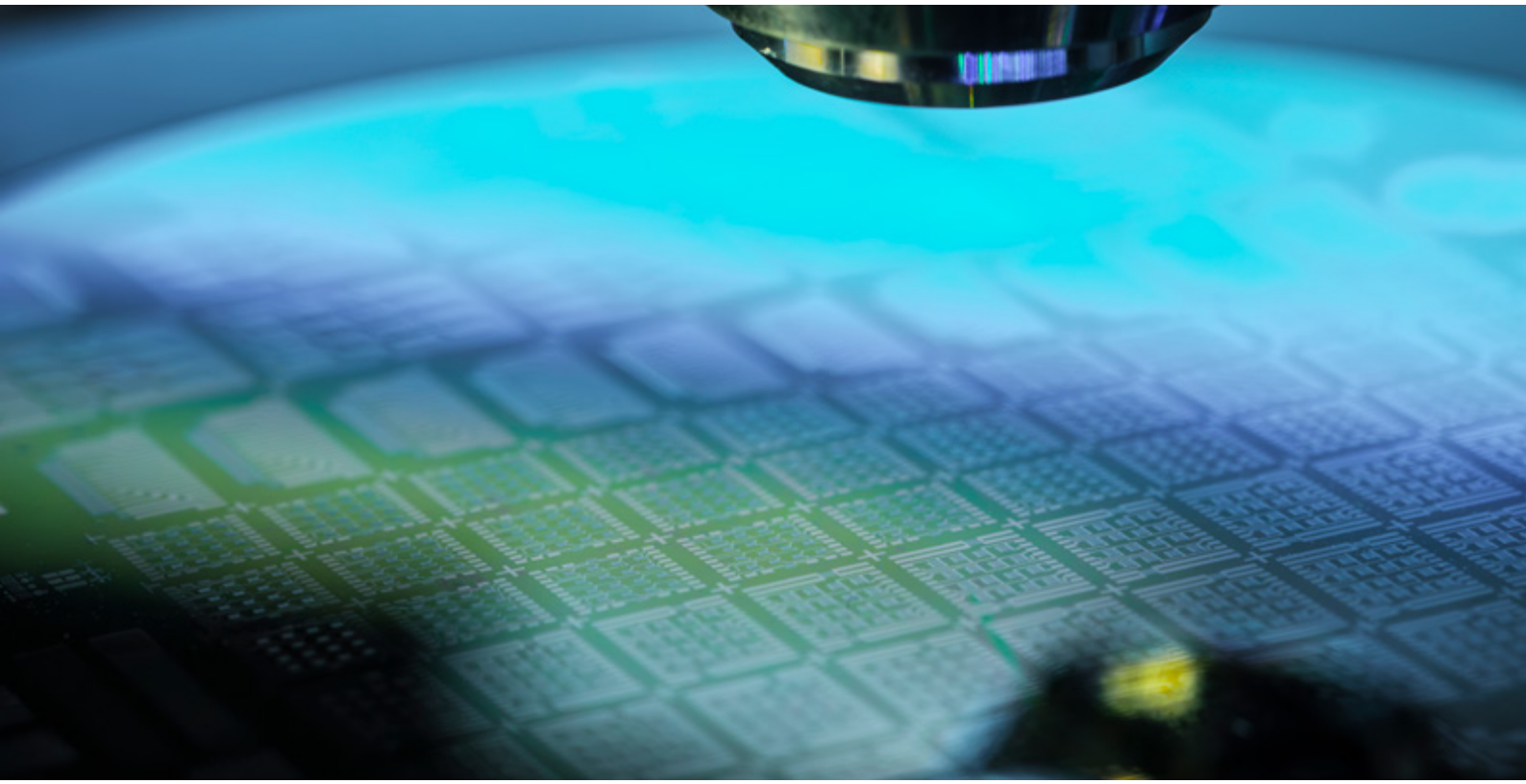
Focus Sensors for temperature measurement

Miniaturized thermopile arrays: Non-contact temperature measurement with a high degree of sensitivity



Highly sensitive thermopile arrays – in this case on a silicon wafer – measure temperatures ranging from 0 to 80 °C, accurately to within a tenth of a degree Celsius. This makes them an interesting concept for many new applications.

