PhD thesis topic

Intensification of heat transfer by boiling in a plastronic heat pipe with integrated hollow fins

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The transport sector is undergoing profound change as a result of the massive electrification of propulsion systems. While this electrification is helping to reduce emissions of local pollutants and, to a lesser extent, carbon dioxide into the atmosphere, it also requires the integration of high-power electronic circuits that are subject to high thermal stresses and large electrical currents. To ensure that the electronic components last long enough and are reliable, the temperature of the semiconductor junction must not exceed a certain limit. Because of the ever-increasing flux densities to be dissipated, conventional cooling devices, generally consisting of an air-cooled finned radiator (Figure 1a), are no longer sufficient. It is therefore necessary to develop more efficient devices, such as heat pipes (Figure 1b).

A heat pipe is a closed enclosure containing a two-phase fluid that evaporates on contact with the hot source (electronic component) and condenses at the cold source, where the heat is dissipated to the outside air. The plastronics techniques mastered at the AMPERE laboratory, a partner in the project, will enable conductive tracks and components to be deposited directly on a polymer substrate, which will therefore form the heat pipe's evaporator (Figure 1c). The radiator is replaced by a highly efficient hollow-fin condenser. The challenge, therefore, is to integrate the cooling system with the electronic device right from the design phase, which will necessarily lead to optimisation of the overall performance.

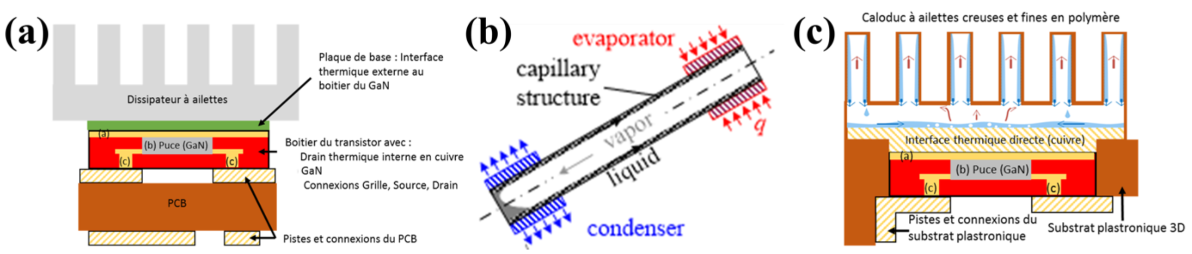

Figure 1: (a) Heat dissipation in a conventional configuration with a metal finned heat sink and external thermal interface, (b) Principle of a heat pipe, (c) Configuration proposed in this project: plastronic heat pipe with a hollow finned polymer condenser allowing direct cooling of the electronic components (scales not respected).

In the first stage, the thesis work will involve sizing the heat pipe for different heat transfer fluids. This involves determining, for an imposed heat flux and a known ambient temperature, the geometry of the heat pipe so as not to exceed the maximum permissible temperature levels for the electronic components. It is also necessary to check that the operating limits of the heat pipe, in particular the boiling limit, are not exceeded.

To carry out the experimental study, a series of test vehicles will be set up in the AMPERE laboratory. A first bench will be developed to visualise and characterise heat transfers between the heated surface and the selected fluids, in particular boiling regimes, heat exchange coefficients and critical flux density. An increase in these transfers will be sought by judicious design of the solid/fluid interface.

To achieve this, it will be possible to modify the thickness, nature or surface state of the various metal layers applied to the polymer substrate, to create meso- or microstructures, etc.

Next, a second test bench will be used to characterise the two-phase flow within the heat pipe and its thermal performance. Observations through the transparent envelope of the heat pipe will highlight the hydrodynamic phenomena limiting performance, in particular the presence of stable liquid plugs in the fins. The scientific challenge here will be to understand the origin of the formation of these plugs, so as to avoid them. This part of the thesis follows on from the work of E. Bérut, who showed that the plugs could be caused by liquid splashing from an evaporator where the fluid is too confined, or by capillary phenomena.

The thesis will be carried out at INSA Lyon and CETHIL (https://cethil.insa-lyon.fr), which has a heat pipe characterisation platform. The PhD student will work closely with the AMPERE laboratory, which has a plastronics platform, and the IMP.

Conditions
The thesis grant is conditional on obtaining funding from the ANR CAPREP project.

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