Supporting Information

A High-Thermal-Conductivity Composite Film for Encapsulation and Passive Cooling of Solar Modules

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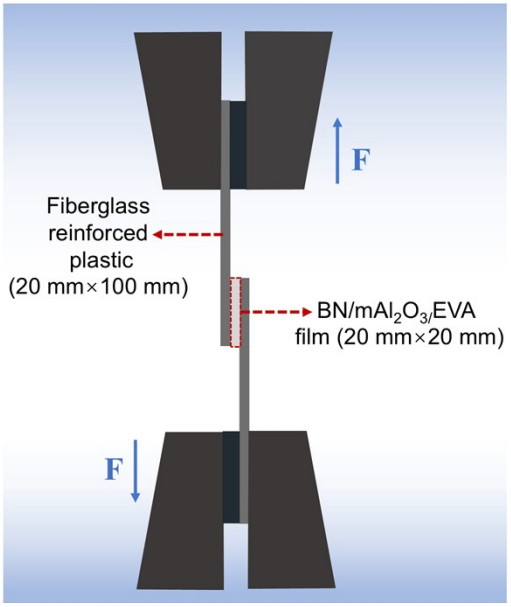

Fig. S1 Schematic diagram of the test specimen for the shear strength of the composite film and fiberglass-reinforced plastics.

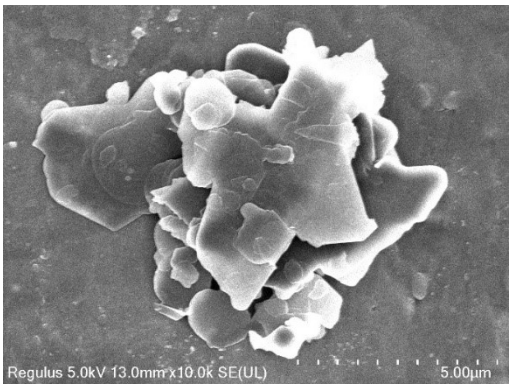

Fig. S2 SEM image of h-BN.

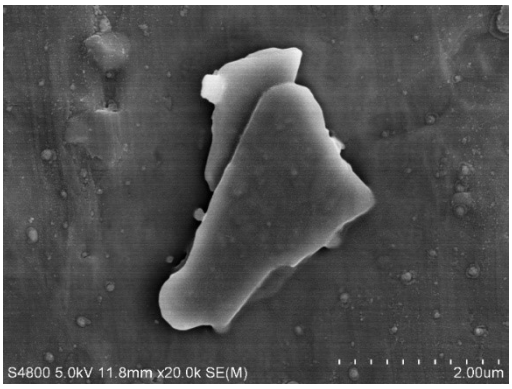

Fig. S3 SEM image of exfoliated BN.

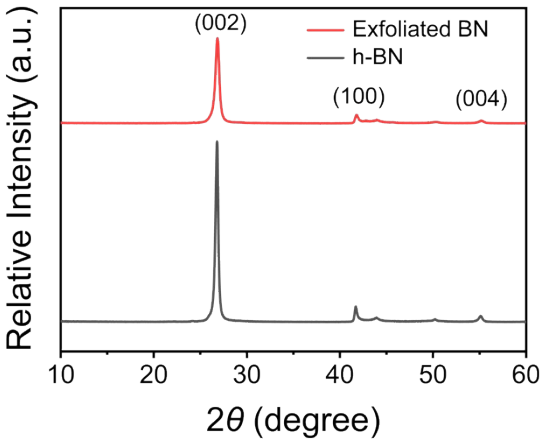

Fig. S4 XRD patterns of h-BN and Exfoliated BN.

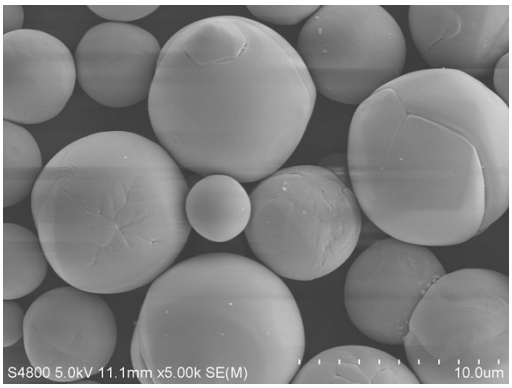

Fig. S5 SEM image of Al_2O_3.

