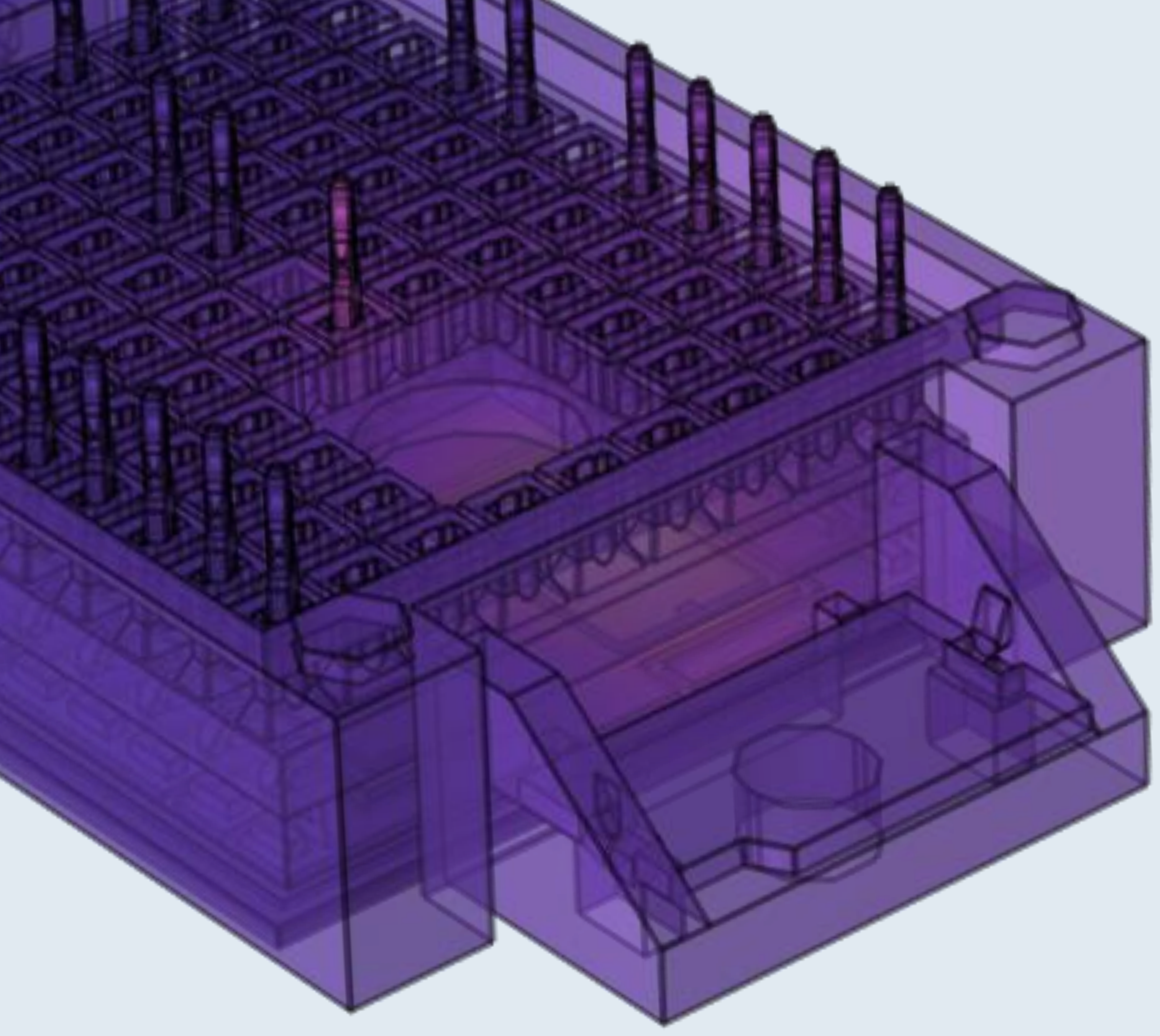

Influence Of Materials And Packaging Solutions On Thermal Behaviour Of Power Modules

Power modules are key players in advancing the energy transition towards alternative energy sources.
This work focuses on designing more efficient devices through innovative materials and processes to maximize the system's thermal management.

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Introduction

Power semiconductor modules are devices, such as power converters, power supplies, motor controls, that are responsible for processing and transferring the electrical power between a source and a load. [1]

The demanded efficiency and power density of these systems are getting higher, due to the recent advancements in **Wide Band Gap** (WBG) semiconductor devices such as **silicon carbide** (SiC) and **gallium nitride** (GaN), operating at high temperatures up to 250°C. [2]

To satisfy the new requirements, an excellent heat dissipation and a continuous scaling of the devices are necessary. Therefore, the performances and the reliability of the package represent the key point of the next generation of power modules.

