Electronic Supplementary Material (ESI) for Materials Horizons.

Supporting Information

Femtosecond Laser Composite Manufacturing Double Bionic Micro-Nano Structure for Efficient Photothermal Anti-Icing/Deicing

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The detailed calculation process of *Q*:[1]

When surface temperature is constant, the amount of heat generated by the photothermal conversion of material is equal to the amount of heat dissipation to the surrounding environment.

$$Q = Q_s = h \times A \times (T_{sub} - T_{surr}) \tag{1}$$

where Q is the heat generated by the photothermal conversion of material. Q_s is the heat dissipation to surrounding environment. A is the surface area, 4 cm^2. T_{sub} is the surface temperature at a stable state. T_{surr} is surrounding temperature, 25°C. h represents the average convective heat transfer coefficient, which can be calculated according to *Eq*. 2.

$$N_u = \frac{h \times L}{\lambda} \tag{2}$$

where L represents the characteristic length of heat transfer region, 2 cm. λ is the thermal conductivity coefficient of air. N_u is Nusselt number, which can be calculated according to *Eq*. 3.

$$N_u = 0.54 \times (G_r \times P_r)_m^{1/4} \tag{3}$$

where G_r is Grashof number. P_r is Prandtl number. The subscript m represents parameters at temperature $T_m = (T_{sub} + T_{surr})/2$. G_r and P_r can be calculated according to *Eq*. 4-5.

$$G_r = \frac{g \alpha_v \Delta T L^3}{\nu^2} \tag{4}$$

$$P_r = \frac{\nu}{a} \tag{5}$$

where g represents the acceleration of gravity, 9.8 m/s^2. α_v is volume expansion coefficient, 1/*T*. ΔT represents the temperature difference between air and surface. ν is viscosity coefficient. *a* represents thermal diffusivity.

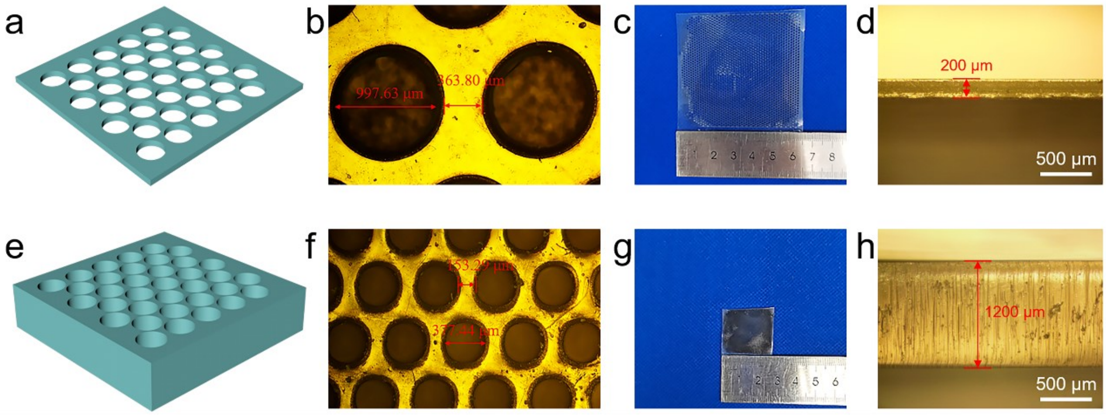

Fig. S1 Geometric characteristics, optical microscope images, and optical images of porous shape memory polystyrene membrane (PSM) film before (a), (b), (c), (d) and after (e), (f), (g), (h) thermal shrinkage.

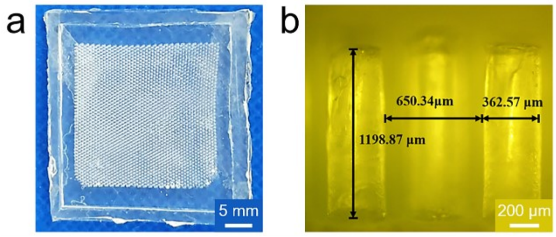

Fig. S2 (a) Optical image of PDMS template. (b) Structural parameters of PDMS template.

