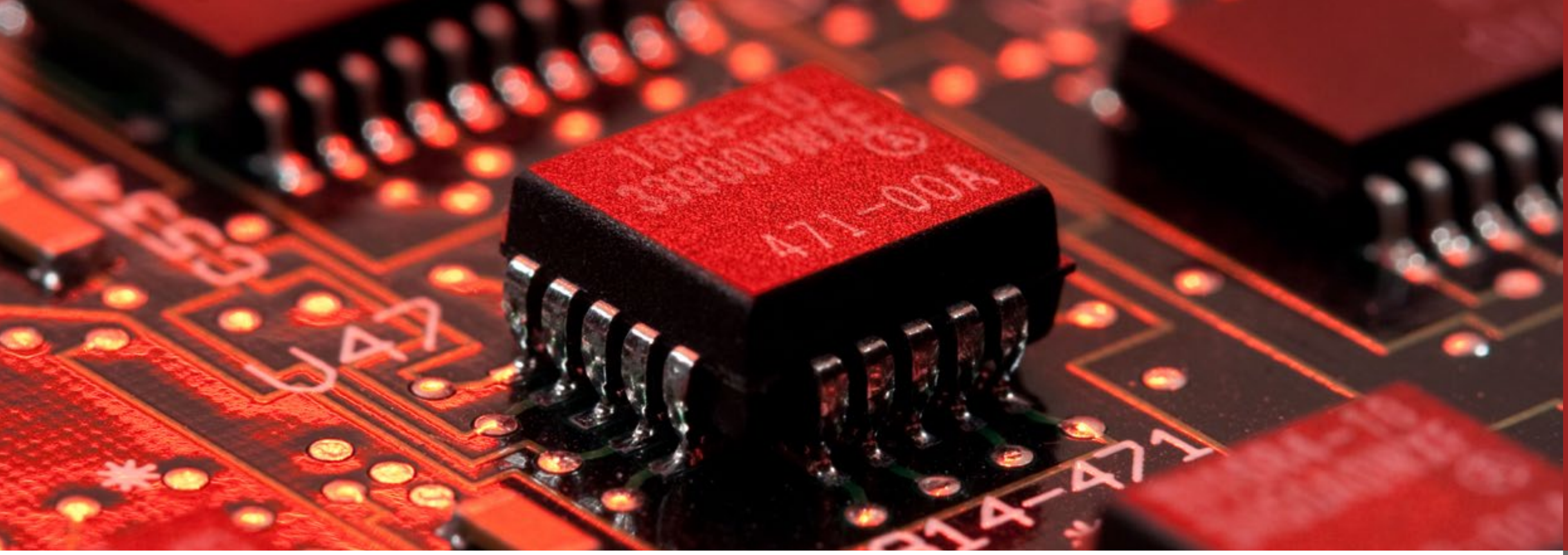


< Highly integrated electronic components generate a lot of heat in a small space. Pulsating heat pipes can be used to efficiently dissipate this heat.

Effectively conducting and switching heat

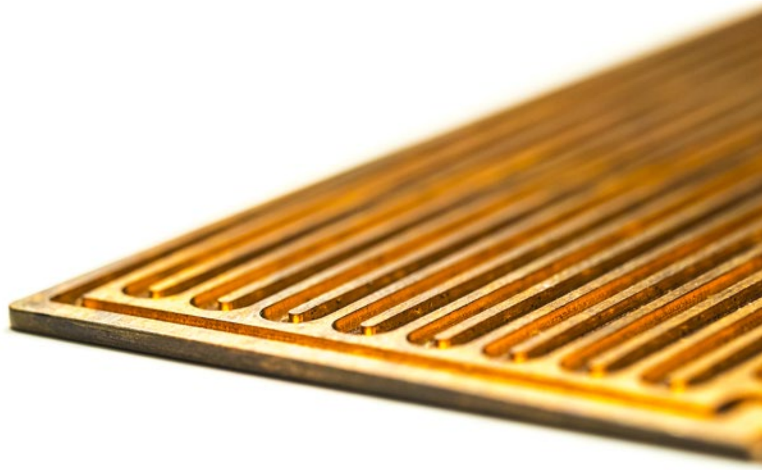
Many industrial sectors have a keen interest in the ability to precisely and effectively regulate temperatures. Heat pipe-based cooling offers an especially efficient option for the thermal management of highly integrated electronic components. Specialized thermal switches can even improve the efficiency of traction batteries, shorten the cold start time for combustion engines, and optimize industrial forming processes. Fraunhofer IPM is conducting research on a new generation of heat pipes and thermal switches and developing application-specific solutions for thermal management.

