Programmable all-thermal encoding

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Abstract. Information processing and storage depend on advanced encoding technologies, which have been studied and implemented adequately in wave fields ranging from electromagnetism to acoustics[1,2]. However, heat is seldom utilized in signal transfer as a significant carrier of information because of the lack of programmability with flexible unit structures. Here, we design and realize a programmable all-thermal encoding strategy, where conductive heat is used for signal read-in, encoding, and output. Thanks to the switchable cloak-concentrator metadevices, the binary signals are distinguishable by the divergent feature of heat flow and detected within local sites regardless of the intrinsic diffusion nature. A proof-of-concept prototype is fabricated with the help of shape memory alloys due to their phase-change behavior under specific temperatures, yielding a robust thermal encoding platform.

Theoretical design.

We use the difference in heat flow between the central region of the cloak and the concentrator to distinguish binary signals; bypassing is 0 state, and concentrating is 1 state. The encoding unit cell based on a switchable cloak-concentrator will produce

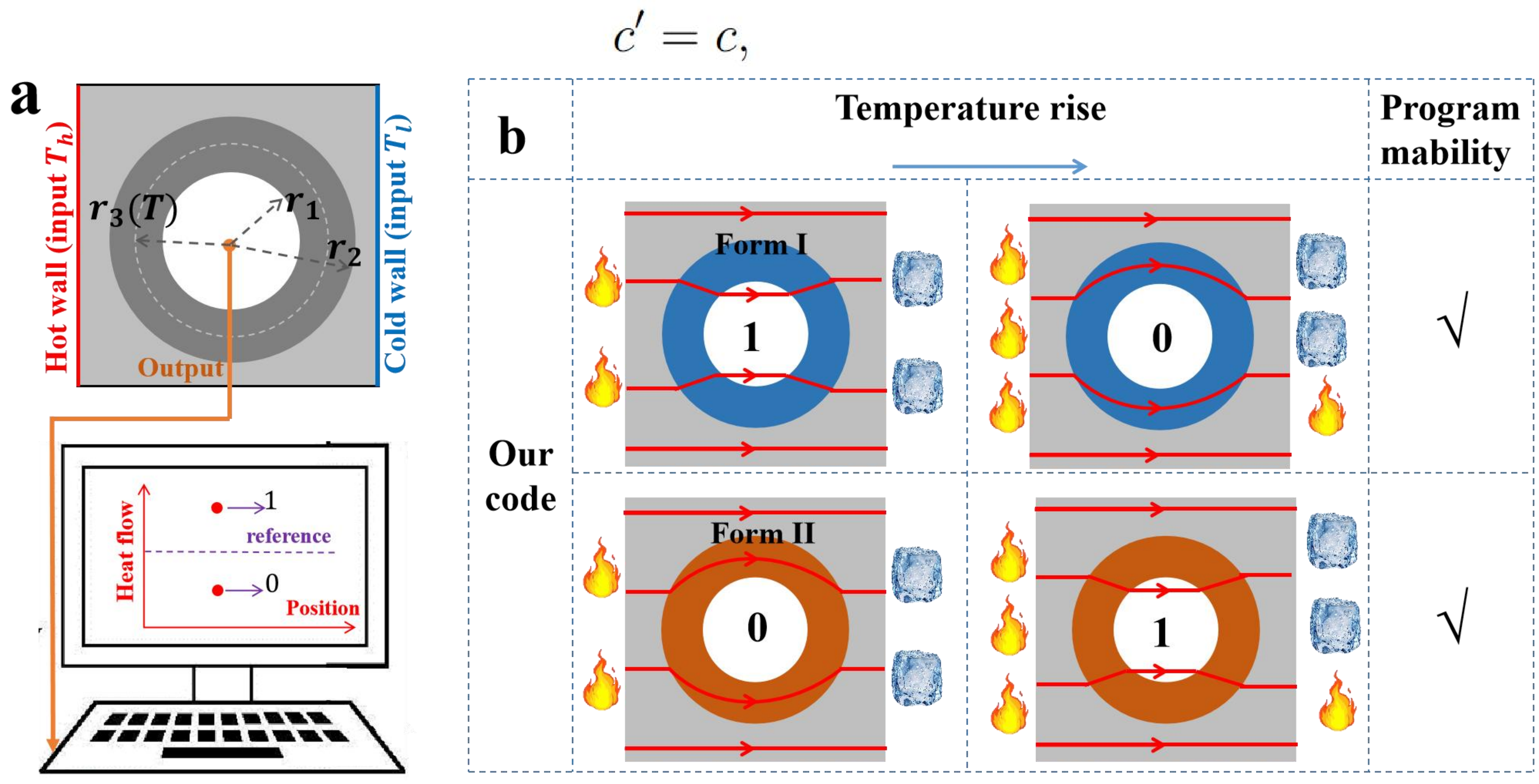
different output digital states under varying ambient temperatures.

