Thermal Paint — MXene Spray Coating Can Harness Infrared Radiation for Heating or Cooling

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An international team of researchers, led by Drexel University, has found that a thin coating of MXene — a type of two-dimensional nanomaterial discovered and studied at Drexel for more than a decade — could enhance a material's ability to trap or shed heat. The discovery, which is tied to MXene's ability to regulate the passage of ambient infrared radiation, could lead to advances in thermal clothing, heating elements and new materials for radiative heating and cooling.

The group, including materials science and optoelectronics researchers from Drexel and computational scientists from the University of Pennsylvania, recently laid out its discovery on the radiative heating and cooling capabilities associated with MXene in a paper entitled "Versatility of infrared properties of MXene" in the Elsevier journal Materials Today.

"This research reveals yet another facet of MXene materials' versatility," said Yury Gogotsi, PhD, Distinguished University and Bach chair professor in Drexel's College of Engineering, who was a leader of the research. "MXene coatings possessing exceptional abilities to contain or emit infrared radiation, while remaining extremely thin — 200-300 times thinner than a human hair — lightweight and flexible, could find applications in both localized thermal management and large-scale radiative heating and cooling systems. There are significant advantages with passive infrared heating and cooling than traditional active ones, that require electrical power to function."

MXene nanomaterial dye could enhance passive heating or cooling abilities of performance apparel.

MXenes are a family of two-dimensional nanomaterials originally discovered by Drexel researchers in 2011, that — because of their composition and two-dimensional structure —

have progressively proven to be exceptional at conducting electricity, storing electrical energy, filtering chemical compounds and blocking electromagnetic radiation, among other capabilities. Over the years, materials scientists have produced and extensively investigated MXenes with various chemical compositions, resulting in the discovery of numerous applications.

In their recent paper, the team measured the ability of 10 different MXene compositions to help or hinder the passage of infrared radiation — a measure called “emissivity” — which correlates with their ability to passively capture or dissipate ambient heat.

“We knew from previous research that MXenes are more than capable of reflecting or absorbing radio waves and microwave radiation, so looking at their interaction with infrared radiation, which has a much shorter wavelength, was the next step,” said Danzhen Zhang, a co-doctoral researcher in Gogotsi’s lab and co- author of the paper. “The advantage of being able to control the passage of infrared radiation is that we can use this type of radiation for passive heating – if we can contain it – or passive cooling – if we can dissipate it. The MXenes we tested showed that they can do both, depending on their elemental composition and the number of atomic layers.”

In comparison to the passive cooling materials available in the market today, which allow the thermal infrared radiation from the body — body heat — to escape through its lightweight and porous textile composition, MXene-coated textiles can do even better, according to Tetiana Hryhorchuk, a doctoral researcher in Gogotsi’s lab, and co-author of the research, because these coated textiles have the additional ability to reflect external infrared radiation, to avoid heating from sunlight, while also allowing the infrared radiation, emitted from the body, to pass.

The researchers found that niobium carbide MXenes could effectively dissipate heat while titanium carbide exhibited exceptional heat shielding, with its temperature rising only to 43 degrees Celsius after being heated for five minutes on a 110-degree hotplate.

“High emissivity like in niobium carbide is also possible in dielectric materials,” Gogotsi said.

“However, MXenes combine this ability with electrical conductivity, which means these MXenes can also be used as active electrical heating elements with the supply of external power.”

A coating of titanium carbide MXene was found to strengthen materials against infrared radiation penetration and emission. In testing, the MXene-coated materials, even with a thin coating, performed better at shielding infrared radiation than polished metals, which are currently the best performing commercial materials. This means that MXenes could be integrated into lightweight clothing that keep the wearer warm in extreme environments.

To test it, the team dyed a cotton t-shirt with a titanium carbide MXene solution and used an infrared thermal camera to monitor the temperature of a person wearing it. The results showed that the MXene-coated shirt kept its wearer about 10-15 degrees Celsius cooler — about room temperature — than a person wearing a normal tee shirt.

These results suggest that MXene-coated garments are effective at maintaining body temperature, while also offering the advantage of being applied via a comparatively easier dip-coating process than most thermal clothing requires.

“Commercial thermal clothes use very thin polymer fibers with low thermal conductivity — fleece, for example,” said Lingyi Bi, a doctoral researcher in Gogotsi’s lab, with expertise in textiles. “They keep us warm by minimizing heat transfer through the fabric, to do this effectively they must be very thick. But MXene primarily keeps us warm by preventing the escape of the body heat as infrared radiation. Therefore, a MXene coating thinner than silk could provide effective warming. This is the same principle that is used in Mylar thermal blankets that runners get after a cold-weather race.”

Gogotsi suggests that the IR-blocking capability could also be used to camouflage people and equipment from thermal detection devices, or to covertly transmit information via radio frequency identification codes visible only to infrared readers.

The team plans to continue studying the mechanisms underlying MXene’s IR block and emitting behavior, as well as testing MXenes with different chemical compositions to optimize their potential as radiative heating and cooling materials.

Read the original article on Drexel University.