In this work, a thermal characterization, based on the **thermal resistance** (Rth j-s) between the dice and the heatsink, is addressed to carry on a comparison between several substrates, designed through a matrix of parameters (Figure 1), and different encapsulation technologies for the package.

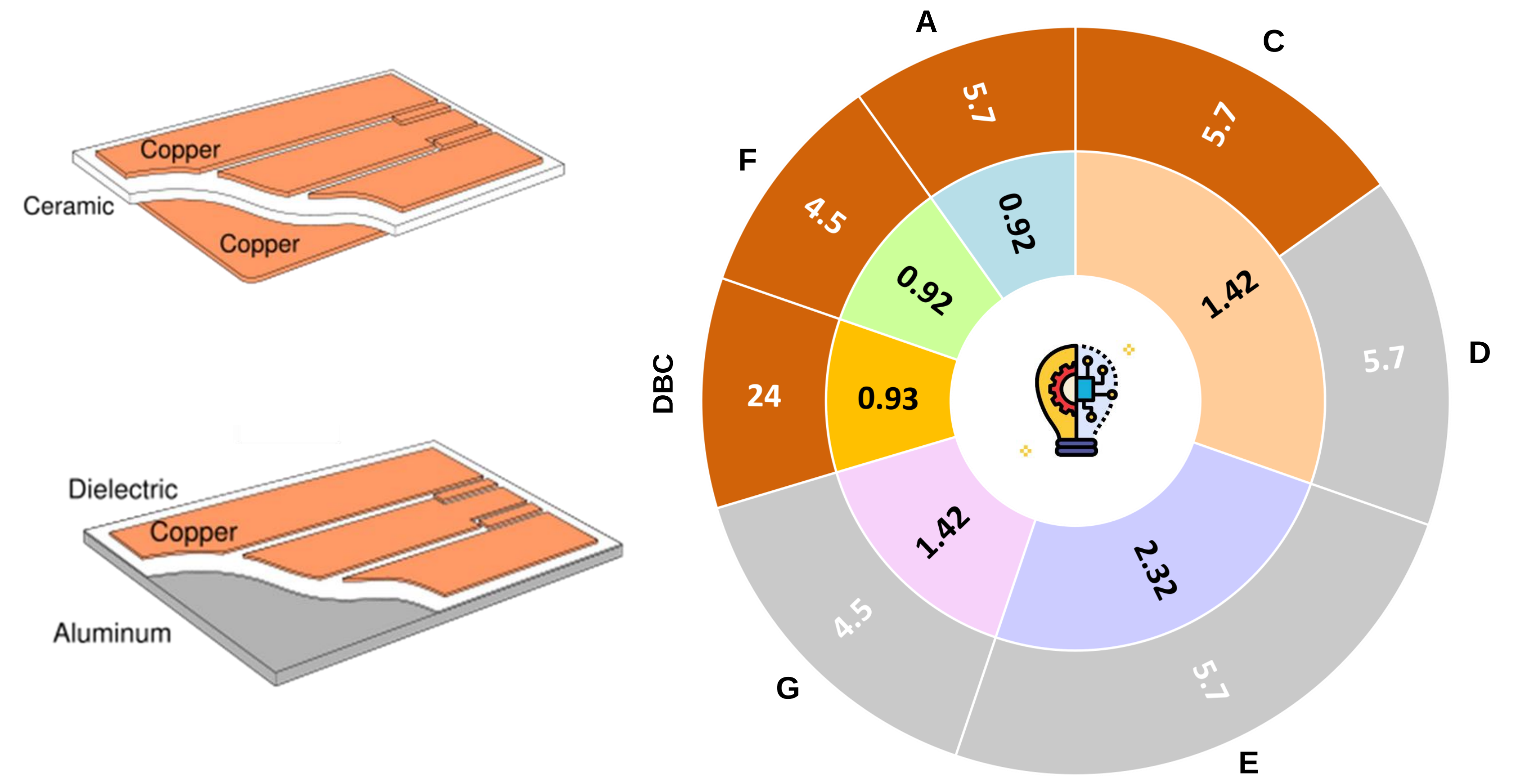

Figure 1. Left: Architecture of DBC substrate (up) and IMS substrate (down). Right: matrix of parameters used for designing 6 combinations of IMS (A-E) and 1 combination of DBC: thickness value [mm] in the inner ring, thermal conductivity [W/m²K] in the outside ring, orange or gray colour in the outer slices indicate copper or aluminum as backside material.

