Cooperative near- and far-field thermal management via diffusive superimposed dipoles

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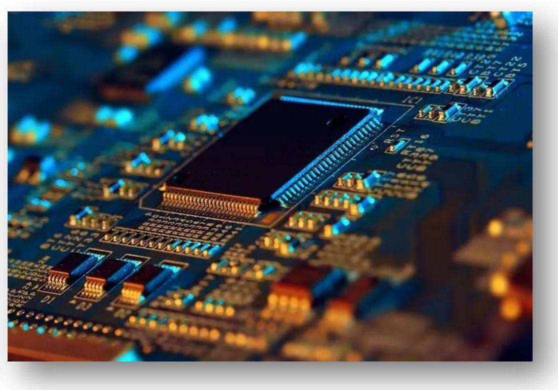
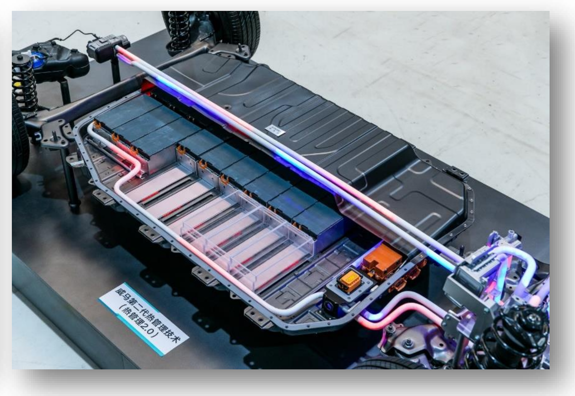
1 Background

Cold-chain logistics

Integrated circuit



New energy vehicles



Conventional thermal management[1] include two inherent limitations:

I. Disturbing surrounding temperature

II. Lacking adaptability

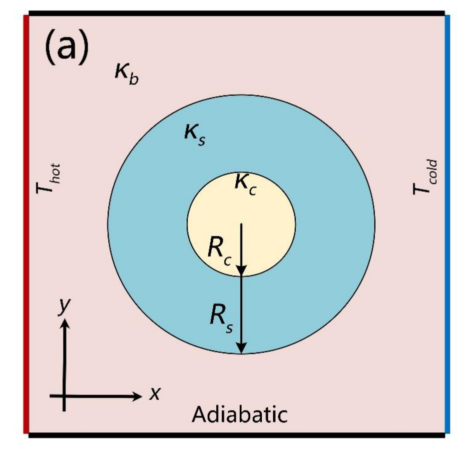
2 Principle

Temperature distribution for external heat source:

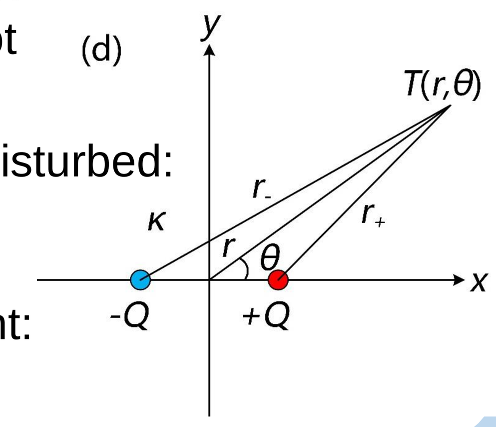
$$\begin{cases} T_{e,c} = A_c r\cos\theta & \text{(Near field)} \\ T_{e,b} = A_b r\cos\theta + B_b r^{-1}\cos\theta & \text{(Far field)} \end{cases}$$

Temperature distribution for thermal dipole[2,3]:

$$\begin{cases} T_{d,c} = 2Mr\cos\theta/(\pi\kappa_c L^2) & \text{(Near field)} \\ T_{d,b} = D_b r^{-1}\cos\theta & \text{(Far field)} \end{cases}$$



Due to the consistency of the temperature form, we can adjust the dipole moment M to ensure that the external field does not disturb the local temperature gradient.

