Imagine for a second that you’re a crab, and a fellow crustacean called a mantis shrimp has decided to make you its lunch. The truth is, it’s not worth struggling. The mantis shrimp uses muscles to cock back two hammer-like appendages under its face, storing energy in a saddle-like divot in the limbs. When it releases the latch, the hammers accelerate so quickly, and strike your shell with such brutality, that they produce cavitation bubbles in the water, which collapse and release a secondary shockwave that knocks you out cold. (If you had decided to put up a fight, the mantis shrimp would have strategically blown off your claws first, then punched you in the face until you died.)

That’s a lot to unpack, and no one knows the struggle better than scientists. For years, they’ve been using high-speed photography to figure out how a
little crustacean can manage what is perhaps the most powerful pound-for-pound punch in the animal kingdom—and in the significant extra drag of water, no less. A big key, researchers report today in the journal *iScience*, is not only the shape of that energy-storing saddle, but its clever material composition. Now the engineering that’s made the mantis shrimp one of the most ferocious killers in the sea could make its way into robots—ideally not of the ferocious killer variety.

The researchers began by investigating the saddle of a mantis shrimp (which is not actually a shrimp, by the way, but a stomatopod) with a technique called nanoindentation. “Basically, you can probe the mechanics at a very small scale,” says coauthor Ali Miserez, a professor who studies bioinspired engineering at Nanyang Technological University in Singapore. “You use a diamond tip and you push on the materials.”

What Miserez and his colleagues found was equal parts strange and evolutionarily brilliant. The saddle is made up of distinct top and bottom
layers: On top is a bioceramic, not unlike what you’d find in a coffee mug, while on the bottom is a stretchy material called a biopolymer.

When you’re in the walloping business, a ceramic might not come to mind as your sturdy material of choice. “We all have the impression that ceramics are brittle,” says Miserez. “If I drop my coffee cup on the floor it would probably shatter. But actually it’s brittle mainly in tension, when you pull on it. But if you compress a ceramic it’s pretty strong.”

When the mantis shrimp loads energy into that saddle, the structure sort of folds in on itself, compressing the top layer of ceramic and exploiting its
material properties. As it does so, the bottom layer of biopolymer stretches, exploiting that material’s particular asset. “Polymers are strong in tension, like silk for instance, but not in compression,” says Miserez. So each material is uniquely suited, given its position on the saddle, to provide strength so the hammer doesn’t snap.

To test this experimentally, the researchers got out a laser. They used a rapidly firing picosecond laser, which cut out precise strips of mantis shrimp saddle material. “If you bend this sample, and you have the top layer in compression and then the bottom layer in tension, just like in the saddle during the actual strike, you can reach much higher strength,” Miserez. Flip the sample upside down and bend it again, and it fails. “That was the experimental proof that indeed this spatial arrangement is critical.”

It’s a big piece of the smashy puzzle that is the mantis shrimp strike. “The use of elastic energy storage to drive extremely fast movements is just not fully understood, and it’s barely studied,” says Duke biologist Sheila Patek, a mantis shrimp expert. “This is a really nice piece of a story that plays out in
mantis shrimp, but is also fundamental across many small organisms that use materials to drive movement.”

So the trap-jaw ant, for example, cocks its jaws back and fires them at 145 miles per hour to smash its enemies and even blast itself out of danger by aiming its face at the ground. The pistol shrimp also uses a latching mechanism to fire bullets of bubbles from its claws. It’s all visually striking, but hard to elucidate if you’re not looking at the structures involved alongside their geometry and materials.

In addition to helping unravel cool biological mysteries, this research could find uses in robotics. Your typical robot is made of metal, not ceramics. But ceramics are actually stiffer and lighter than metals, which might be useful if we can offset their brittle nature. “If you have a bilayer arrangement, then in principle you can overcome this brittleness,” says Miserez. “You could store a higher amount of energy at a lower weight cost.”

You know, for things like jumping. Not punching crabs (or humans) in the face.