2018 T.C. Graham Prize: Professors Create a Steely Defense Against Infectious Disease

By Sam Kusic

One of the greatest achievements of modern medicine is arguably the development of antibiotics, which effectively put an end to the days when something as insignificant as a paper cut had the potential to become a mortal injury.

However, medical researchers say that years of overuse have allowed bacteria to become more resistant to antibiotic treatments. Indeed, in the U.S. alone, at least 2 million people contract an antibiotic-resistant infection each year, and approximately 23,000 people will die of those infections, according to the Centers for Disease Control and Prevention.

But two Georgia Tech chemical engineering professors believe they have developed a veritable piece of steel armor that could help prevent people from contracting infections. And for that, the professors, Julie Champion (pictured below) and Dennis Hess, have been named winners of AIST's 2018 T.C. Graham Prize.

Awarded annually, the prize is meant to encourage and recognize innovative applications for steel that could help improve demand for this mainstay material.

Champion and Hess, who teach at Georgia Tech's School of Chemical & Biomolecular Engineering, are working on a surface processing technique that can enhance common stainless steel, imbuing it with improved corrosion resistance and, more importantly, disease resistance.

At the heart of their idea is an electrochemical etching process that essentially roughens the surface of steel at a cellular scale. The process creates tiny spikes and pores on the surface that at once seem to prevent some bacteria from sticking to it and appear to kill those that do by puncturing them.

These spikes and pores are incredibly small, measuring less than a micron — one-ten-thousandth of a millimeter. You can't see these structures with the naked eye, and you can't feel them. But based on the research so far, they seem to make for a very effective antimicrobial surface.

"The possibility that we could minimize bacterial contamination on steel surfaces that are encountered routinely by consumers is most exciting. If we could reduce the likelihood of spreading diseases, this would be a very nice contribution that links scientific and technological advances with societal needs," said Hess.

The technique is derived from the electrochemical process already used industrially to electropolish stainless steel. In that process, the component being treated is submerged in a chemical bath as an electrical current is passed through it. The result is an electrochemical reaction that removes tiny bits of metal, leaving a smooth, shiny surface. The microetching technique works the same, except that the electrical power is varied to produce the effect.

"Modification of current electropolishing processes should make implementation of this technology straightforward in terms of manufacturing and regulatory approval," Champion said. "It's literally as simple as turning down the dial."

The professors said the idea arises from a decade's worth of research into ways to control wetting of material surfaces by altering those surfaces. But the antimicrobial stainless steel bubbled up from conversations with research team member and doctoral student Won Tae Choi, who was married to another team member, Yeongseon Jang.

"All four of us began to wonder what biological or medical applications might be possible with stainless steel surfaces that repelled water. Won Tae and Yeongseon decided to evaluate bacteria-surface interactions; that is when the very interesting results were generated. Our initial interest was in medical/surgical applications such as implants. But when AIST called for proposals for new applications for steel, Julie and I began talking about additional directions for the work," Hess said.

Champion said their surface treatment offers several advantages over other types of metallic, antimicrobial materials. For one, she said, it doesn't rely on a chemical coating, so it diminishes the possibility that bacteria develop a resistance and eliminates problems related to human toxicity. Also, because the surface treatment is not a coating, it can't deteriorate or "wear off."

"Nanotexture is not a coating and cannot be used up. It is a direct modification of stainless steel through removal, not addition, of material on the surface by electrochemical etching. Since the mechanism of bacterial repulsion and killing is physical in nature, it is less likely to induce bacterial resistance compared to electrochemical antibacterial coatings."

The professors said there are a variety of practical applications for this type of surface-treated stainless steel. It could be used as a material for everyday objects that are frequently touched by the public, things like door handles, soap dispensers, railings and utensils.

There are additional applications in the food and beverage industries, such as in pipes, conveyors and countertops. But it also has uses as a material for medical implants, like artificial hips and pacemakers.

And right now that is where they are concentrating their efforts. As Champion explained, infection is a major complication arising from medical implants, and those infections often are extremely resistant to antibiotics. Sometimes the only way to cure the infection is to remove the implant.

By making implants from microetched stainless steel, the problem could potentially be lessened.

"This is a place that could make a big difference fast," Champion said.

She and Hess have teamed up with an orthopedic surgeon at the Emory University School of Medicine in Georgia to study the efficacy of microetched stainless steel bone plates and screws relative to the electropolished plates and screws that are used now.

She also said they hope to connect with an implant manufacturer, as use of a microetched implant would require approval from the U.S. Food and Drug Administration. But in the meantime, they are having discussions with a few other companies on how to apply this technology to everyday items, such as doorknobs and water bottles.

This is the fourth year AIST has awarded the Graham Prize, which is made possible through a US$100,000 gift from Thomas C. Graham Sr., a longtime steel industry executive. Graham donated funding for the award to show steel producers that innovative steel ideas are all around, and aren't limited to steel companies' research and development divisions. To that end, the Graham Prize is open to the public.

This year's contest drew a number of novel proposals, and after several rounds of review by AIST staff and industry professionals, only three advanced to a final round of judging by a panel of steel executives. On the panel this year were John Ferriola, chairman, president and chief executive officer, Nucor Corp. (represented by AIST past president Randy Skagen, Nucor Steel Tuscaloosa Inc.); Mark Millett, president and chief executive officer, Steel Dynamics Inc.; Roger Newport, chief executive officer, AK Steel; and Barbara Smith, president and chief executive officer, Commercial Metals Company.

The T.C. Graham Prize includes a check for US$20,000, and Champion said they intend to plow the winnings back into their research. And, to be sure, there is more research to be done, she said.

One thing that needs to be more closely examined is the durability of the processed surfaces. In theory, the surface treatment is permanent, but it is not yet known how robust the spikes and pores are, especially in the harsh environment inside the human body.

"The prize money will allow us to further our research by acquiring new data and showing alternative applications useful in stainless steel products."

She said that possibly more important than the cash prize itself is the visibility that comes with it.

"This will really expose us to steel companies that might be interested in partnering to implement our technology into their products. As an academic professor, we have a limited ability to get something to the commercial arena and have it available for people to use."

But if they can commercialize it, they believe people will use it. Champion said that an aging population will drive increased demand for medical implants. In fact, the demand for replacement joints alone is expected to increase to 3.8 million units by 2030, Champion said.

"Nanotextured steel would be well positioned to regain market share lost to titanium and ceramics," she said.

Hess, too, said the prize will help to advance their work.

"Since we currently have no funds specifically allocated to this project, the T.C. Graham funds allow us to perform surface analyses and purchase chemicals and equipment needed to further our work. We are extremely grateful for this recognition and hope that this will spark further interest from funding agencies, metal suppliers, and users of stainless steel." ✦

Applications are now being accepted for the 2019 T.C. Graham Prize. For more information, please visit **AIST.org.**