Building Better Armor: Lessons from Mantis Shrimp

X-ray microdiffraction reveals structure of Nature’s most durable hammer

- The fist-like club of a small crustacean accelerates underwater faster than a 22-caliber bullet. Repeated blows from these mantis shrimps, or stomatopods, destroy mollusk shells and crab exoskeletons, both of which have been studied for decades for their impact-resistant qualities. These biological hammers survive 50,000 rapid, aggressive strikes without breaking, providing a potential model for manufactured materials.

- Physicists at the National Synchrotron Light Source performed x-ray diffraction experiments at beamlines X6A and X13B, combining high-throughput methods and high spatial resolution techniques to map the intricately structured samples on the whole-organ (millimeters) and fine-grained (microns) scales required.

- X-ray diffraction revealed that the arrangement of different composite materials allows for tiny cracks to open up within the clubs, allowing for shock absorption and preventing the kind of rigidity that might lead to more substantial fractures.

- Proposed applications for this remarkable structure include developing lighter, more durable materials for airplanes, electric cars, and military-grade body armor.

A series of 2.5 mm synchrotron maps reveals the mineral concentrations in the mantis shrimp’s dactyl club. The hard impact surface of the club was shown to be a well-crystallized form of hydroxyapatite, a mineral found in bones and teeth, which then transitions to an interior region where the mineral becomes more amorphous. Underlying and reinforcing both regions is a shock-absorbing matrix of fibrous chitin, a complex sugar.