Microscopy TODAY

Coming Events

2020

15th European Molecular Imaging Meeting – EMIM 2020
March 24–27, 2020
Thessaloniki, Greece
www.e-smi.eu/index.php?id=1976

FOM2020 – Focus on Microscopy
April 5–8, 2020
Osaka, Japan
http://focusonmicroscopy.org

2020 MRS Spring Meeting & Exhibit
April 13–17, 2020
Phoenix, AZ
www.mrs.org/spring2020

Microscopy & Microanalysis 2020
August 2–6, 2020
Milwaukee, WI
www.microscopy.org

emc2020: 17th European Microscopy Congress
August 23–28, 2020
Copenhagen, Denmark
www.emc2020.eu

16th International Congress of Histochemistry and Cytochemistry (ICHC)
August 30–September 2, 2020
Prague, Czech Republic
http://ichc2020.com

Neuroscience 2020
October 24–28, 2020
Washington, DC
www.sfn.org/meetings/neuroscience-2020

2021

Microscopy & Microanalysis 2021
August 1–5, 2021
Pittsburgh, PA
www.microscopy.org

2022

Microscopy & Microanalysis 2022
July 31–August 4, 2022
Portland, OR
www.microscopy.org

2023

Microscopy & Microanalysis 2023
July 24–28, 2023
Minneapolis, MN
www.microscopy.org

2024

Microscopy & Microanalysis 2024
July 28–August 1, 2024
Cleveland, OH
www.microscopy.org

Carmichael's Concise Review

Finding New Synthetic Routes to Complex Structural Materials

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Material scientists appreciate structures in nature that have exceptional mechanical properties. Nature has optimized high-performance materials with unrivaled strength, toughness, and resilience using three-dimensional (3D) hierarchical architectures that extend from the macro- down through micro- and nano-scale, and all the way to the atomic scale, with precision that human technology has yet to achieve. In fairness to material scientists, nature has had a few million years to work on this, whereas human endeavors only date back a couple thousand years or so.

A recent example is the elegant study by an international group headed by Jiseok Gim and Robert Hovden [1], who studied nanoscale deformation mechanics in dehydrated samples of nacre from the shell of a large Mediterranean clam (*Pinna nobilis*). Nacre, sometimes referred to as mother-of-pearl, lines the shells of most molluscs and is known to have excellent mechanical properties that could inspire new designs of structural materials. It is constructed from layered interdigitated polygonal (or pseudo-hexagonal) platelets and grains of aragonite (a form of calcium carbonate; $CaCO_3$). The platelets are 0.5 to 1 micron thick and 10 to 20 microns wide. They are bonded together by a thin (5 to 30 nanometer) layer of organic biopolymer material (the interlamellar membrane). There are also organic inclusions within the platelets. The organic material accounted for about 3.4 percent of the nacre by weight, the remainder being aragonite.

Gim et al. used high-resolution scanning/transmission electron microscopy (S/TEM) combined with *in situ* nanoindentation in their studies. This allowed sub-nanometer resolution imaging of the deformation process and provided precise assessment of when and where a fracture occurred in the nacre. During compression, the aragonite grains and organic inclusions reversibly rotate and deform, indicating nanoscale resilience of the nacre platelets. The platelets lock to continuously redistribute stress across the organic interface. Remarkably, the completely locked interface recovers its original morphology without any deformation after the compression is released, and it retains its full mechanical strength.

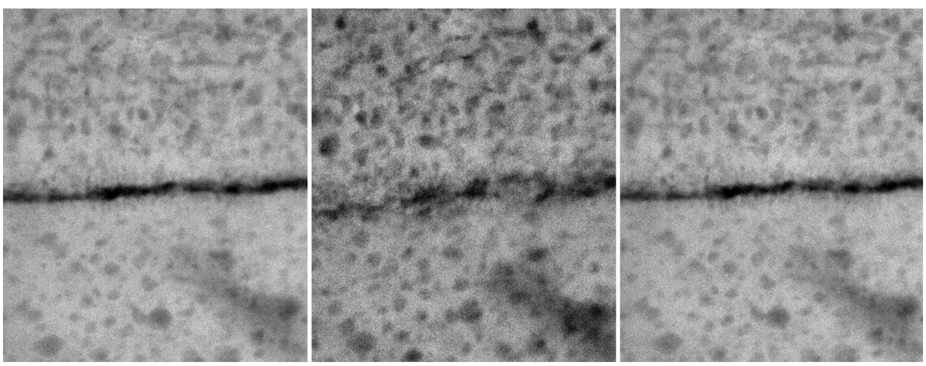

Figure 1: Highly deformed and recovered nacre. (Left) High-resolution S/TEM image of two tablets and their organic interface before compression. (Middle) Tablets heavily interlocked under 40 µN compressive load. (Right) After the indenter was retracted, the tablets and organic interface fully recovered their initial morphology. Field of view for all images is 400×465 nm.

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When a fracture did appear, Gim et al. found that the organic components resisted crack propagation both within and between platelets. The overall macroscale architecture was sustained through multiple fractures that allowed further structural loading. They found that nacre absorbs roughly 1 to 3 times more mechanical energy than aragonite alone.

S/TEM revealed that when heavily compressed, opposing nacre platelets interlocked across the mineral-organic interface to form temporary inorganic connections. After releasing the load, the mineral connections at the deformed organic interface and the intraplatelet nanostructure perfectly recovered their initial morphology without any sustained deformation. It is as if an organic "mortar" that holds the platelets together is pushed aside under pressure and springs back into place when force is removed.

The approach employed by Gim et al. enables investigation of a wide range of biominerals with desirable structural properties. The better understanding of deformation and recovery in nacre demonstrated by Gim et al. may inspire new routes to synthesize complex structural materials.

References

[1] Gim et al., *Nat Comm* 10 (2019) 4822.

[2] The author gratefully acknowledges Dr. Robert Hovden for reviewing this article.

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