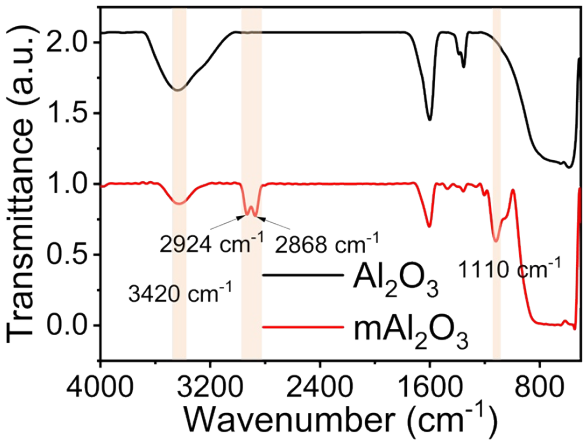

Fig. S6 FTIR spectra of Al_2O_3 and mAl_2O_3.

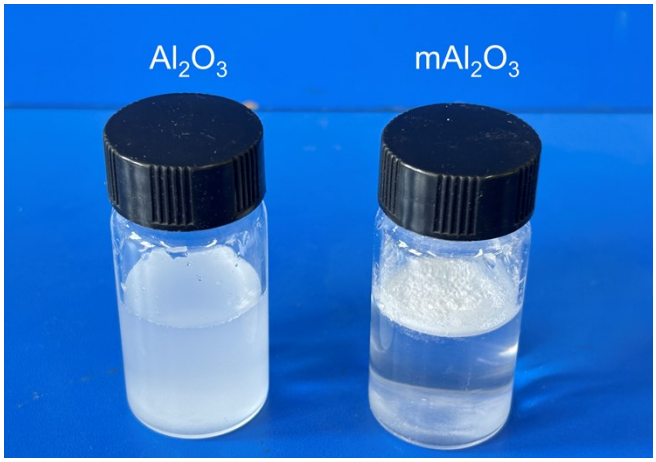

Fig. S7 Optical photographs comparing the states of Al_2O_3 and mAl_2O_3 in water, respectively. The mAl_2O_3 particles are floating above the water, indicating excellent hydrophobicity.

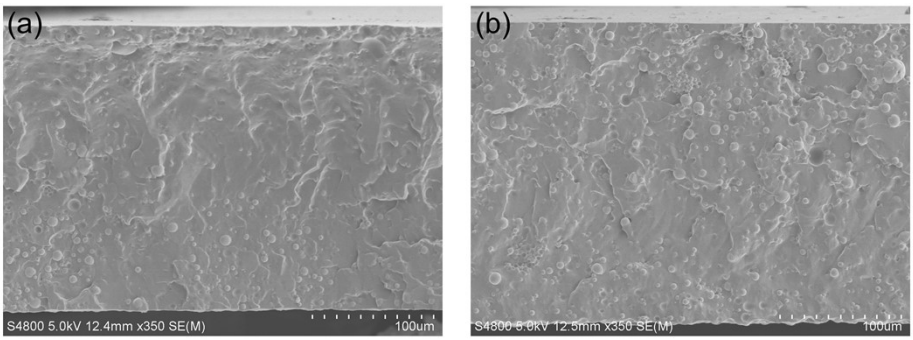

Fig. S8 SEM images of (a) Al_2O_3/EVA and (b) mAl_2O_3/EVA.

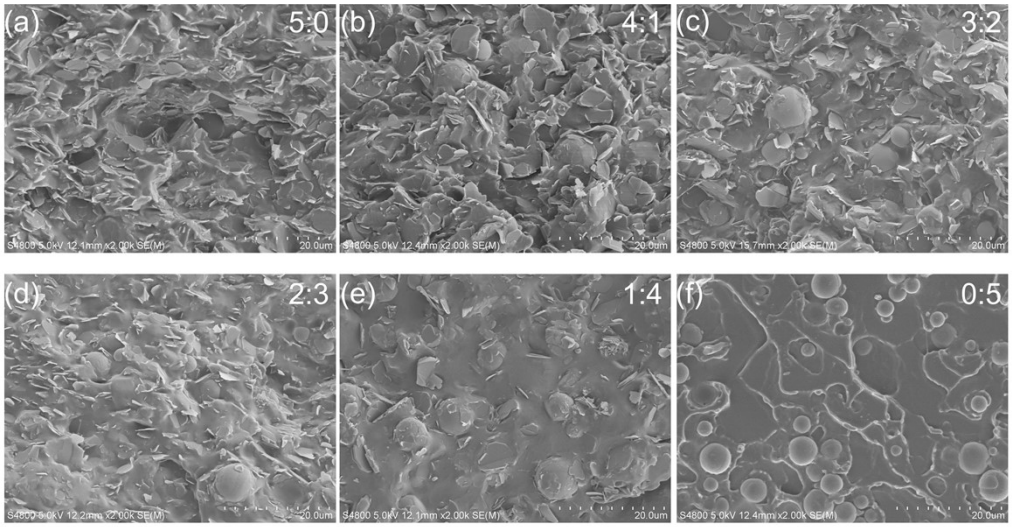

Fig. S9 Cross-sectional SEM images of BN/mAl_2O_3/EVA film with different mass ratio: (a) 5 : 0, (b) 4 : 1 (c) 3 : 2, (d) 2 : 3, (e) 1 : 4, (f) 0 : 5.