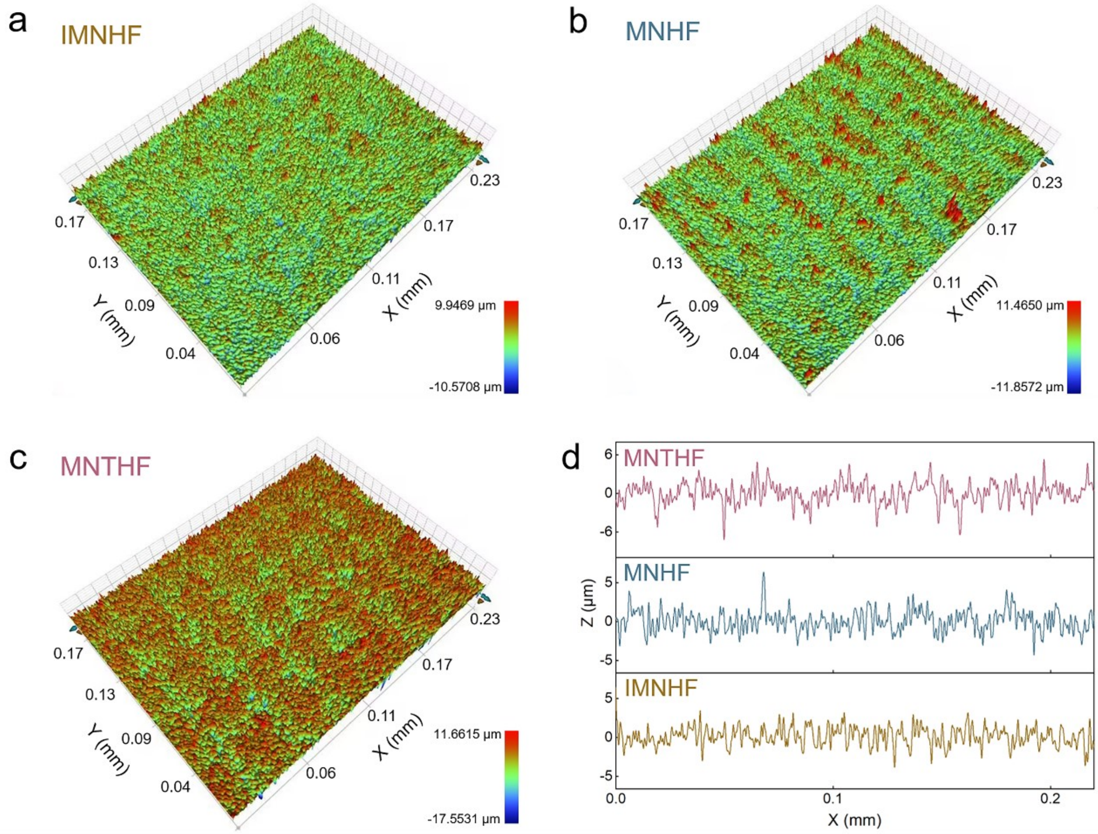

Fig. S3 The 3D surface topography of (a) IMNHF, (b) MNHF, and (c) MNTHF. (d) Cross section profiles of IMNHF, MNHF, and MNTHF.

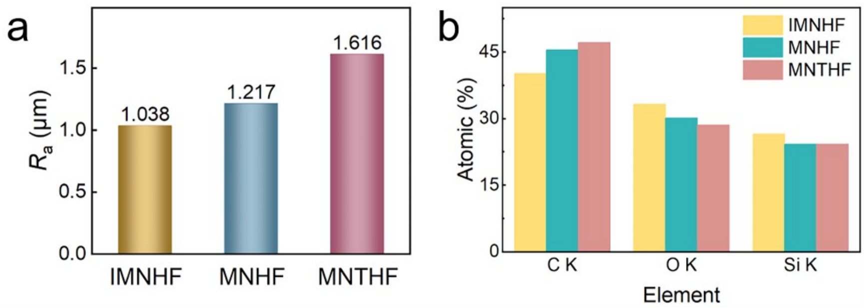

Fig. S4 (a) Roughness of IMNHF, MNHF, and MNTHF. (b) Element content analysis of IMNHF, MNHF, and MNTHF.

