American Mineralogist, Volume 97, pages 1381–1393, 2012

Controlled morphogenesis of amorphous silica and its relevance to biosilicification

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Abstract

Biogenetic biosilica displays intricate patterns that are structured on a nanometer-to-micrometer scale. At the nanoscale, it involves the polymerization products of silica, apparently mediated by the interaction between different biomolecules with special functional groups. In this paper, using tetraethyl orthosilicate [TEOS, $Si(OCH_2CH_3)_4$] as a silica source, phospholipid (PL) and dodecylamine (DA) were introduced as model organic additives to investigate their influence on the formation and morphology of silica in the mineralization process. Morphology, structure, and composition of the products were characterized using a range of techniques including FESEM, TEM, SAXRD, TG-DTA, solid-state ^{29}Si NMR, FTIR, and nitrogen physisorption. The FESEM and TEM analyses demonstrate that increasing PL concentrations at constant DA content leads to the formation of siliceous elongated structures. Localized enlargement can also be observed during further growth of elongated structures, displaying some features of the earliest recognizable stage of valve development in diatoms. In addition, in the presence or absence of PL, a series of control experiments using ammonia instead of DA show that no elongated structures are obtained, suggesting that the formation of elongated silica structures results from the cooperative interactions between PL and DA molecules. Because both organic amines (e.g., long-chain polyamines, LCPA) and phospholipid membranes (e.g., silicalemma) are of special importance for biosilicification in diatoms and sponges, our results imply that phospholipids are involved in the formation of organic aggregates, and thus influence the amines-mediated silica deposition. As such, our results may provide a new insight into the mechanism of biosilicification.

Keywords: Biosilica, phospholipids, organic amine, biomimetic mineralization, biosilicification