New plastic is strong as steel, transparent

By mimicking a brick-and-mortar molecular structure found in seashells, University of Michigan researchers created a composite plastic that's as strong as steel but lighter and transparent.

It's made of layers of clay nanosheets and a water-soluble polymer that shares chemistry with white glue.

Engineering professor Nicholas Kotov almost dubbed it "plastic steel," but the new material isn't quite stretchy enough to earn that name. Nevertheless, he says its further development could lead to lighter, stronger armor for soldiers or police and their vehicles. It could also be used in microelectromechanical devices, microfluidics, biomedical sensors and valves and unmanned aircraft.

Kotov and other U-M faculty members are authors of a paper on this composite material, "Ultrastrong and Stiff Layered Polymer Nanocomposites," published in the Oct. 5 edition of *Science*.

The scientists solved a problem that has confounded engineers and scientists for decades: Individual nano-size building blocks such as nanotubes, nanosheets and nanorods are ultrastrong. But larger materials made out of bonded nano-size building blocks were comparatively weak. Until now.

"When you tried to build something you can hold in your arms, scientists had difficulties transferring the strength of individual nanosheets or nanotubes to the entire material," Kotov said. "We've demonstrated that one can achieve almost ideal transfer of stress between nanosheets and a polymer matrix."

The researchers created this new composite plastic with a machine they developed that builds materials one nanoscale layer after another.

The robotic machine consists of an arm that hovers over a wheel of vials of different liquids. In this case, the arm held a piece of glass about the size of a stick of gum on which it built the new material.

The arm dipped the glass into the glue-like polymer solution and then into a liquid that was a dispersion of clay nanosheets. After those layers dried, the process repeated. It took 300 layers of each the glue-like polymer and the clay nanosheets to create a piece of this material as thick as a piece of plastic wrap.

Mother of pearl, the iridescent lining of mussel and oyster shells, is built layer-by-layer like this. It's one of the toughest natural mineral-based materials.

The glue-like polymer used in this experiment, which is polyvinyl alcohol, was as important as the layer-by-layer assembly process. The structure of the "nanoglue" and the clay nanosheets allowed the layers to form cooperative hydrogen bonds, which gives rise to what Kotov called "the Velcro effect." Such bonds, if broken, can reform easily in a new place.

The Velcro effect is one reason the material is so strong. Another is the arrangement of the nanosheets. They're stacked like bricks, in an alternating pattern.

"When you have a brick-and-mortar structure, any cracks are blunted by each interface," Kotov explained. "It's hard to replicate with nanoscale building blocks on a large scale, but that's what we've achieved."

Source: University of Michigan