Overheating is the cause of electronics failures in computers, cars, or airplanes in more than half of all cases. As microelectronic components become ever smaller and more powerful, they produce thermal losses that at times can exceed 100 watts per square centimeter. Cooling these hot spots effectively is essential to ensure that components function faultlessly. Passive cooling designs such as heat pipes (HPs) are especially suitable for these applications, because – unlike active water or air cooling – they have no moving parts and do not require an external power supply. Heat pipes are connected to components and dissipate heat via a condensation and evaporation circuit.

Planar pulsating heat pipes: effective, compact and stable

Fraunhofer IPM develops pulsating heat pipes (PHPs) as an efficient cooling concept for hot spots. In contrast to conventional HPs, PHPs allow for an especially compact, flat, and stable design that simultaneously ensures a high heat transport capacity. This makes them ideal for cooling electronics where the HP height should not exceed 3 mm. In PHPs, heat is transported by both sensible and latent heat. They consist of a capillary structure filled with a working fluid that separates into vapor and fluid segments. Temperature differences between a heat source and a heat sink generate a pulsating movement of these segments, which results in the self-sustaining transport of the fluid through the channels and dramatically improves heat transfer. PHPs can be used as highly effective heat conductors or heat spreaders. As part of various R&D projects, researchers at Fraunhofer IPM have been developing and testing PHPs in a variety of designs using different materials such as copper or glass. In addition, essential techniques were investigated for evacuating, filling, and assembling the pipes, including transient liquid phase (TLP) bonding as well as other soldering and welding techniques. With its prototype of a planar PHP made of copper, Fraunhofer IPM has achieved a thermal conductivity comparable to that of diamond. For the prototype, thin meandering channels were milled into a 1.5 to 2 mm thick copper plate and then partially filled with fluid and evacuated. These planar PHPs could be directly integrated into printed circuit boards. They are far more stable than so-called vapor chambers (planar heat pipes with hollow-chambers) and thus can better withstand the pressure used to laminate printed circuit boards.

Heat pipe-based cooling concepts are an especially attractive option for industry, which is why the team at Fraunhofer IPM is working to find solutions for simulation-based design that would make it possible to model the complex physical relationships in a PHP. The goal is to be able to optimize variables such as size, working fluid, and the connection to the heat sink for each specific application. Intensive research is also underway at the institute on alternative materials and manufacturing processes such as 3D printing or roll bonding, in order to enable flexible, form-specific, and cost-effective manufacturing.



Heat pipes aren't limited to pipe form. They can also be produced as plates just 2 to 3 millimeters thick, making them especially suitable for an integrated cooling of electronic components.

THERMAL SWITCHES based on heat pipes can be produced with integrated functional materials. One of the approaches investigated is based on switchable hydrophilic/hydrophobic coatings that make it possible to change the preferred direction of the heat flow (actively switchable thermal diodes). Research is also being conducted on hydrogels, which absorb the working fluid in the heat pipe when the temperature drops below a specified point, thereby "locking it in." When the temperature rises above the set point, the fluid is released again, activating the heat pipe (temperature-sensitive thermal switch).

Switching heat on and off

Heat pipes not only dissipate heat, they also make it possible to turn heat flows on and off and regulate them precisely – just as with electric switches. While such thermal switches can be used to enhance, simplify, or even replace active temperature control systems, they have some drawbacks: Their design is complex and they typically only transfer small heat flows. Fraunhofer IPM is collaborating with other Fraunhofer institutes on a new generation of thermal switches based on switchable hydrophilic/hydrophobic coatings and hydrogels. These switches are small and do not require any moving parts. Thanks to their simple design, they are easy to integrate and promise significant improvements in heat transport capacity. The institute has already realized a conceptual study of a heat pipe-based thermal switch featuring a constant hydrophilic coating and including all of the necessary assembly, connection, and filling technology.

from: Fraunhofer IPM: Measuring, Monitoring, Optimizing. Annual report 2019/2020, Freiburg i.B., 2020. pp 66-67

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