Role of Biosilica in Materials Science: Lessons from Siliceous Biological Systems for Structural Composites

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Abstract The unique mechanical response of spicules of Hexactinellid sponges, notably, *Euplectella aspergillum*, are reviewed and related to the structure, architecture, and failure modes of those natural rigid composite materials. In particular, exceptional levels of resilience, damping capacity, and the ability to dissipate mechanical energy prior to failure have been observed, all these properties greatly exceeding those of synthetic melt-fabricated glass. How these observations can be related to the design of new structural composites that are based on glass are described.
1 Background

The occurrence and formation of biosilica in sponges has been discussed at length by Hartman (1981), Garrone et al. (1981), Perry and Keeling-Tucker (2000), Müller et al. (2003), Uriz et al. (2003), Uriz (2006), and others, in substantive detail.

Interest in the structure–mechanical property relationships in Hexactinellid sponges was kindled by a paper by Levi et al. (1989). In this brief and important paper, the authors reported on the existence of both remarkable resilience and toughness that was observed in a large spicule of *Monorhaphis chuni*, the failed surfaces of which are shown in the scanning electron microscopy (SEM) image in Fig. 1. This attractive combination of properties, in a material with such a large proportion of silica in its structure, has been of strong interest to the materials science community. In comparison, silica rods of like diameters (about 2 mm in thickness) typically show much lower resilience and low toughness, as shown in Fig. 2.

![Fig. 1 SEM image of a broken spicule of a Monorhaphis chuni sponge (courtesy of P. Lehuede)](image1)

![Fig. 2 Flexural stress versus strain of Hexactinellid sponge spicule compared to that of glass rod (Sarikaya et al. 2001)](image2)