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Cling-On Warriors

An interdisciplinary group of researchers at UC Santa Barbara has taken strides in the development of an underwater adhesive that has the potential for a variety of biomedical and non-biological applications. Areas such as tissue repair, dental adhesives and other surface adhesion applications — which are often required under adverse conditions, such as salty sea water and in aqueous solutions containing organic impurities — could benefit from this glue, which replicates the adhesion strategy of the Sandcastle worm (Phragmatopoma californica), a segmented marine invertebrate commonly found along the California coast.

Known for constructing hive-like shelters in colonies out of grains of sand glued together by a protein adhesive, sandcastle worms, along with mussels and other glue-secreting inhabitants of the intertidal zone, have served as inspiration for scientists and engineers seeking to develop an adhesive that can perform in wet, submerged and otherwise inhospitable conditions.

“Sandcastle worms secrete a robust underwater adhesive to build a tube reef (sandcastle) in harsh intertidal environments, where wind and wave velocity often exceed 25 meters per second,” said Kollbe Ahn, a research faculty member at UCSB’s Marine Science Institute and co-lead author of a paper on this research that appears in Nature Materials. “We successfully replicated the strong wet-contact adhesion of the bio-adhesion featuring nanoscopic chemical and microscopic porous structures,”Ahn added.

While wet glues have been the subject of research and development for years, they have yet to approach the performance of the natural substances in terms of stickiness and the rapidity with which the adhesion process occurs. In fact, synthetic underwater adhesives have typically required complex processing and functionalization, adding several steps to what would ideally be a simple process.

“From practical perspectives, simple processing saves time and labor, and ultimately reduces costs,” said UCSB materials scientist and lead author Qiang Zhao. The sandcastle worm-inspired glue is particularly noteworthy, he said, because through a phenomenons called solvent exchange, adhesion becomes a little more streamlined.

“The processing of this wet glue does not need pre-immersive dry curing or applied compressing pressure that are normally required in conventional studies,” Zhao continued. The synthetic glue also promotes adhesion between a variety of surfaces, including plastics, glasses, metals, wood and biological tissues.

Additionally, the resulting microarchitecture of the synthetic glue, which mimics the porous structure of sandcastle worm adhesive, makes it more resistant to cracking.

“Porous structures, or cellular structures, are ubiquitous in nature, such as in cork, bones and coral, and they are found to increase fracture energy of these materials,” Zhao said. “Here in the context of wet adhesion, we found that the porosity was reminiscent of the porous structures of sandcastle worm cement, and significantly improved wet adhesion.”

This development is the latest effort at UCSB to formulate an adhesive that performs in wet and especially adverse conditions, and could lead to a variety of applications, such as dental adhesion and the repair of tissue, skin, bones and membranes that are surrounded by bodily fluids. Additionally, industrial and commercial applications that require adhesion in wet environments could also benefit from this technology. Through studies of mussels and sandcastle worms, the researchers hope to create and optimize an adhesive that not only bonds quickly and performs well under a variety of conditions and with various surfaces, but also eliminates the need for organic solvents, which results in a more environmentally friendly adhesion process.

Research on this paper was conducted also by Dong Woog Lee, Sungbaek Seo, Yair Kaufman, Jacob Israelachvili and J. Herbert Waite, all at UCSB.

About UC Santa Barbara

The University of California, Santa Barbara is a leading research institution that also provides a comprehensive liberal arts learning experience. Our academic community of faculty, students, and staff is characterized by a culture of interdisciplinary collaboration that is responsive to the needs of our multicultural and global society. All of this takes place within a living and learning environment like no other, as we draw inspiration from the beauty and resources of our extraordinary location at the edge of the Pacific Ocean.