Temperature-dependent transformation thermotics[3] can achieve switchable cloak-concentrator. The trans , density, and thermal capacity can be expressed as

$$\kappa'(T') = \frac{\mathrm{A}(T)\kappa_0\mathrm{A}^{\mathrm{tr}}(T)}{\det \mathrm{A}(T)},$$

$$\rho' = \frac{\rho}{\det \mathrm{A}(T)},$$

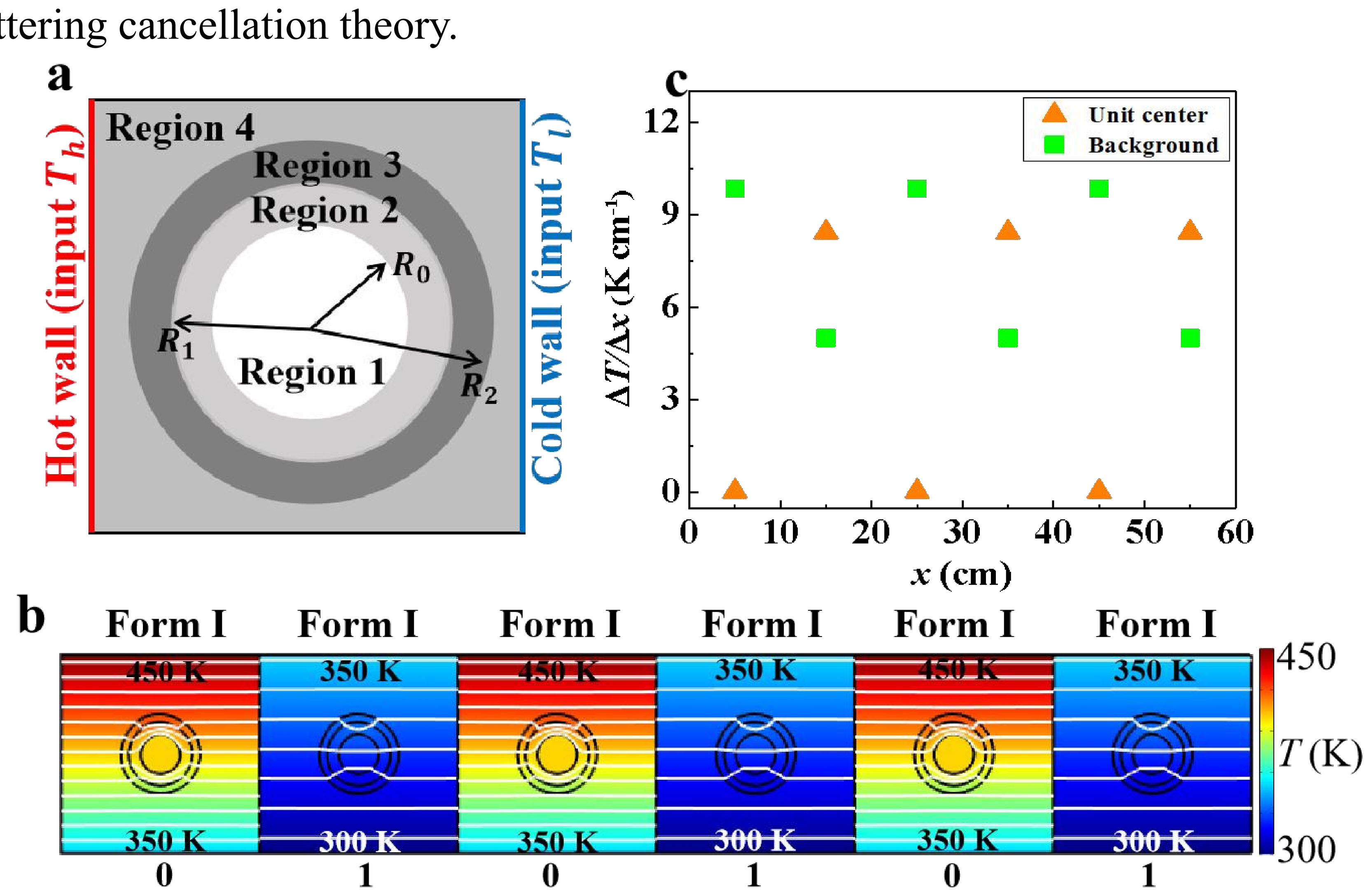
$$c' = c,$$



(a) Principle of programmable all-thermal encoding. (b) The encoding unit produce different output digital states under varying ambient temperatures.