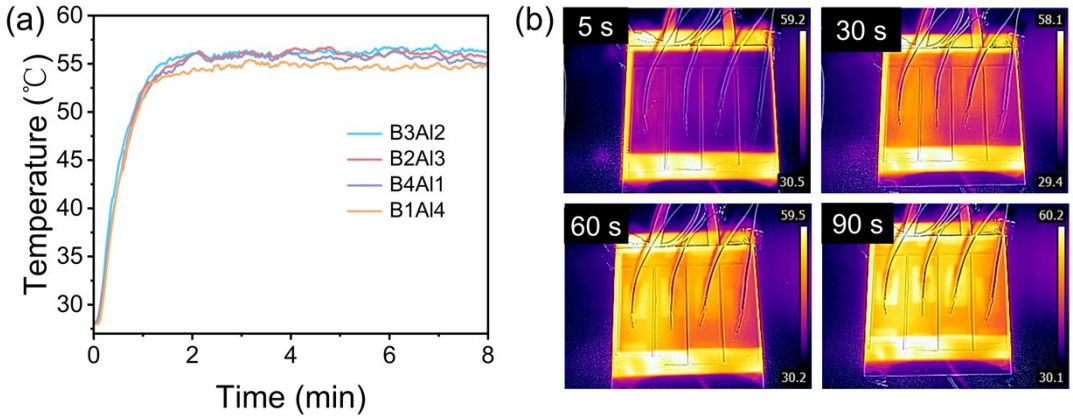

Fig. S10 (a) Surface temperatures changes with heating time of the original B3Al2, B2Al3, B4Al1and B1Al4 films on the hot stage; (b) Infrared thermal images of the corresponding films during the heating process from left to right, they are B3Al2, B2Al3, B4Al1 and B1Al4.

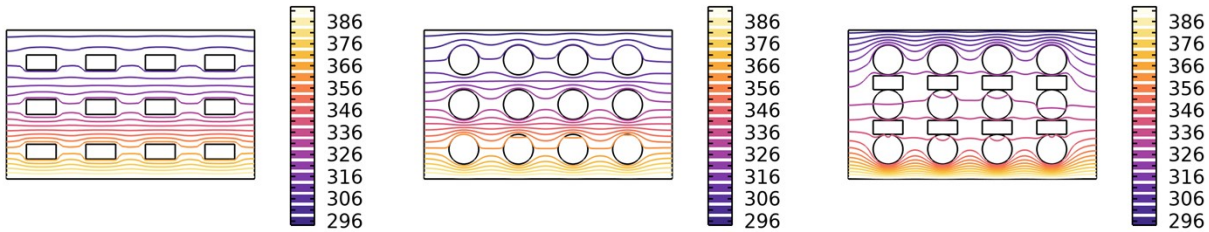

Fig. S11 Linear isotherms of BN/EVA, mAl_2O_3/EVA, and BN/mAl_2O_3/EVA composite films

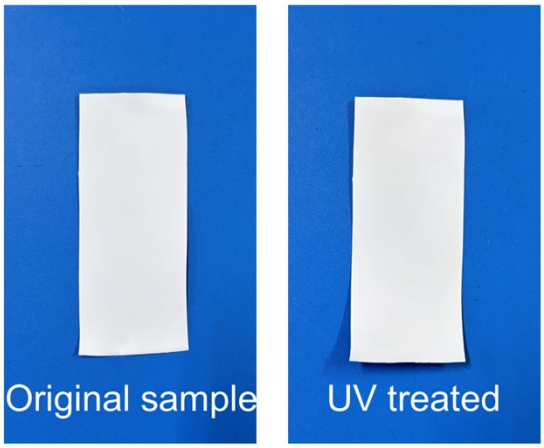

Fig. S12 Photos of the B3Al2 composite film before and after irradiation with ultraviolet light for 720 hours.