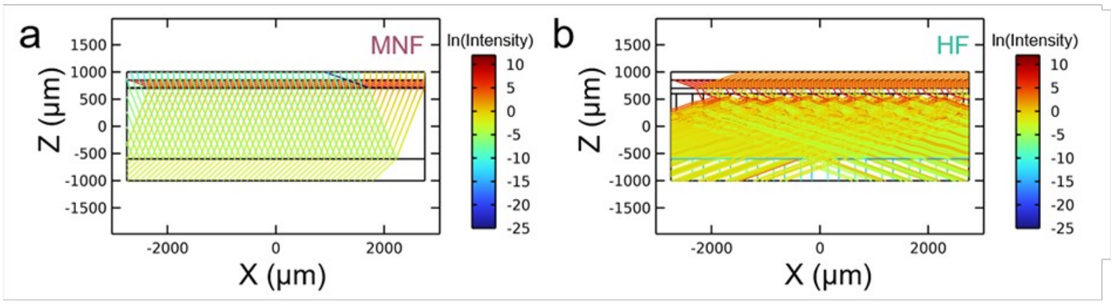

Fig. S5 (a) Ray-tracing simulation results of MNF surface. (b) Ray-tracing simulation results of HF surface.

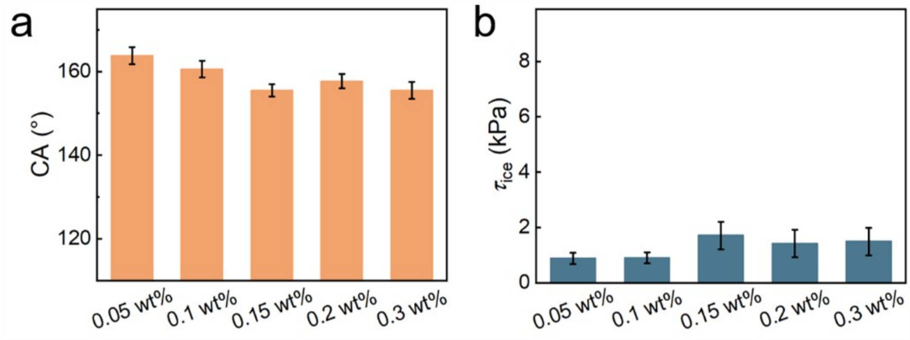

Fig. S6 (a) Effect of the concentration of MWCNTs on CAs. (b) Effect of the concentration of MWCNTs on ice adhesion strength.

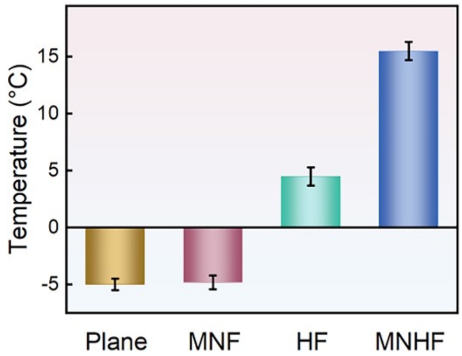

Fig. S7 Temperatures of Plane, MNF, HF, and MNHF surfaces at -10 °C for 10 min.

