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A Conversation with Paula Hammond

Katherine Bourzac

The chemical engineer talks about one of layer-by-layer assembly's many applications.

When you skim through a list of the titles of Paula Hammond's papers, you quickly realize her lab is not afraid to try new things. In one paper they're making new battery electrodes or fuel-cell membranes; in the next they're reporting a new way to formulate cancer drugs. Katherine Bourzac talked to Hammond—who recently became the head of the Department of Chemical Engineering at the Massachusetts Institute of Technology—about the chemical assembly methods that unite her work and how she's using the approach to help soldiers on the battlefield.

You work on such a diverse array of projects. What do they have in common?

Layer-by-layer assembly is one of my major toolsets. You can build up films by this very simple method of alternating layers of oppositely charged materials. The simplicity of the layer-by-layer approach has allowed us to do a large number of fairly complicated things. Anything can go into the film—as long as you play the charge game. The way we've applied that to different areas has been really amazing.

We can incorporate carbon nanotubes with metal nanoparticles and create an electrode for a battery. In the drug delivery area, what's really exciting is that nature makes so many charged things: gene-silencing RNA, DNA, proteins big and small. Small-molecule drugs are charged, too. You can stack drugs and have them release in a staged order. Also, you can incorporate these biomolecules without worrying about damaging them: It is all done at room temperature, in water.

With layer-by-layer, you can put anything anywhere as long as you follow the rules. There is a kind of limitless feeling to it. When I'm sitting in a talk, I'll sometimes go, "Hey, that's charged! That means I can put it in a film!" You can get really inventive. It is fun.

How are you applying layer-by-layer assembly to battlefield wound healing?

Something like 80% of battlefield deaths are caused by loss of blood following an injury. There's a need for something to rapidly stop blood loss, that can be deployed readily by the soldier, and that is easily manufactured, storable, and a reasonable cost.

We've been looking at incorporating a peptide in our layer-by-layer films that self-assembles into nanofibers that mimic the behavior of fibrin—the protein that forms blood clots. The peptides were developed by my MIT colleague Shuguang Zhang. They can be used to stop bleeding in the operating room. The problem is, how do you bring that to a soldier?

Is there a way to develop something like a bandage or a patch that can be applied to a wound and can elute these peptides in a way that allows you to re-create clotting very rapidly? We would need to be able to pack the peptide very densely, because we would want to rapidly deploy sufficient amounts of the peptide and still have enough remaining for additional clotting power later on. Layer-by-layer turns out to be a great approach to doing this.

What is your strategy for making such a bandage?

We found some simple, naturally occurring polymers that we can layer with the peptide, that allow us to build up a film that is stable, that does not fall apart when you handle it, and can be stored for long time periods. In fact, we tested these films and they remain stable for two months at temperatures as high as 60 °C, which is hotter than the hottest point on

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Earth, and as low as −40 °C. When we apply the films to the wound, they immediately release these peptides, and you can see clotting: The peptides form tiny little stacks that become kind of a ropey network. It is a lightweight system with very high potency.

How close is it to being used in the field?

We are beginning to work with the military to test this. The new peptide is small, so it would be simple and inexpensive to manufacture. We're excited to test its performance. We're also investigating whether we can combine those peptides with an antibiotic.

Katherine Bourzac is a freelance contributor to Chemical & Engineering News, the weekly newsmagazine of the American Chemical Society. Center Stage interviews are edited for length and clarity.

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