Thermal management towards reliable flexible electronics

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Large scale thermal flow sensor array attached onto a tube (Diameter: 7.5 cm) (left), and corresponding flow mapping results (right). Credit: Kaichen Xu

Researchers at Osaka Prefecture University (OPU, Japan) have developed the first prototype of macroscale, thin-film-based flexible thermal flow sensor array that can observe the flow distribution over curved surfaces through judicious manipulation of thermal energy transfer.

Manipulation of thermal energy transfer enables the development of many modern technologies. One promising subfield based on thermal management is skin-inspired thermal sensing. However, accurate thermal-related sensing based on a thin flexible film remains a challenge due to untethered heat transfer between an objective surface and its surroundings, giving rise to a thermal perception limited to a localized governable space. Although such unrestrained heat transfer-induced imprecise thermal related sensing universally exists in skin-inspired Internet of Things (IoT) applications, this issue has yet to be addressed.

In a recent study published in *ACS Nano* titled "Highly Precise Multifunctional Thermal Management-Based Flexible Sensing Sheets," researchers from Osaka Prefecture University (OPU) realized precise thermal-associated sensing over a variety of surfaces. This study reports a flexible multifunctional thermal management-based sensing sheet by incorporating a low thermal conductive medium. This highly accurate thermal-based sensing sheet platform has two contributions. Firstly, the large-scale thermal flow sensor array not only monitors the air flow distribution on high-thermal conductive stages dynamically, but also implements air flow mapping over curved surfaces for the first time by deliberate heat transfer. Such flexible thermal flow sensors built on thin films overcome the intrinsic drawback of traditional bulk silicon-based microelectromechanical system (MEMS) technology-based flow sensor technology that disturbs the pristine nature of air flow. Secondly, the thermal-regulated flexible temperature sensor can precisely diagnose the skin temperature variations in real time, even if the surrounding conditions change suddenly.

"It is very important to consider the thermal energy transfer with the external environment when conceiving thermal-related sensing techniques. The untethered heat transfer between an objective surface and its surroundings generally restricts the thermal perception within a localized governable space. This work subtly applies a superior facilely accessible insulator air onto the flexible thermal sensing sheets for versatile applications," says Dr. Kaichen XU, first author of the publication.

Prof. Kuniharu Takei, the leader of the project, said, "We have made a breakthrough in developing macroscale flexible flow sensor array that can measure flow distribution without disturbing the initial air flow property. This technique provides a guidance to investigate flow separation induced by airfoil and other aerodynamics. Additionally, the thermal-regulated temperature sensor can precisely monitor skin temperature even if the ambient conditions change abruptly."

Currently, the researchers are dedicated to improving the performance of macroscale flow sensor arrays, such as seeking lower thermal conductive media to form thinner effective thermal barriers, a larger working range of thermal flow sensors, as well as multiplexed detection strategy to minimize the electrical interconnections. They plan to commercialize this technique in the near future.

Readers might also be interested in the authors' recent review paper regarding the multifunctional flexible sensor systems in *Advanced Materials Technologies*, part of the special series on advanced intelligent systems.

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More information: Kaichen Xu et al. Highly Precise Multifunctional Thermal Management-Based Flexible Sensing Sheets, *ACS Nano* (2019). DOI: 10.1021/acsnano.9b07805

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