Experiment design.

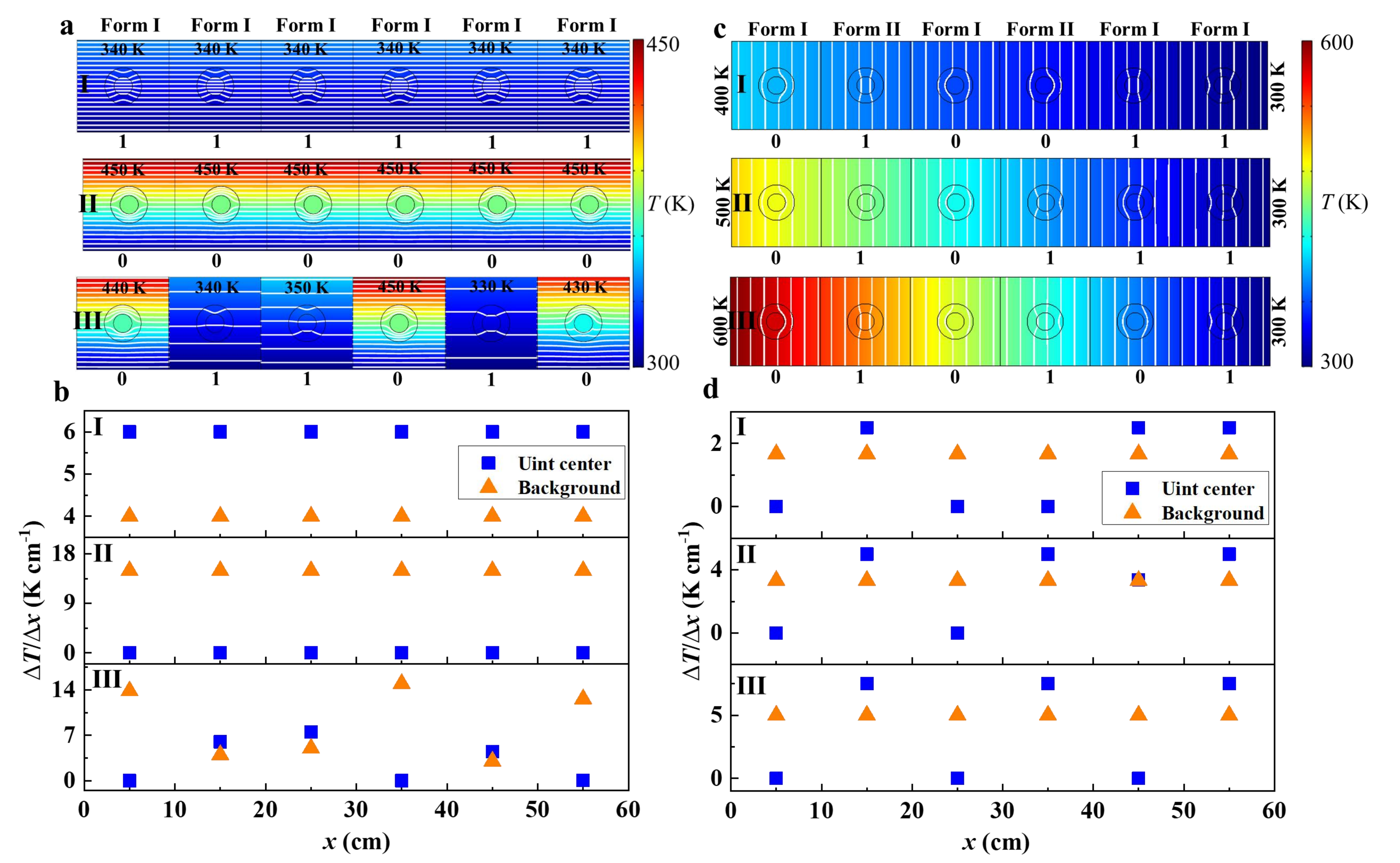
Thermal encoding based on temperature-dependent scattering cancellation theory.



(a) Schematic diagram of bilayer temperature-controlled encoding unit structure. (b) Simulation results. (c)Temperature gradient-position curve corresponds to (b).

