

Scientists make new 'green' electronic polymer-based films with protein nanowires

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An interdisciplinary team of scientists at the University of Massachusetts Amherst has produced a new class of electronic materials that may lead to a "green," more sustainable future in biomedical and environmental sensing, say research leaders microbiologist Derek Lovley and polymer scientist Todd Emrick.

They say their new work shows it is possible to combine protein [nanowires](#) with a [polymer](#) to produce a flexible electronic composite material that retains the electrical conductivity and unique sensing capabilities of protein nanowires. Results appear in the journal *Small*.

Protein nanowires have many advantages over the [silicon nanowires](#) and carbon nanotubes in terms of their biocompatibility, stability, and potential to be modified to sense a wide range of biomolecules and chemicals of medical or environmental interest, says Lovley. However, these sensor applications require that the protein nanowires be incorporated into a flexible matrix suitable for manufacturing wearable sensing devices or other types of electronic devices.

As Lovley explains, "We have been studying the biological function of protein nanowires for over a decade, but it is only now that we can see a path forward for their use in practical fabrication of electronic devices." Postdoctoral research Yun-Lu Sun, now at the University of Texas at Austin, discovered the proper conditions for mixing protein nanowires with a non-conductive polymer to yield the electrically conductive composite material. He demonstrated that although the wires are made of protein, they are very durable and easy to process into new [materials](#).

"An additional advantage is that protein nanowires are a truly 'green,' sustainable material," Lovley adds. "We can mass-produce protein nanowires with microbes grown with renewable feedstocks. The manufacture of more traditional nanowire

materials requires high energy inputs and some really nasty chemicals." By contrast, he says, "Protein nanowires are thinner than silicon wires, and unlike silicon are stable in water, which is very important for biomedical applications, such as detecting metabolites in sweat."

Emrick adds, "These electronic protein nanowires bear surprising resemblance to polymer fibers and we're trying to figure out how to combine the two most effectively."

In their proof-of-concept study, the protein nanowires formed an electrically conductive network when introduced into the polymer polyvinyl alcohol. The material can be treated with harsh conditions, such as heat, or extreme pH such as high acidity, that might be expected to ruin a protein-based composite, but it continued to work well.

The conductivity of the protein nanowires embedded in the polymer changed dramatically in response to pH. "This is an important biomedical parameter diagnostic of some serious medical conditions," Lovley explains. "We can also genetically modify the structure of the protein nanowires in ways that we expect will enable detection of a wide range of other molecules of biomedical significance."

The electrically conductive protein nanowires are a natural product of the microorganism *Geobacter* discovered in Potomac River mud by Lovley more than 30 years ago. *Geobacter* uses the protein nanowires to make electrical connections with other microbes or minerals. He notes, "Material science experts like Todd Emrick and Thomas Russell on our team deserve the credit for bringing [protein nanowires](#) into the materials field. It's not just about mud anymore."

In this work supported by UMass Amherst campus funds for exploratory research, next steps for the collaborative materials-microbiology team include

scaling up production of nanowire-polymer matrices, Lovley says.

He points out, "Materials scientists need a lot more nanowires than we're used to making. We're were making thimblefuls for our biological studies. They need buckets full, so we are now concentrating on producing larger amounts and on tailoring the nanowires so they'll respond to other molecules." The researchers have also applied for a patent on the idea of a conductive polymer made with [protein nanowires](#).

More information: Yun-Lu Sun et al, Conductive Composite Materials Fabricated from Microbially Produced Protein Nanowires, *Small* (2018). [DOI: 10.1002/sml.201802624](https://doi.org/10.1002/sml.201802624)

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