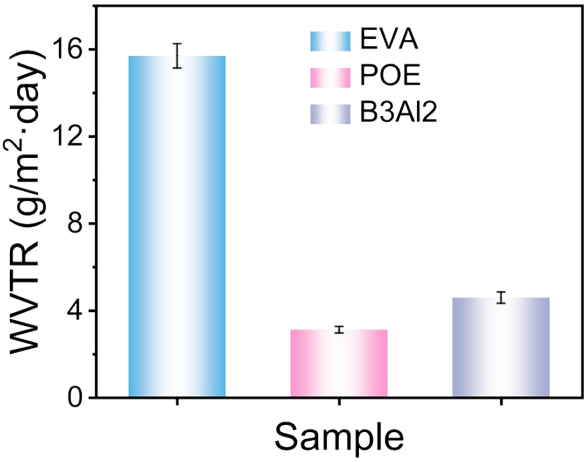

Fig. S13 Water Vapor Transmission Rates of the EVA, POE and B3Al2 films

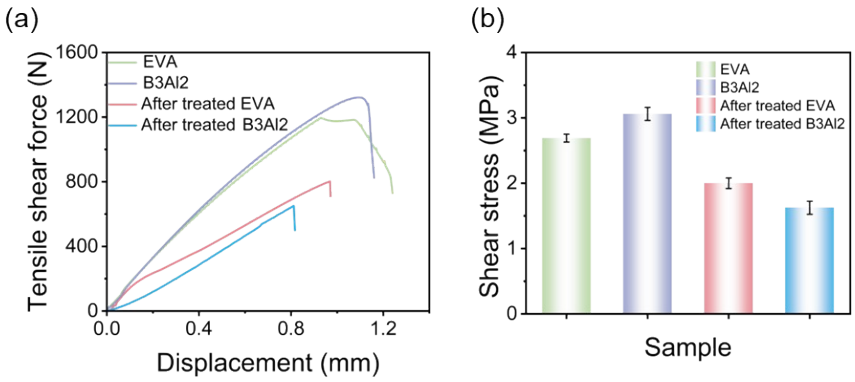

Fig. S14 The load-displacement curves (a) and shear strength (b) of the EVA and B3Al2 films before and after treatment of 720 hours of ultraviolet irradiation and 520 hours of treatment at 85℃ and 85% humidity.

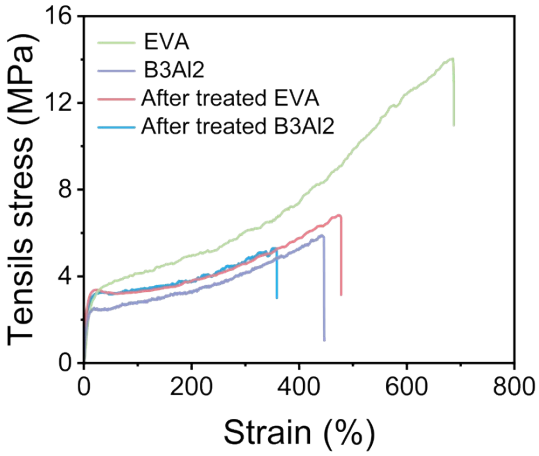

Fig. S15 The tensile stress-strain curves of EVA, B3Al2 films before and after treatment of 720 hours of ultraviolet irradiation and 520 hours of treatment at 85℃ and 85% humidity.

Table S1 Raw materials and their prices

Materials	Specification	Unit price (CNY/kg)
EVA particles	Photovoltaic grade, VA 28–33%	9
BN powder	Industrial grade, 99%, 1–3 μm	100
Al_2O_3 powder	Industrial grade, 99.5%, 1–5 μm，Silane modification	7.5

Table S2 Cost calculation of the pure EVA film and the BN/Al2O3/EVA film

Sample	EVA (kg)	BN (kg)	Al_2O_3 (kg)	EVA (CNY)	BN (CNY)	Al_2O_3 (CNY)	Total (CNY)
Pure EVA film	1	0	0	9	0	0	9
BN/Al_2O_3/EVA film	0.6	0.24	0.16	5.4	24	1.2	30.9

Note: Bulk procurement (≥10 tons, FOB China); total filler loading of the composite is 40 wt%; the mass ratio of h-BN to mAl_2O_3 is 3 : 2; The cost comparison only accounts for the main materials, namely the EVA matrix and inorganic fillers, and excludes processing fees, additives, taxes, profits, and other related expenses.

Table S3 The cooling methods and performance comparison of the BN/mAl_2O_3/EVA film with reported photovoltaic packaging materials or backsheet materials.

Samples	Heat dissipation method	Thermal conductivity		Emissivity (%)	Reflectance (%)	Tensile strength (MPa)	Cooling effect (℃)	Ref
		In-plane (W/m·K)	Out-of-plane (W/m·K)					
BN@EVA	Heat conduction	0.65	/	~ 30	68.4	~ 3	1-1.5	2
polyamide/aluminum/PET/PA	Heat conduction	13.53	0.38	/		/	1-2	3
biochar-based PCM	Heat conduction	1.10	/	/	/	/	/	4
BN-EVA	Heat conduction	0.75	/	/	/	/	0.7	5
BN/LiBr/PVA	Radiative/Evaporative	4.3	/	94	92	0.221	3-9	6
EVA+ZnO	Heat conduction	0.8	/	/	/	/	1.7	7
TPX/SiO_2	Heat radiation	/	/	85.6	/		1	8
BN/mAl_2O_3/EVA	Heat conduction/ Radiation/Light refection	2.71	1.01	85.48	85.38	6	2.2	This work

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