Miniaturized thermopile array sensors play an increasingly important role when it comes to measuring temperature. Thanks to their highly sensitive and contactless measuring method, they have the potential to revolutionize numerous areas of application – from temperature control to safety technology and process control. They can detect movements and the presence of people, monitor ceramic hobs and take someone's temperature without contact, among other applications. Many of these tasks can also be carried out by traditional infrared detectors, such as photodetectors, bolometers and pyroelectric sensors, but these detectors are more expensive, more complex or simply not sensitive enough. If the specific aim is object capture by measuring temperature, pyroelectric sensors have the added disadvantage that they cannot capture static objects.

Thermopile array sensors – design and development

Thermopile array sensors essentially consist of three components: a lens, an IR band-pass filter and an infrared detector array made from thermopiles. Thermopile arrays detect the IR radiation of an object according to its surface temperature. They are cost-effective, do not require an external power supply and

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can detect both static and moving objects over larger distances and areas thanks to their matrix arrangement. They comprise n- and p-type semiconductor elements that are connected thermally in parallel and electrically in series. These semiconductor elements, also known as thermopiles or thermoelements, use the Seebeck effect and convert thermal energy directly into electrical energy: Depending on the temperature, an electrical voltage is created at the junction point of the two thermoelectric materials and this can be easily measured to a high degree of sensitivity.

Thermopile array sensors can already be customized and optimized in terms of spectral sensitivity for use in many applications. But the standard CMOS-compatible silicon thermopile arrays also have a major limitation: They can only measure temperature with poor accuracy.

Greater measuring accuracy opens up new possibilities

Unfortunately, thermopile array sensors currently on the market are unsuitable for many otherwise promising applications due to this limited measurement accuracy. As part of the in-house Fraunhofer TAPIR project, a team from Fraunhofer IPM has therefore developed highly sensitive miniaturized thermopile arrays. To achieve this, the researchers used the material bismuth telluride (Bi_2Te_3), which has a particularly high thermoelectric figure of merit at room temperature.

A single thermoelement comprises two semiconductive materials: n-bismuth telluride and p-bismuth antimony telluride. The original idea of applying the thermopiles to a polymer substrate was rejected during the project. Instead, over the course of the project, the team opted to use the well-known silicon substrate optimized using a thin polymer layer. The entire thermopile array of the novel thermal imaging camera from Fraunhofer IPM ended up consisting of 8×8 of these thermoelements, providing an image resolution of 64 pixels. This may not sound much in comparison to optical sensors, but this resolution is ideal for taking high-precision temperature measurements in many applications. The team was able to measure temperatures ranging from 0 to 80 °C, accurately to within a tenth of a degree Celsius. It is not only the industry that will benefit from these high-precision thermopile array sensors; among other applications, the sensors can also make life safer for elderly or infirm people living in their own homes, because they can detect critical situations and automatically raise the alarm. And when it comes to object monitoring, the sensor's 64-pixel image can, for example, safely differentiate between people and animals without violating privacy rights. Many highly promising conversations are already taking place, mainly with small and medium-sized businesses, with the aim of opening up new areas of application for highly sensitive thermopile array sensors.

> Many applications involving temperature measurement will benefit from our highly sensitive thermopile arrays."
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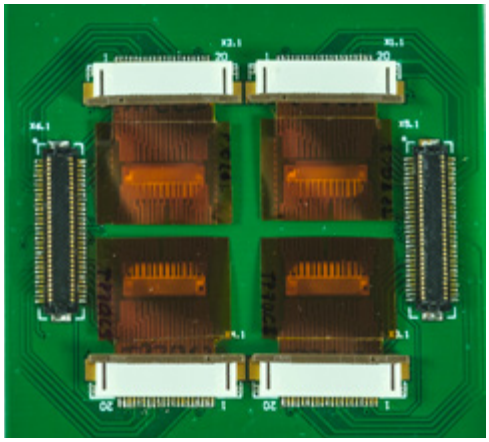
> *Professor Jürgen Wöllenstein, Head of Department*



First prototype with thermopile arrays, which were initially processed on polymer substrate