MS18 Biomineralogy and bioinspired materials

MS18-05

Mg-rich nanoparticles within Mg-poor calcite matrices: from coralline red algae to a widespread phenomenon in biomineralization

I. Polishchuk [1], N. Bianco-Stein [1], B.P.O.K.R. Pokroy [1]

[1]Technion - Haifa (Israel)

Abstract

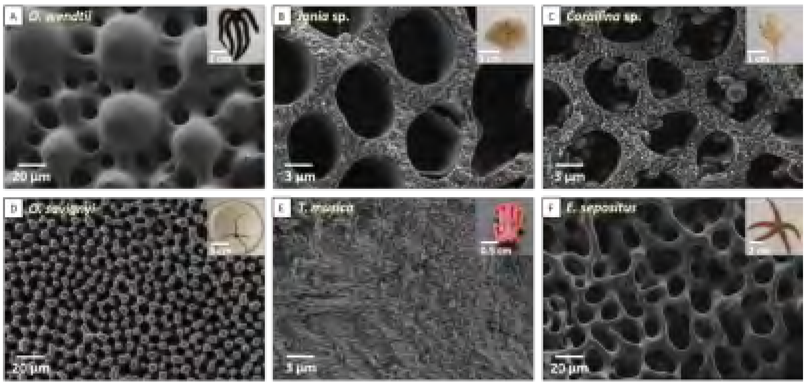
In the course of biomineralization, organisms utilize various biostrategies to enhance the mechanical durability of their skeletons. In this research, we investigated the structure and chemical composition of high-Mg biomineralized tissues of several marine organisms. The case study of articulated coralline red algae unraveled that their high-Mg calcite cell wall nanocrystals are arranged in layers with alternating Mg concentrations and that this organization facilitates crack deflection, thereby preventing catastrophic fracture. (1-2) We also discovered that these nanocrystals contain incoherent Mg-rich nanoparticles which self-arrange periodically throughout the alga's mineralized cell wall. We further show the evidence of high-Mg calcite nanoparticles in the cases of six biologically different organisms belonging to different phyla and even kingdoms.(3) Our experimental results lead us to suggest that Mg-rich nanoparticles form via spinodal decomposition of the Mg-ACC precursor. Such decomposition is independent of the biological characteristics of the studied organisms but rather originates from their similar chemical composition and a specific Mg content within their skeletons, which generally ranges from 14 to 48 mol % of Mg. We establish that the presence of high-Mg nanoparticles embedded within lower Mg-calcite matrices is a widespread strategy utilized by various organisms to improve the mechanical properties of their high-Mg calcite skeletons. The valuable knowledge gained from this biostrategy significantly impacts the understanding of how biominerals, though comprised of intrinsically brittle materials, can effectively resist fracture.In the course of biomineralization, organisms utilize various biostrategies to enhance the mechanical durability of their skeletons. In this research, we investigated the structure and chemical composition of high-Mg biomineralized tissues of several marine organisms. The case study of articulated coralline red algae unraveled that their high-Mg calcite cell wall nanocrystals are arranged in layers with alternating Mg concentrations and that this organization facilitates crack deflection, thereby preventing catastrophic fracture. We also discovered that these nanocrystals contain incoherent Mg-rich nanoparticles which self-arrange periodically throughout the alga's mineralized cell wall. We further show the evidence of high-Mg calcite nanoparticles in the cases of six biologically different organisms belonging to different phyla and even kingdoms. Our experimental results lead us to suggest that Mg-rich nanoparticles form via spinodal decomposition of the Mg-ACC precursor. Such decomposition is independent of the biological characteristics of the studied organisms but rather originates from their similar chemical composition and a specific Mg content within their skeletons, which generally ranges from 14 to 48 mol % of Mg.(3) We establish that the presence of high-Mg nanoparticles embedded within lower Mg-calcite matrices is a widespread strategy utilized by various organisms to improve the mechanical properties of their high-Mg calcite skeletons. The valuable knowledge gained from this biostrategy significantly impacts the understanding of how biominerals, though comprised of intrinsically brittle materials, can effectively resist fracture.

References

1. Bianco-Stein N, Polishchuk I, Seiden G, Villanova J, Rack A, Zaslansky P and Pokroy B*. Helical Microstructures of the Mineralized Coralline Red Algae Determine Their Mechanical Properties. Adv Sci 2020; 7:2000108.

2. Bianco-Stein N, Polishchuk I, Lang A, Atiya G, Villanova J, Zaslansky P, Katsman A and Pokroy B*. Structural and Chemical Variations in the Calcitic Segments of Coralline Red Algae Lead to Improved Crack Resistance. Acta Biomater 2021; 130:362.

3. Bianco-Stein N, Polishchuk I, Lang A, Portal L, Dejoie C, Katsman A and Pokroy B*. High-Mg calcite Nanoparticles within a Low-Mg Calcite Matrix: a Widespread Phenomenon in Biomineralization. PNAS 2022, DOI: 10.1073/pnas.2120177119.


A
B
Jania sp.
C
Corallina sp.
D
E
T. musica
F
E. sepositus
20 µm
3 µm
0.5 cm