Methodology

Power modules are composed by two primary parts: substrate and package. **Direct Bonded Copper** (DBC) and **Insulated Metal Substrate** (IMS) are the main known **substrates** (Figure 2). While for the **package**, there are **Vacuum Potting Gel** (VPG) and **Transfer Molding** (TM).

The FEA method has been set to reproduce correctly the experimental set-up for all the combinations of substrate. Each silicon die dissipates about 110 W. Each module was simulated as mounted on a water-cooled heatsink with a 40 µm thick thermal grease layer interposed. A steady state study is performed also for modules with VPG and TM package. Both 2D temperature profiles are presented in Figure 2.

Results

From the thermal point of view all the IMS groups are almost aligned to DBC values of Rth j-s, and the experimental data are approximately confirmed by the FEA results (see Figure 3).

The most thermal performing substrate in IMS substrates is group C, characterized by a thicker copper layer on the backside. It shows a Rth j-s value 10% lower than DBC.

Experimental data show a Rth improvement of 20% in TM than VPG, while FEM data show no variations in the heat extraction flow (Figure 2). The discrepancy is probably due to the different warpage of the module as result of the TM process, varying the pressure contact with the thermal grease on the heatsink.

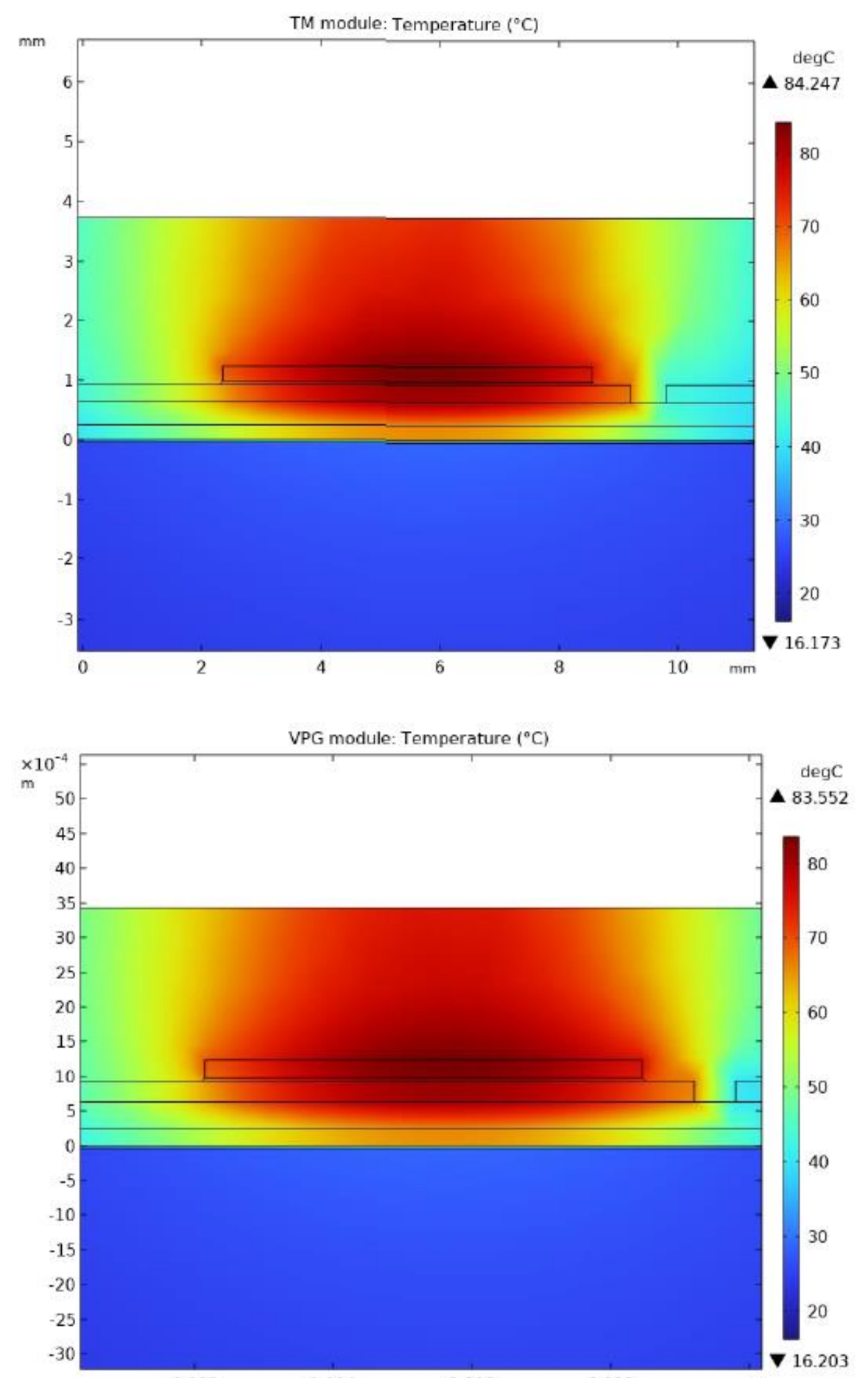

Figure 2. Left: temperature profile for a DBC - VPG module (bottom) and for a DBC – TM module (top).

