Scientists reveal secret of material for promising infrared cameras

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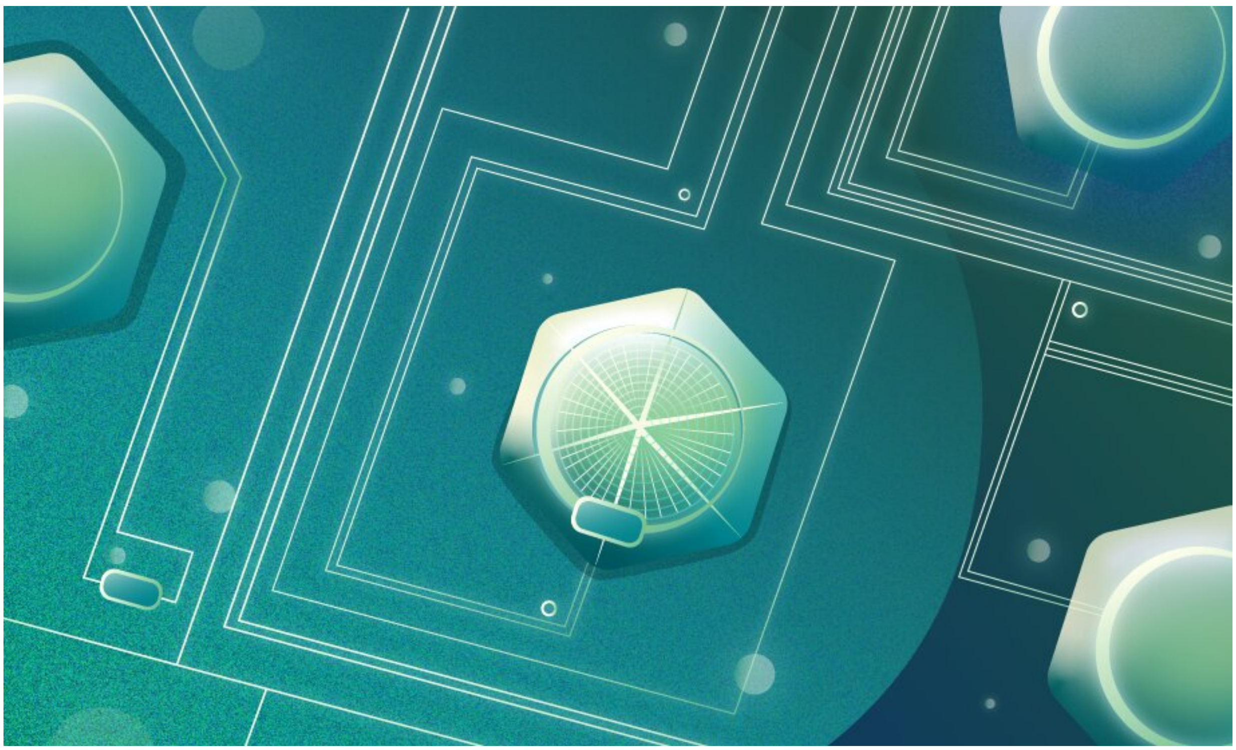

Bolometer. Credit: Daria Sokol/MIPT

Researchers from the Moscow Institute of Physics and Technology and the RAS Institute for Theoretical and Applied Electromagnetics have discovered what makes vanadium dioxide films conduct electricity. Published in *Physical Review B*, their findings will enable thermal imaging devices with a sensitivity and reaction rate superior to those of the currently existing analogs.

While 100-nanometer thin films of vanadium dioxide (VO_2) do not normally conduct electricity, their resistance drops up to 100,000 times when slightly heated. This may happen under applied voltage, for example. That property is used to create high-speed switchable devices and sensors for direct current or alternating signal in the terahertz, microwave, optical, or infrared range.

Materials scientists found VO_2 films could become conductive in the mid-20th century. Until now, the precise mechanism behind the change in the material's electrical properties was unknown. Being aware of that mechanism enables application-oriented materials design. That includes the synthesis of thin films with predefined properties, such as the temperature at which conductivity changes or the ratio between the resistances before and after heating.

"Among the most useful things these films could be valuable for are sensors for uncooled bolometers. Bolometers underlie thermal imaging systems. VO_2 films can boost their sensitivity and reaction rate, extending their applicability to rapidly moving objects," commented study co-author and MIPT doctoral student Viktor Polozov of the university's Landau School of Physics and Research.

MIPT researchers proposed a scenario for a VO_2 film transition between the insulating and the conductive state. First the film heats up and conductive areas sporadically emerge in it. Then those areas become linked, turning into a channel that makes the film conduct current. Further heating widens the channel, reducing the film's resistance.

This process occurs via a so-called blow-up regime. Similar observations have already been made in other materials. For example, this regime is also characteristic for the superconducting transition in high-temperature superconductors.

To prove that VO_2 films undergo a similar process, the Russian researchers relied on a combination of theory and experiment. On the one hand, they used the available models that describe processes occurring in the blow-up regime to theoretically predict the films' current-voltage characteristics and how the resistance should vary with temperature. On the other hand, the team synthesized its own films with distinct properties and measured their parameters experimentally.

"The theoretical calculations agreed with the experimental findings, and that was true about films of different structures deposited on different substrates. This led us to conclude that the mechanism involved is universal—that is, it explains thermally induced conductivity in all thin VO_2 films," said Professor Alexander Rakhmanov of Landau School of Physics and Research at MIPT, who co-authored the study.

The researchers confirmed their hypothesis about the transition in VO_2 being characterized by a blow-up regime. Now that they know this mechanism underlies the transition, the team can model that process. This is going to be the focus of their future research.

More information: V. I. Polozov et al. Blow-up overheating instability in vanadium dioxide thin films, *Physical Review B* (2020). DOI: 10.1103/PhysRevB.101.214310

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