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Passive Heat Spreader Using Temperature-Sensitive Magnetic Fluids with Controlled Magnet Arrangement

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Magnetic fluids have attracted considerable attention as functional refrigerants for passive thermal management systems. In particular, temperature-sensitive magnetic fluids (TSMFs) exhibit strong temperature dependence of magnetization, enabling self-driven flow under non-uniform magnetic fields. This unique property offers a promising approach for realizing compact and energy-efficient heat spreaders without mechanical pumps.
In this study, a passive heat spreader using TSMF with a controlled magnet arrangement is proposed, and the effect of magnet configuration on heat transport performance is experimentally and numerically investigated. The device consists of a thin plate-type container filled with a water-based TSMF (TC3030W), with heating and cooling sections installed at both ends. Cylindrical permanent magnets are arranged beneath the container, and multiple configurations—including single-row, double-row, and staggered arrangements—are systematically examined to control the magnetic field distribution.
Experiments are conducted under constant temperature boundary conditions, and the temperature field is visualized using infrared thermography. The results demonstrate that the magnet arrangement significantly influences fluid flow and heat transport behavior. In particular, the single-row aligned configuration achieved the lower thermal resistance, which was supported by numerical results showing rapid thermal diffusion and a high-velocity main flow from the heating section to the cooling section, as illustrated in Figure 1(b). In contrast, the staggered configuration resulted in relatively higher thermal resistance because numerical analysis indicated that local flows around individual magnets disturbed the formation of a continuous heat-transport flow, as shown in Figure 1(c). Compared to the no-field condition (Figure 1 (a)), the application of magnetic fields effectively reduced thermal resistance, confirming the contribution of magnetically induced flow. These results highlight the importance of controlled magnet arrangement in improving heat spreading performance.

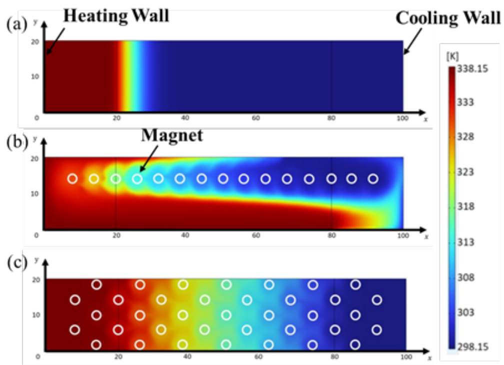

Figure 1. Temperature field for different magnet arrangements: (a) no-field condition; (b) single-row aligned configuration; (c) staggered configuration.

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