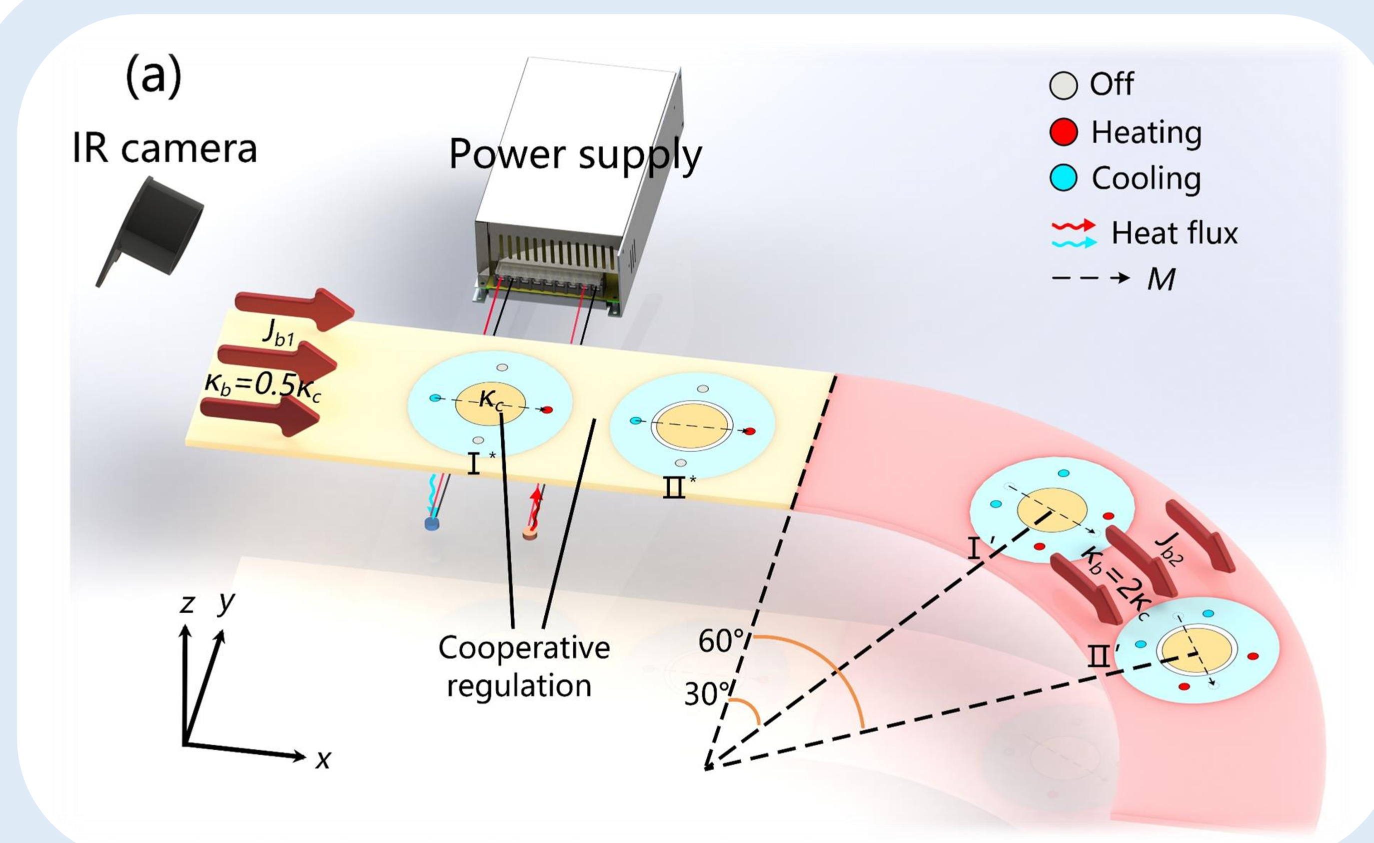


I. Ensuring background T undisturbed:

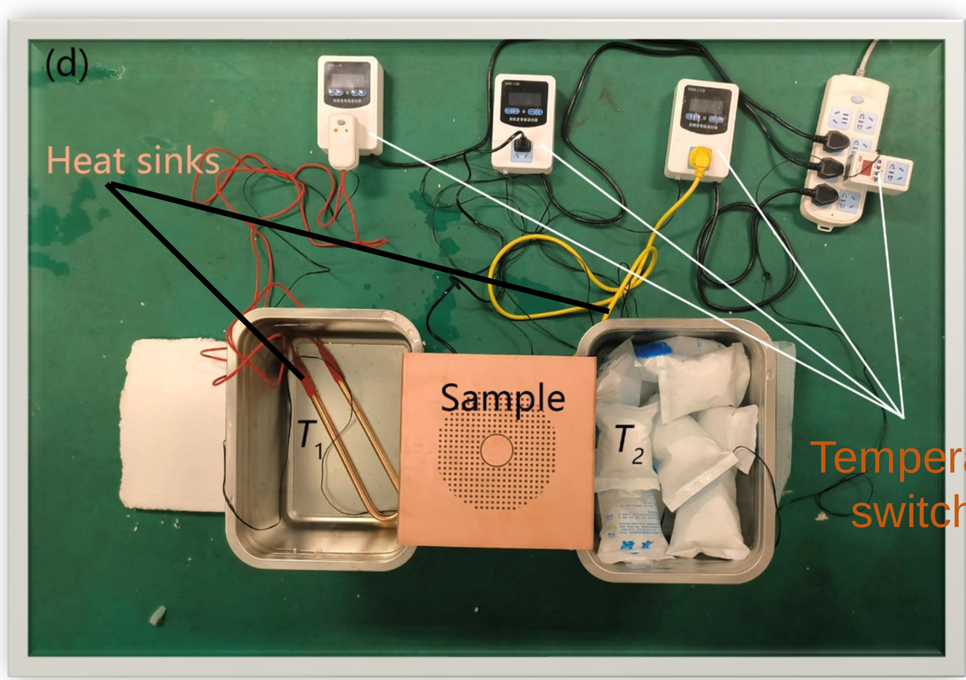
