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Chemical Thermometers Take Temperature to the Nanometric Scale

Scientists from the Coordination Chemistry Laboratory and Laboratory for Analysis and Architecture of Systems, both of the CNRS, recently developed molecular films that can measure the operating temperature of electronic components on a nanometric scale. These patented temperature-sensitive molecules have the distinctive quality of being extremely stable, even after millions of uses. They were presented in an article published in *Nature Communications* on 17 July 2020, and could soon be deployed in the microelectronics industry.

The miniaturisation of electronic components coupled with their increasing integration density has considerably expanded heat flows, which can lead to overheating. But how to measure these nanometric events when conventional solutions such as infrared thermography cannot go below a micrometre (1,000 times bigger than a nanometre)?

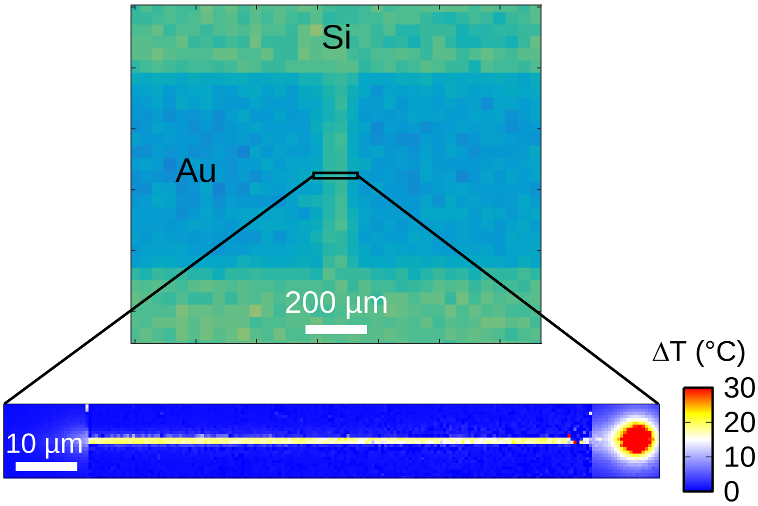
A research team bringing together scientists from two CNRS laboratories, the Coordination Chemistry Laboratory and the Laboratory for Analysis and Architecture of Systems, has proposed doing so by using the bistability properties of a family of chemical compounds known as spin-crossover (SCO) molecules. They exist into two electronic states with different physical properties, and can switch from one to the other when they absorb or lose energy. For instance, some of them change colour depending on the temperature.

Once deposited in the form of a film on an electronic component, the optical properties of SCO molecules change depending on the temperature, enabling this chemical thermometer to establish a nanometric-scale thermal map of the surface of microelectronic circuits. However, the primary feat of these SCO molecular films is actually their unique stability: the properties of the molecules remain unchanged, even after more than 10 million thermal cycles under ambient air and high temperatures (up to 230°C).

This innovation[1] overcomes the primary hurdle for SCO molecules, namely their fatigability, or the fact that their properties are often altered after multiple transitions from one electronic state to another. It could soon be used in the microelectronics industry to probe local thermal processes, and to thereby improve the design of future devices.

Notes

1. It was granted patent protection on 1 October 2019 (patent no. FR1910886)



Temperature map of a gold nanowire on a silicon substrate, Joule-heated by the application of an electrical current of 7 mA, obtained through infrared thermography (top) and a spin-crossover surface thermometer (bottom). While heating remains undetectable in infrared due to low thermal and spatial resolution, temperature distribution is well resolved using an SCO-based thermometer, which reveals a "hot spot" resulting from a malfunction of the component.

Bibliographie

Unprecedented switching endurance affords for high-resolution surface temperature mapping using a spin-crossover film. Karl Ridier, Alin-Ciprian Bas, Yuteng Zhang, Lucie Routaboul, Lionel Salmon, Gábor Molnár, Christian Bergaud and Azzedine Bousseksou. *Nature Communications*, 17 July 2020. DOI:10.1038/s41467-020-17362-7

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