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Thermal Rectification Techniques

Master Thesis / Internship

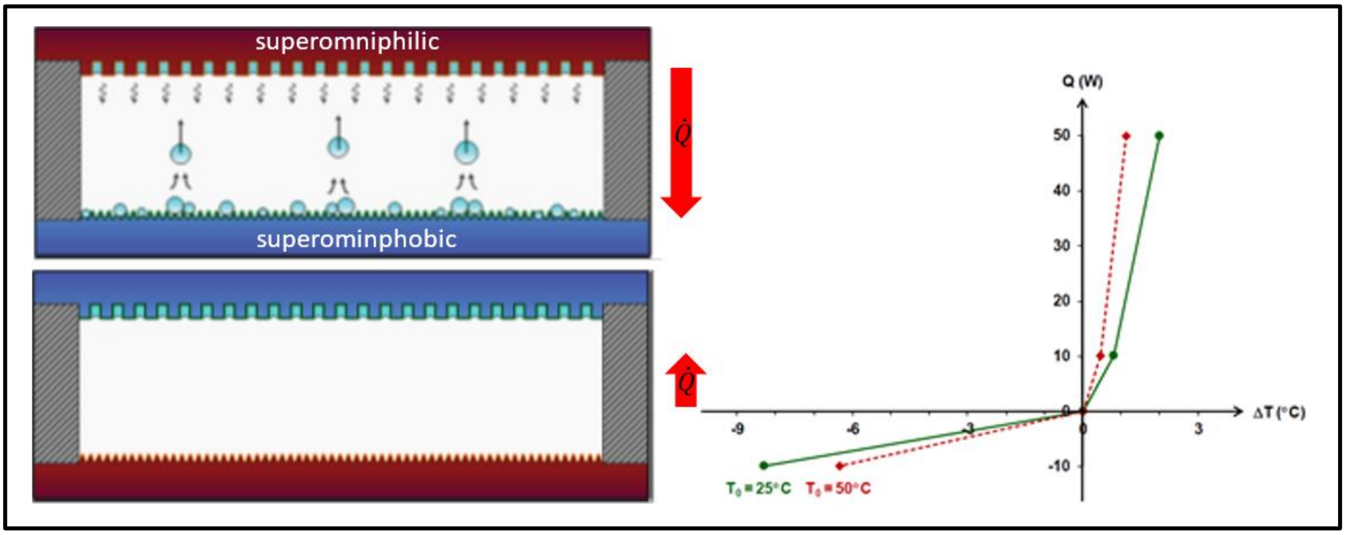

Figure: Thermal diode principle and diode-like behavior of heat transport

Introduction:

One of the major challenges in current and future projects is thermal control. Increasing performance requirements on instrumentation lead to increased data gathering rates, while miniaturisation of components allows for a higher density of on-board electronics. The result are significantly increased heat densities while simultaneously high-performance units often are more sensitive and have more stringent cooling requirements than their less powerful counterparts. This challenge can be met by increasing radiator size and improving heat transport from source to radiator via high conductance elements such as heat pipes.

However, the state-of-the-art heat pipes are not unidirectional. This means that if by an – accidentally or intentionally performed – orbit manoeuvre the radiator points such that it is subject to an incoming heat flux, then the heat pipe directly transports this heat into the device which should actually be cooled, putting sensitive equipment at a high risk of getting damaged. Such a fail case can be avoided by the implementation of thermal diodes which have a high heat transport capability in one direction, but block it in the opposite direction.

Among others, a technological solution that allows to achieve such a behaviour is based on the jumping drop effect (JDE). A typical jumping-drop thermal diode (see Figure, left) consists of a vapor chamber with a superominphobic and superomniphilic plates.

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Heating the superomniphilic plate (see Figure, top left) causes the working fluid to evaporate and condense on the superominphobic surface. The coalescence of condensed droplets generates excess interface free energy, causing the merged droplet to jump back to the evaporator thus completing an efficient phase-change heat transfer cycle. Heating the superominphobic surface (see Figure, bottom left) blocks phase-change heat transfer because the liquid phase remains trapped on the superomniphilic surface. In this case, the heat transfer results much lower than the previous one.

Such diodes will be put forward as a future development project in this thesis. The realization of such thermal diodes has already been investigated as part of several master thesis, resulting in the construction and testing of first working prototypes (using water as working fluid) and improvement/implementation of numerical models for the jumping drop velocity prediction.

In continuation of these works, the goal of the current thesis will be to assess the feasibility of a jumping-drop thermal diode using space-compatible working fluids like ethanol and ammonia. To do so, the main challenge is the fabrication of superomniphobic surfaces for these fluids.

In the initial phase of the thesis, the student will review existing literature and the state of the art. Additionally, she/he will conduct simulations to identify surface parameters that theoretically enable droplets jumping. Subsequently, the student’s task will be to manufacture the surfaces with the selected characteristics, integrate them in the existing test cell and evaluate the performance.

Tasks:

The thesis will consist of the following steps:

- Conduct a literature review on the development of superomniphobic surfaces for ethanol, ammonia, etc.
- Perform numerical analysis to determine the optimal parameters
- Development/improvement of fabrication techniques
- Benchmarking of test samples in laboratory environment
- Documentation (in English) and presentation of the work

Desired Skills:

- Solid understanding of materials science and chemistry
- Hands-on experience in surface treatments is a plus
- Familiarity with laboratory equipment
- Proficiency in data analysis, and software for interpreting results (Matlab/Python)
- Understanding of thermodynamic processes

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Framework:

The thesis/internship is planned for a six month period, and shall be performed in the "Thermal Systems & Products Germany" department of Airbus Defence and Space GmbH, Friedrichshafen, Germany.

The student is responsible for supervision and acceptance of his work by the university. Circulation of results of the work to other institutions than the university needs permission of Airbus Defence and Space GmbH.

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