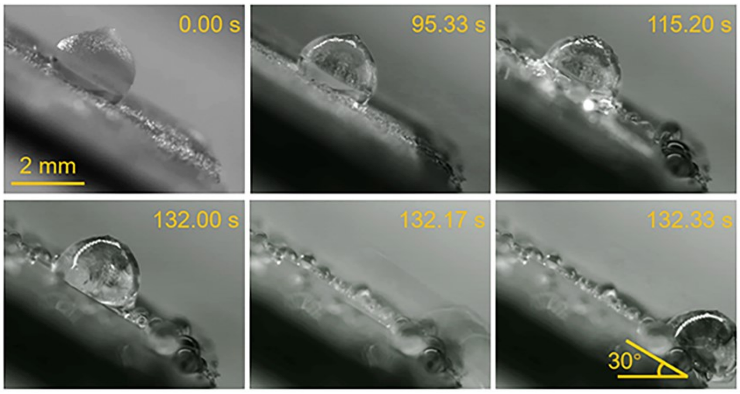

Fig. S8 Ice melting process on MNHF surface at 30° inclination.

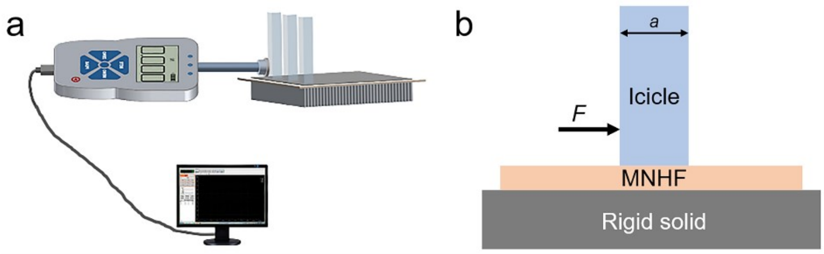

Fig. S9 (a) Ice adhesion strength measuring device. (b) Schematic diagram of measuring process.

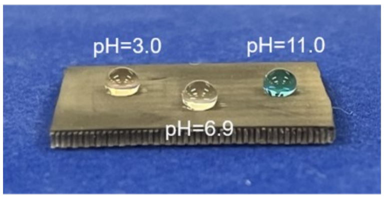

Fig. S10 Optical image of solutions with different pH on MNHF surface.

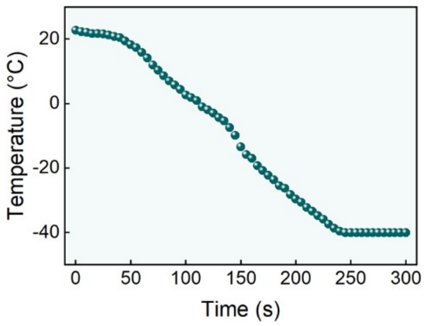

Fig. S11 The temperature changes of cooling table over time.

Table S1 The data related to calculation of photothermal conversion efficiency.

Parameters	Plane	MNF	HF	MNHF
T_s (°C)	53	62	61	63
ΔT (°C)	28	37	36	38
T_m (°C)	39	43.5	43	44
T (K)	312	316.5	316	317
P_r	0.733	0.733	0.733	0.733
N_u	6.054	6.382	6.349	6.413
Q (mW)	89.67	126.57	122.33	130.81
$\lambda\times10^2$ (W/m·K)	2.645	2.680	2.676	2.684
$v\times10^6$ (m^2/s)	17.50	17.95	17.90	18.00
$a\times10^6$ (m^2/s)	23.886	24.504	24.436	24.572
$\alpha_v\times10^3$ (K^{-1})	3.21	3.16	3.16	3.15
$G_r\times10^{-4}$	2.155	2.665	2.607	2.713
h (W/m^2·K)	8.006	8.552	8.495	8.606
η (%)	22.42	31.64	30.58	32.70

Movie S1: Heat shrinkage process of porous PSM

Movie S2: Photothermal deicing processes of MNHF, MNF, and HF

Movie S3: Liquid droplet returns to Cassie state under light conditions

Movie S4: Ice melting process on MNHF surface at 30° inclination

Movie S5: Self-cleaning experiment

Reference

1 Z. Xie, H. Wang, M. Li, Y. Tian, Q. Deng, R. Chen, X. Zhu and Q. Liao, *Chem. Eng. J.*, 2022, **435***,* 135025.