$$B_b + D_b = 0$$

II. Concentrating coefficient:

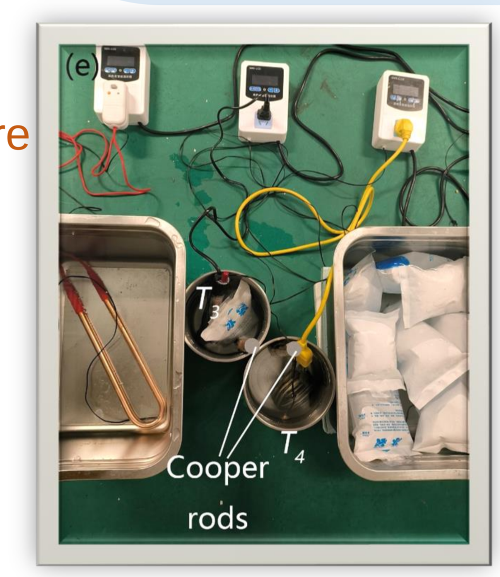
$$\eta = \nabla T_c / \nabla T_b$$



3 Methods



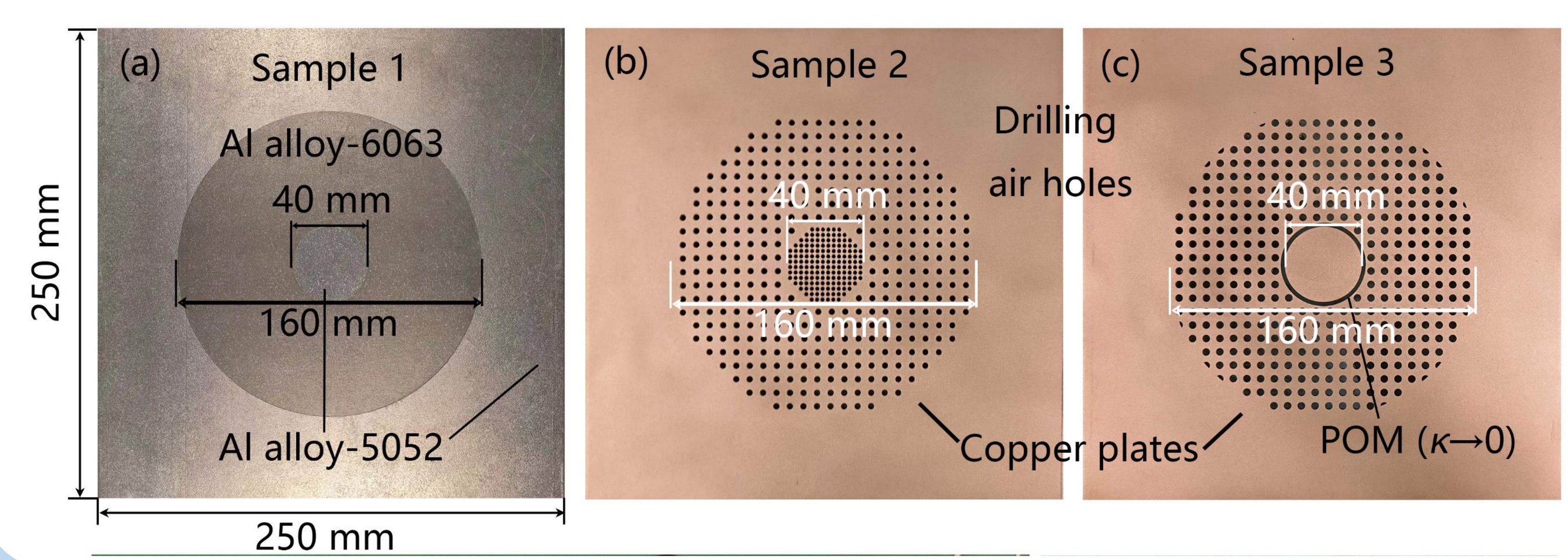
Photograph of the experimental setups.



