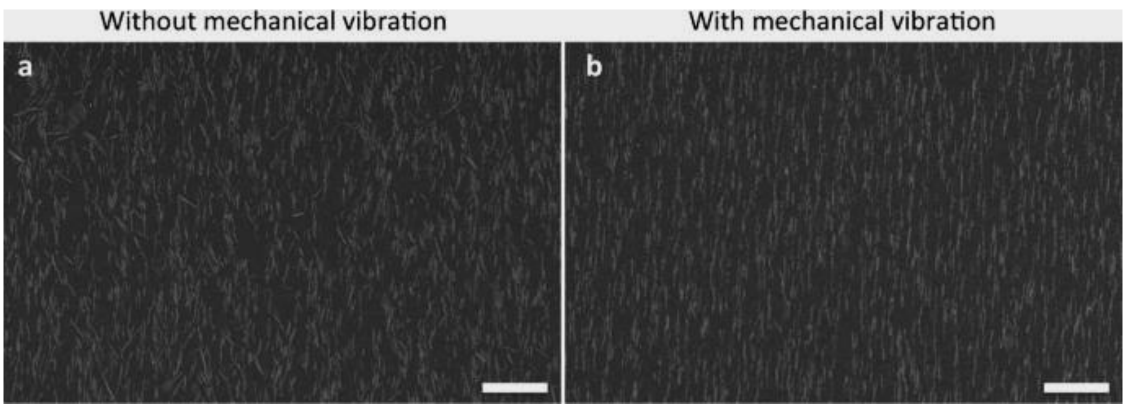

Figure 1. Scanning electron microscopy images of polished surfaces illustrating the degree alignment in composites containing 11 vol% of reinforcing platelets assembled (a) without and (b) with mechanical vibration. Scale bars: 40 µm. Adapted from ref. [2].

Such combination of stimuli allowed us to increase the maximum volume fraction of biaxially-aligned platelets in the composite material from about 15 vol% to 27 vol%. The mechanical performance and fracture behavior of the resulting composites under compression and bending can be deliberately tuned by assembling the reinforcing platelets into optimized microstructures. By combining high alignment degree with volume fractions of reinforcing platelets up to 27 vol%, we fabricated platelet-reinforced composites that are potentially compatible with cost-effective polymer processing routes while still exhibiting properties that are comparable to those of the state-of-the-art glass-fiber composites. The results presented in this work contribute to a better understanding of the structure-property relationships in platelet-reinforced composites exhibiting tailored architectures.

References

[1] R. M. Erb, R. Libanori, N. Rothfuchs, A. R. Studart; Science 335, 199-204 (Jan 13, 2012).
[2] R. Libanori, R. M. Erb, A. R. Studart; ACS Applied Materials & Interfaces 2013, 5 (21), 10794-10805.