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Composites reinforced via mechanical interlocking with surface roughened platelets

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Motivation

Developing strategies that enhance the reinforcing effect of anisotropic particles can lead to the fabrication of composite parts with substantially reduced weight for energy-saving applications in the aerospace and automobile industries. Recently, computer simulations studies have suggested that promoting mechanical interlocking at the interface between reinforcing particle and matrix can result in composite materials with enhanced energy dissipation mechanisms [1]. In this study, we present a model composite system that is reinforced with platelets with tailored roughness size and density. The mechanical performance of the resulting composites are evaluated and discussed in light of the energy dissipation mechanism implemented at the matrix-reinforcing platelet interface.

Fabrication processes

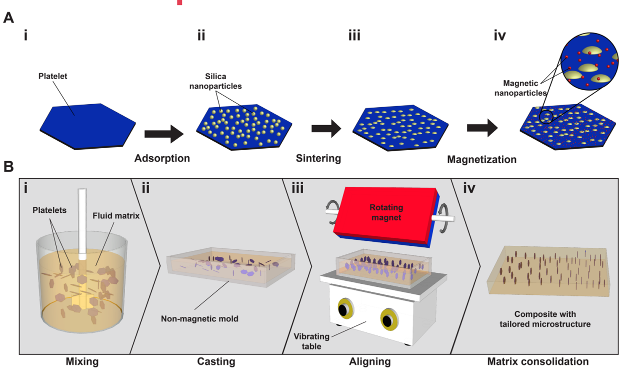

Figure 1. (A) Scheme depicting the processes involved in the surface roughening of alumina platelets. Bare alumina platelets (i) are modified with silica nanoparticles (ii). After sintering and sieving, roughened platelets (iii) are isolated for further magnetization using magnetic nanoparticles (iv). (B) Scheme illustrating the steps involved in the vibration-assisted magnetic assembly of composites with tailored microstructure [2, 3]: (i) mixing platelets and polymer resin/cement paste; (ii) casting in Teflon molds; (iii) alignment using mechanical and magnetic stimuli; (iv) consolidation of the matrix.

Roughened platelets

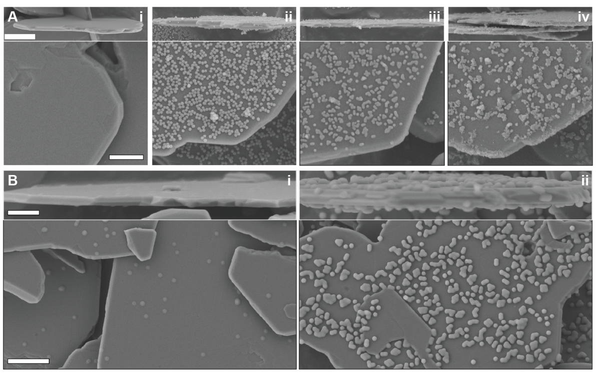

Figure 2. (A) SEM images depicting each one of the steps involved in the surface roughening and magnetization approaches of alumina platelets: (i) bare alumina platelet; (ii) alumina platelet with 100 nm silica nanoparticles adsorbed on its surface; (iii) roughened alumina platelet after sintering; (iv) roughened platelet with 12 nm superparamagnetic iron oxide nanoparticles. The insets show the cross-section of the platelets. Scale bars in (i-iv) and their respective insets correspond to 2 µm. (B) SEM images showing the modified surfaces and cross-sections of roughened platelets with asperity sizes and surface coverages of (i) 100 nm and 1.9% and (ii) 250 nm and 19%, respectively. The scale bars in the images and insets are 2 µm and 1 µm, respectively.

Mechanical properties

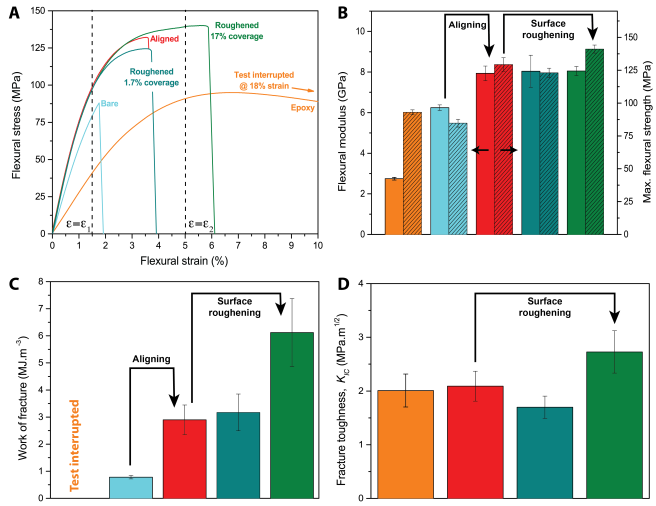

Figure 3. Mechanical performance of epoxy-based composites reinforced with roughened platelets (volume fraction of alumina platelets: 15 vol%). (A) Representative stress-strain curves of the fabricated composites clearly show the enhancement of mechanical properties due to the magnetic alignment and surface roughening on (B) flexural modulus and strength, (C) work of fracture, and (D) fracture toughness.

Mechanical interlocking mechanism

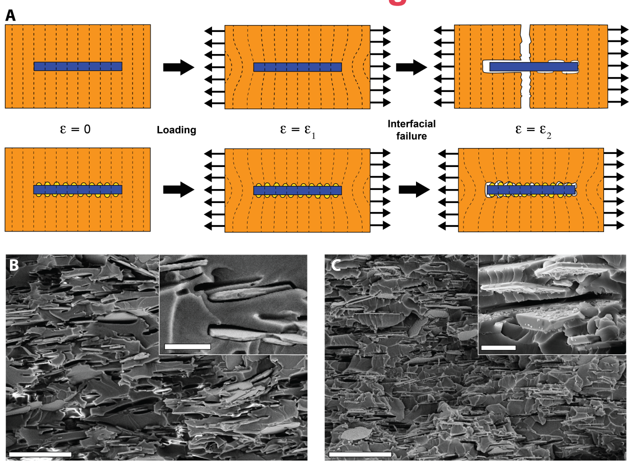

Figure 4. (A) Failure mechanisms observed in magnetically-assembled composites reinforced with flat (top) and roughened (bottom) platelets. Reference lines are drawn to indicate the expected strain field in the platelets and the surrounding matrix. Fracture surfaces of freshly cleaved composites reinforced with (B) smooth and (C) roughened platelets. The insets show a closer view of the matrix-platelet interface. Scale bars are 20 µm and 2 µm in the images and insets, respectively.

Conclusions

Reinforcing platelets with tailored surface roughness can be fabricated using a simple and robust procedure based on electrostatic adsorption and selective particle sintering. Structure-property relationships observed in model systems allowed us to understand the mechanical interlocking mechanism controlling the failure behavior of composite materials reinforced with roughened platelets.

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References: [1] Li, Y. N et al., *Phys Rev E* 2012, 85 (3).
[2] Libanori, R. et al., *ACS App. Mater. & Inter.* 2013, 5 (21), 10794-10805.
[3] Erb, R. M. et al., *Science* 2012, 335 (6065), 199-204.