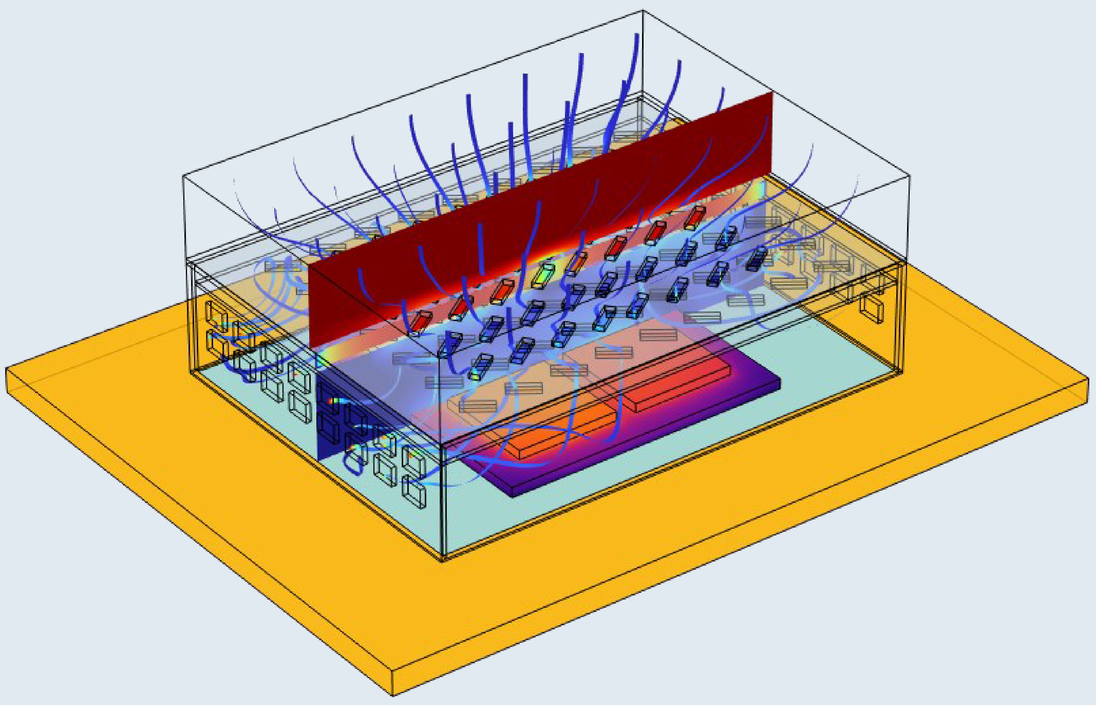


Multiphysics Analysis of Bilayer Staggered Shields with Graded Ventilation for Chiplet Packages

Numerical investigation of thermal–flow distributions, opening-gradient effects on cooling, and frequency-dependent cavity electric fields.

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Introduction & Goals

Localized heating and electromagnetic interference challenge high-power Chiplet packages. Ventilation promotes forced-convection cooling but may provide paths for electromagnetic coupling. Nonuniform chip power makes cooling demand vary across the package. This study examines a bilayer staggered shield with openings graded by local heat load. The goals are to:

- resolve airflow, temperature, and relative electric-field distributions;
- quantify how opening gradient affects peak chip temperature and chip-to-chip temperature spread;
- characterize the frequency dependence of the cavity-region electric-field metric.

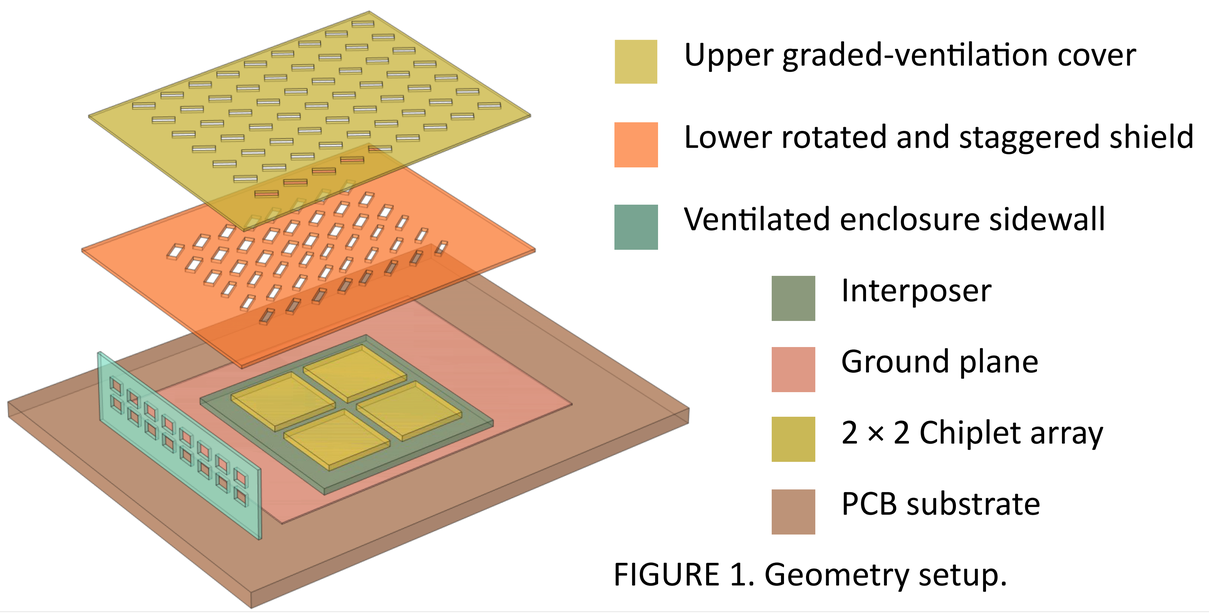


FIGURE 1. Geometry setup.