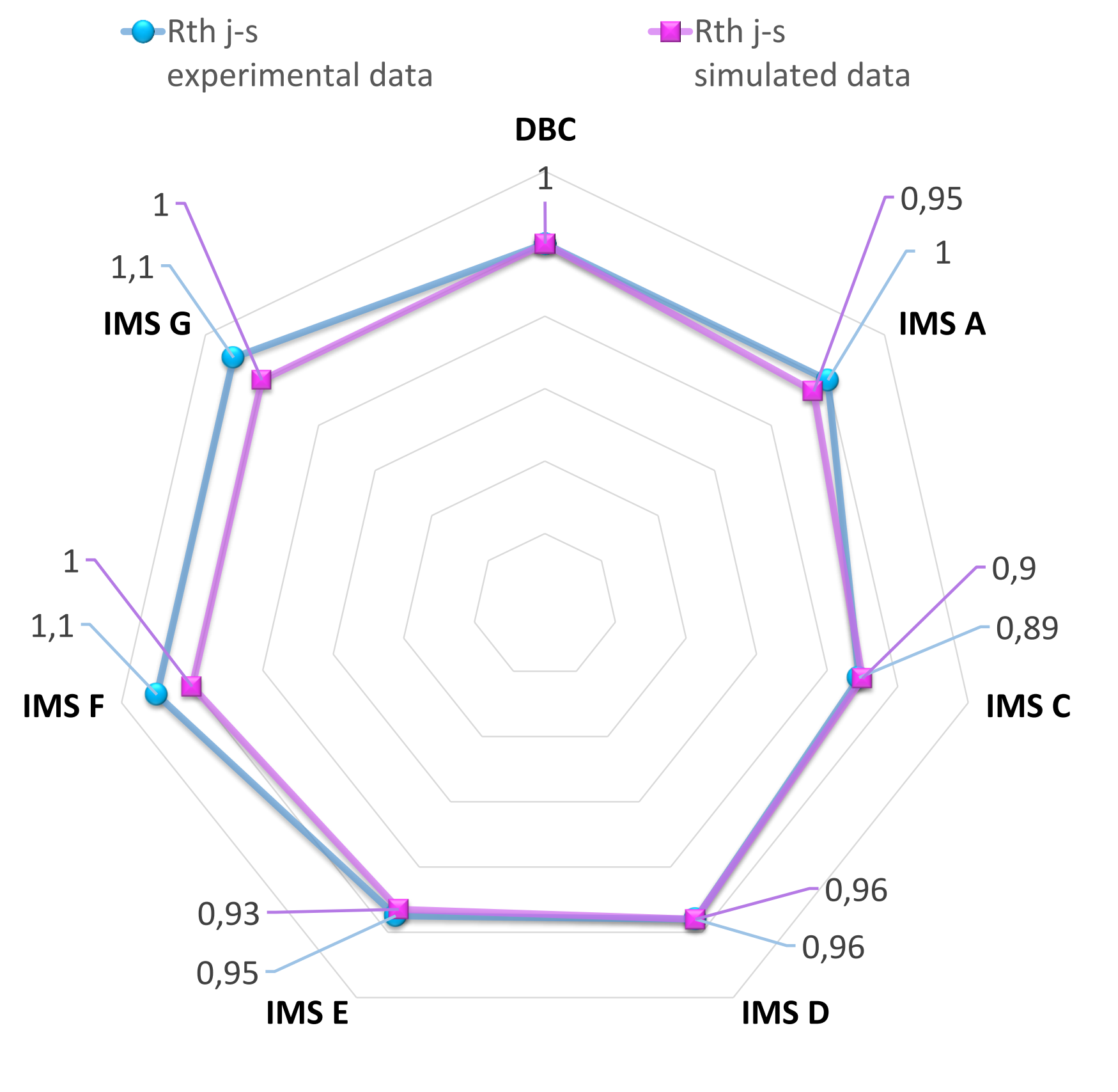

Figure 3. Comparison of DBC and all IMS groups normalized values of Rth j-s between simulation and experimental results.

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