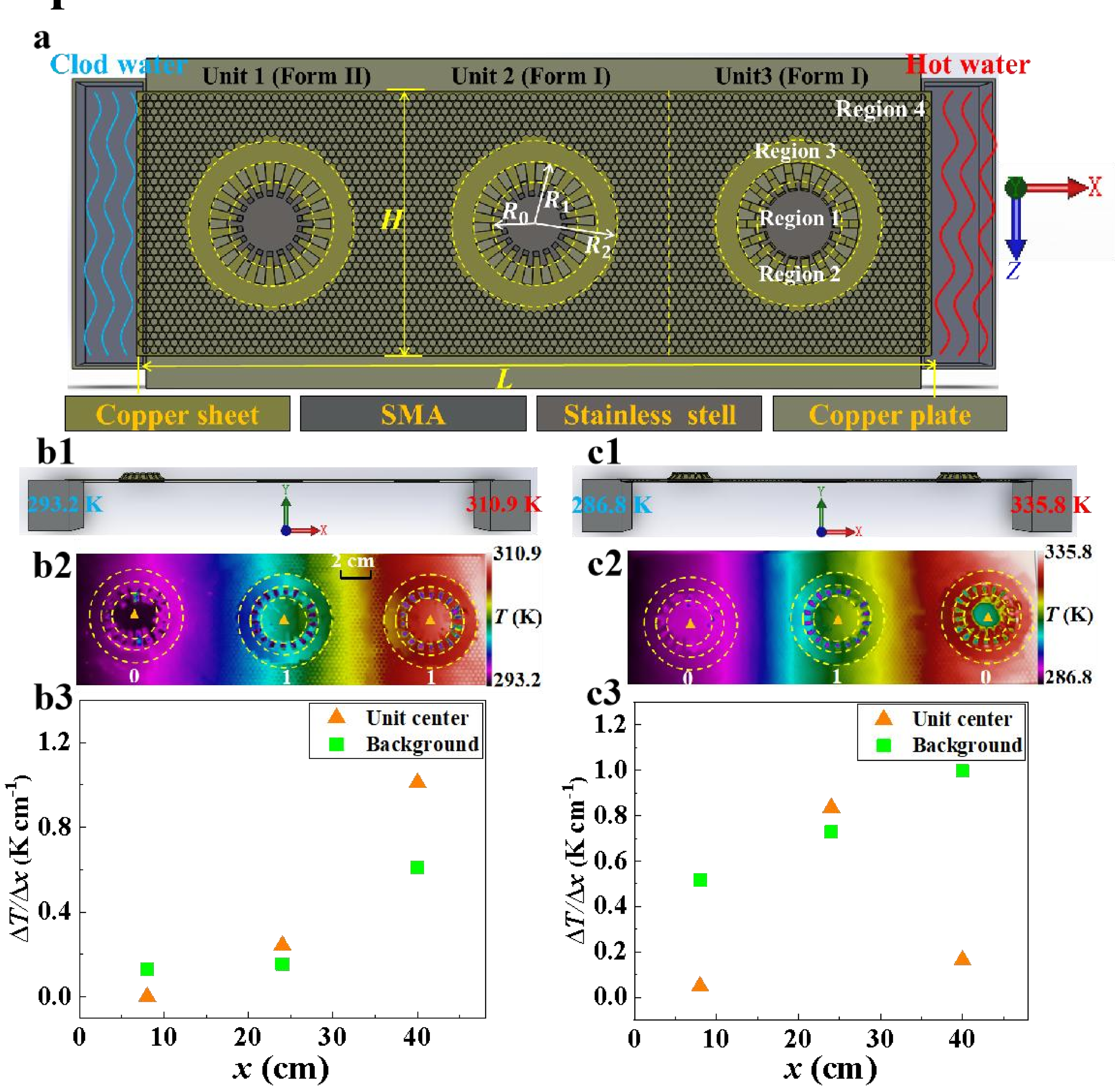
Numerical simulations.

The results of encoding array based on temperature-dependent transformation thermotics in steady state.



(a) Individual control; (c) Batch control. (b) shows the temperature gradients of units' center and background in (a), and (d) corresponds to (c).

Experimental results.



(a) Top view of a temperature-controlled thermal encoding device. (b1) and (c1) are front views of the device at different temperatures. (b2) and (c2): experimental results. (b3) and (c3): temperature gradient-position curve.

Conclusion.

- We design and realize a programmable all-thermal encoding strategy, for the first time in macroscopic diffusion systems.
- The robustness of our design is verified by numerical simulation under both steady and transient environments.
- A proof-of-principle prototype is demonstrated to depict the encoding process, echoing the design blueprint.

Reference.

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