4 Materials

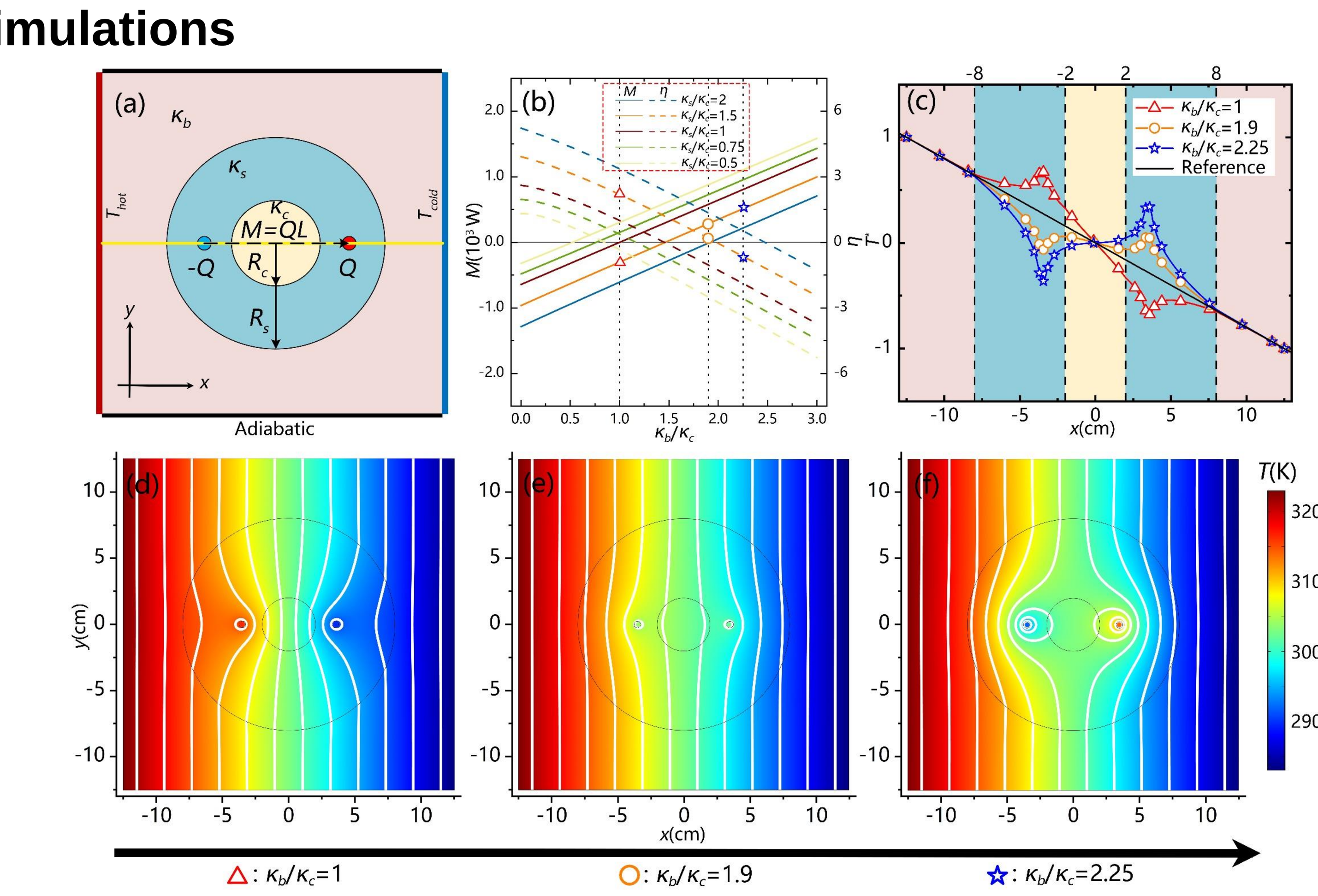
Region	Material
Core and background (1)	Al-5052
Shell (1)	Al-6063
Core (2)	Copper
Shell (2)	Copper
Background (2)	Copper
Core and background (3)	Copper
Shell (3)	Copper
Insulated layer (3)	POM

Fabricated samples. (a) Sample 1: enhanced-center transparency. (b) Sample 2: weakened-center transparency. (c) Samples 3: cloak.