A 3D COMSOL model combines a 2 × 2 Chiplet array (7/6/4/3 W) with a graded vented cover and a rotated, laterally offset lower shield. Steady nonisothermal laminar flow and conjugate heat transfer resolve airflow, chip temperature, and pressure drop. The resulting temperature field informs a subsequent frequency-domain electromagnetic analysis. Vent gradient, slit angle, offset, interlayer spacing, and inlet velocity are parameterized to assess thermal, flow, and electric-field responses.

Results

Temperature and airflow fields show a hotspot above the highest-power Chiplet and flow through the staggered bilayer vents, linking nonuniform heating to the package cooling path. The electric-field map reveals localized concentrations near apertures and within the cavity, indicating that the openings influence both airflow and electric-field distribution. The opening-gradient sweep reveals two distinct thermal objectives: increasing the coefficient from 0 to 0.55 lowers peak chip temperature from 271.36 to 270.58 °C; chip-to-chip temperature spread continues to decrease from 37.78 to 35.76 K across the tested range. The cavity electric-field metric varies non-monotonically with frequency, reaching its highest plotted value near 26.25 GHz. Together, these results show that bilayer staggered graded ventilation affects local cooling and cavity electric-field distribution, providing a numerical basis for coordinated thermal management and electromagnetic shielding design in high-power Chiplet packages.

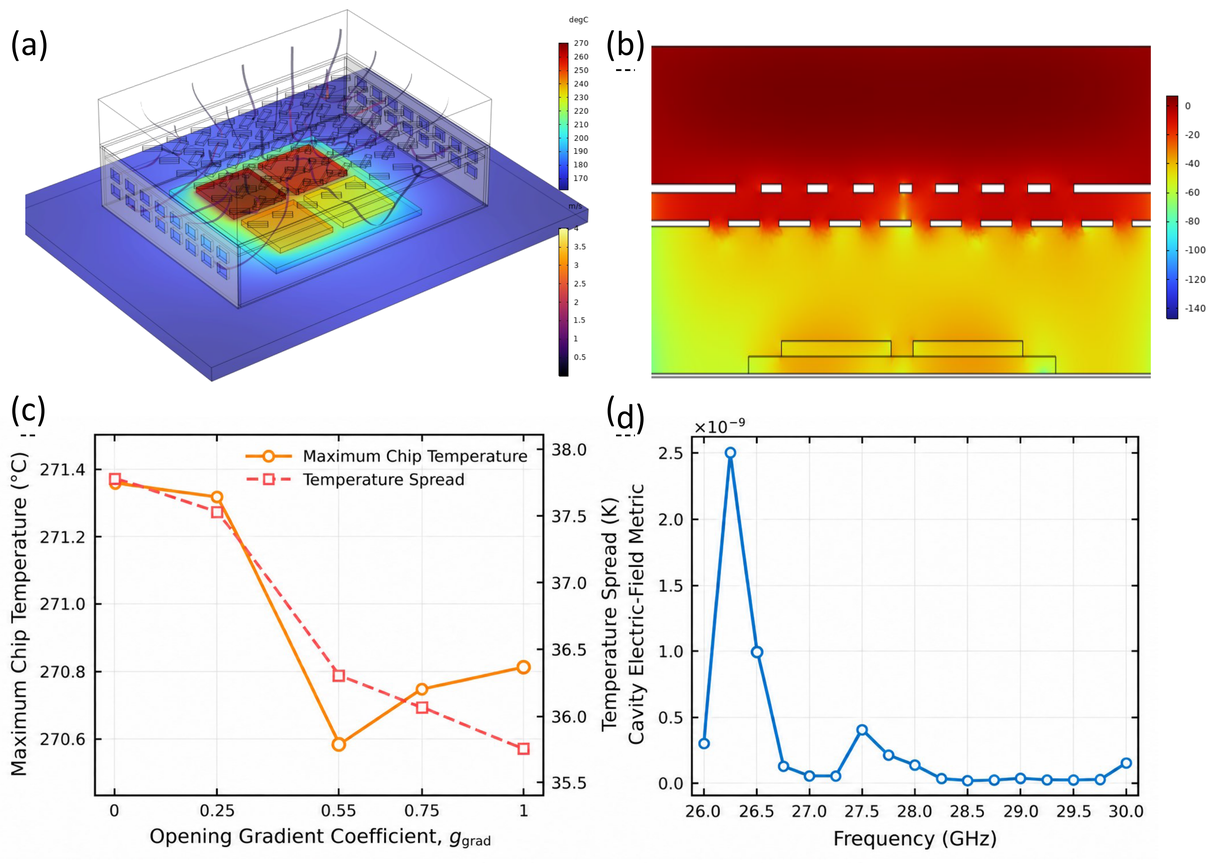


Figure 2. Representative higher-order modes, effective-index spectrum, and index-contrast-dependent modal characteristics.

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