Abalone Shell Inspires Lightweight Body Armor

Researchers at the University of California, San Diego (UCSD) hope that a seaweed-eating snail could show them how to create strong and lightweight body armor for soldiers and police. Marc A. Meyers, a professor in UCSD's Jacobs School of Engineering, and Albert Lin, an engineering graduate student at UCSD, have studied the oval shell of the red abalone, a seaweed-eating snail that is usually valued for use in mother-of-pearl jewelry (Figure 2). Despite the weak and brittle nature of calcium carbonate (chalk), which makes up 95% of the shell, the abalone shell is able to absorb heavy blows without breaking.

"In our search for a new generation of armors, we have exhausted the conventional possibilities, so we've turned to biology-inspired, or biomimetic, structures," said Meyers, a former scientist with the U.S. Army Research Office. "The laminate structure of abalone shell has stimulated our group to develop a new synthetic material using this lowly mollusk as a guide."

While abalone shell would not be able to stop a bullet, researchers have discovered that the shell is made of a highly ordered brick-like tile structure that is the toughest arrangement of tiles theoretically possible. At the nanoscale, abalone shell is made of thousands of layers of tiles that measure approximately 10 micrometers across and 0.5 micrometers thick.

Key to the strength of the shell is a positively charged protein adhesive that binds to the negatively charged top and bottom surfaces of the calcium carbonate tiles. The glue is strong enough to hold layers of tiles firmly together, but weak enough to permit the layers to slip apart, absorbing the energy of a heavy blow in the process. Abalones quickly fill in fissures that form in the shells due to impacts and, during seasonal lulls in shell growth, deposit growth bands of organic material that further strengthen the shells.

Figure 2. The mother-of-pearl growth surface of abalone shell is colored due to the way light refracts as it strikes tiny terraces of calcium carbonate. Photo

"Contrary to what others have thought, the tiles abutting each other in each layer are not glued on their sides, rather they are only glued on the top and bottom, which is why adjacent tiles can separate from one another and slide when a strong force is applied," said Meyers. "The adhesive properties of the protein glue, together with the size and shape of the calcium carbonate tiles, explain how the shell interior gives a little without breaking. On the contrary, when a conventional laminate material breaks, the whole structure is weakened."

Once their analysis of the abalone shell is complete, Meyers and Lin plan to generate a mathematical description that can be used to construct body armor based on the abalone.