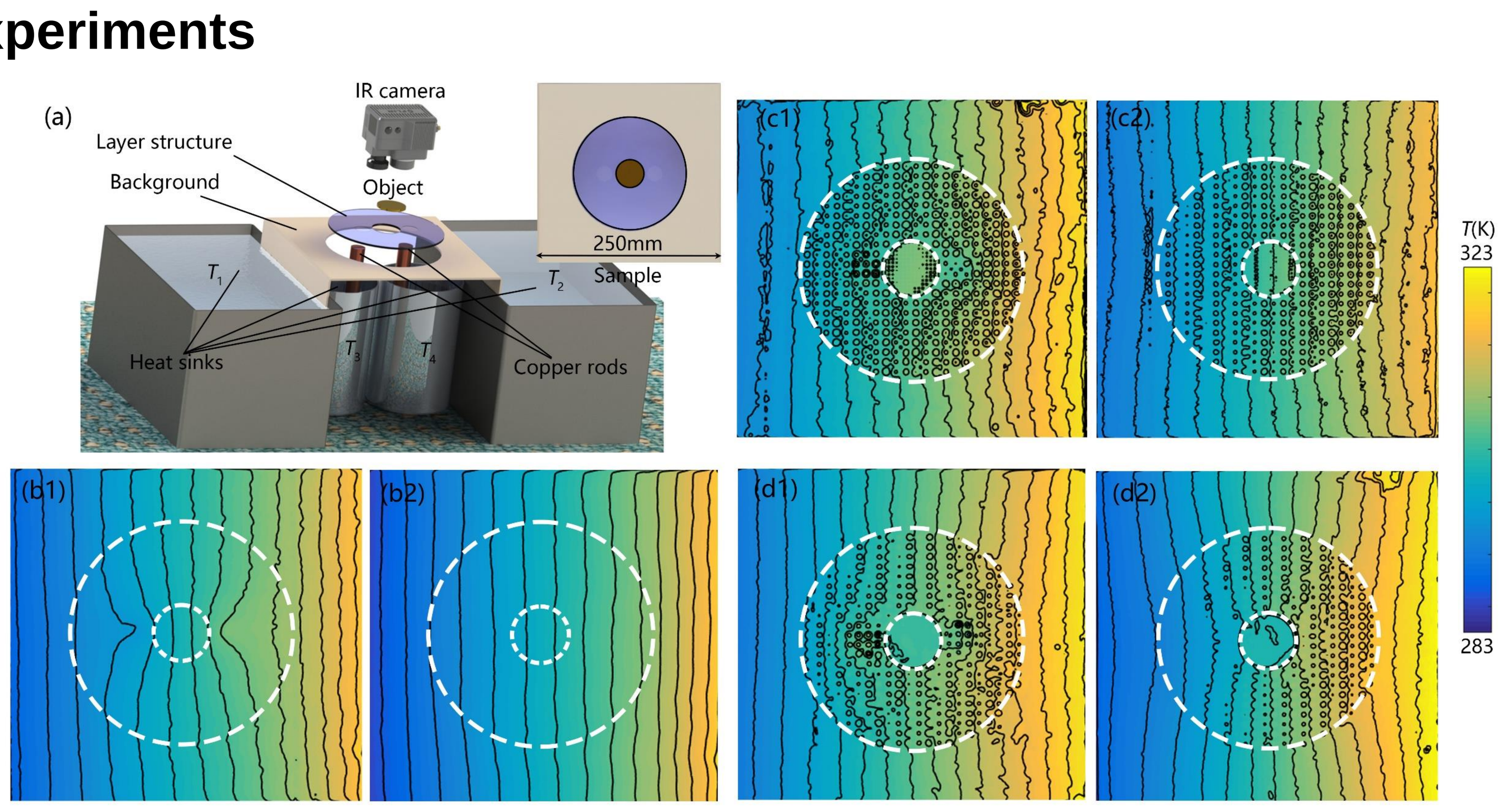


5 Results

I. Simulations



II. Experiments



6 Conclusions

- **Diffusive superimposed dipoles assisted thermotics is proposed for active scattering cancellation in the Laplace field.**
- **Leveraging the combined influence of the far-field and near-field from superimposed thermal dipoles, two innovative thermal meta-devices have been conceptualized and designed, including transparency and cloak.**
- **These metadevices work effectively even when taking into account the thermal resistance of the interface.**
- **Our schemes can be implemented across 2D and 3D cases, as well as in geometrically isotropic and anisotropic scenarios using isotropic and homogeneous materials.**

7 References

1. H. Song, J. Liu, B. Liu, J. Wu, H.-M. Cheng, and F. Kang, Two-dimensional materials for thermal management applications, Joule 2, 442-463 (2018).
2. L. J. Xu, S. Yang, and J. P. Huang, Dipole-assisted thermotics: Experimental demonstration of dipole-driven thermal invisibility, Physical Review E 100, 062108 (2019).
3. P. F. Zhuang, X. C. Zhou, L. J. Xu, and J. P. Huang, Cooperative near- and far-field thermal management via diffusive superimposed dipoles, Applied Physics Reviews (IF: 15) 11, 011416 (2024). Selected as a Featured Article.