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Flexible armor inspired from natural fish scales and osteoderms

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ABSTRACT

The skins of armadillo, rhinoceros, and fish display interesting combinations of resistance to penetration, flexibility, and light weight. These armors are made of stiff and hard plates of finite size (tiles or scales), embedded in soft tissues. The plates are orders of magnitude harder and stiffer than the soft tissues to resist penetration, but they can also move relative to each other to provide compliance. Here, we have implemented these bio-inspired principles in an artificial system consisting of small hexagonal glass plates resting on a soft silicone substrate. Compared with a continuous layer of glass, the flexural stresses in our segmented armor were greatly reduced, and as a result the puncture resistance was up to 70% higher. We also duplicated the robustness of natural armor: as opposed to pristine glass which is entirely destroyed by sharp puncture, damage in our segmented armor was confined to only one hexagonal plate. The structure and mechanics of this system can be translated to armor-grade materials for high-performance flexible, light-weight, puncture resistant, and robust protective systems.