Shaochen Chen, a UCSD professor of nanoengineering, led the research on a device that removes toxins produced by infections, stings and bites. — Joshua Knoff/UC San Diego Jacobs School of Engineering

Inspired by the structure of the liver, UC San Diego scientists have developed a device that efficiently removes blood toxins produced by infections, stings and animal bites.

The device could be ready for testing in people in a couple of years, said Shaochen Chen, a professor of nanoengineering who led the research. Constructed with rapid 3D printing technology, the detoxification device contains nanoparticles that attract and sequester the toxins. When toxins are detected, the device turns red.

The device completely neutralized the toxin melittin, a component of bee venom, in lab tests using mouse blood. Melittin belongs to a group of poisons called pore-forming toxins the device is designed to remove. These toxins, including those from anthrax and the superbug MRSA, kill cells by punching holes in cell membranes.

Chen's versatile technology forms hexagonal structures hollow at the center, like those in the liver where detoxification takes place. The structures are made of a material that traps the toxins. They're embedded in hydrogels, soft substances that Chen is also testing for use in printing blood vessels. This could be useful in 3D bioprinting of human organs from cellular components, because the organs will need a blood supply.

Chen is exploring nanoscale bioprinting under a four-year, $1.5 million grant from the National Institutes of Health.

The research was published Thursday in the journal Nature Communications. Chen was the senior author; Maling Gou, also of UCSD, was the first author.

A different approach to neutralizing pore-forming toxins is being developed by another UCSD nanoengineering professor, Liangfang Zhang. His approach is to wrap nanoparticles in the membranes of red blood cells, which are targeted by the toxins. These "nanosponges" remove the toxins from the bloodstream; the toxin-laden nanosponges are later metabolized later by the liver. Mice injected with the nanosponges and then given a lethal dose of toxin from MRSA survived 89 percent of the time, compared to 44 percent survival in mice not given the nanosponges. That study was reported in Nature Nanotechnology on April 14, 2013.

In another use reported in Nature Nanotechnology on Dec. 1, 2013, a Zhang-led team said the nanosponges provide a safe and effective method of vaccination against a MRSA toxin.
Chen said his approach to treating toxins avoids the risk of causing liver damage from the toxin-laden nanosponges, especially in those already at risk for liver failure.

"The key idea of this device is that the particles stay in the device rather than running around the body where you don't have any control," Chen said.

The nanoparticles are made out of polydiacetylene, or PDA, irradiated with ultraviolet light. The surface takes on a configuration like that of cell membranes, enabling toxin capture.

The PDA nanoparticles are embedded in a hydrogel called PEGDA, or polyethylene glycol diacrylate, which solidifies on exposure to light. The hydrogel is fashioned in the liver-inspired hexagonal pattern with technology called dynamic optical projection stereolithography, developed in Chen's lab. The system projects an image of a pattern, using precisely controlled mirrors, at the micro- or nano-scale.

The bioinspired liver-like device can be customized by adding nanoparticles that

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