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Thermally conductive h-BN/polymer composites for heat management in textiles

2DWEB

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Background

❑ General background

- Heat stress affects personal health and curtails work productivity. Clothing is important to regulation of personal thermal comfort at different environmental conditions, via heating or cooling.

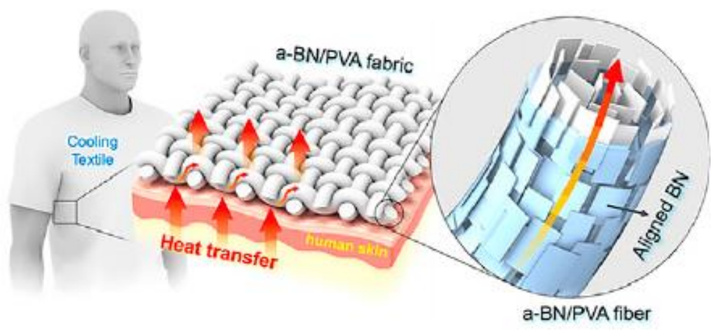

Figure 1: Structure illustration of a designed cooling textile, image reproduced from REF [1].

Textile materials with **high thermal conductivity** are ideal for **personal cooling** by accelerating the heat dissipation between the human body and hot atmosphere via thermal conduction [1].

Motivations & Materials

❑ Hexagonal boron nitride (h-BN) is a prime candidate as a heat-conductive material for next-generation electronics with high performance or passive heat-regulating textiles [4]

- **H-BN shows excellent in-plane thermal conductivity:**
  370 W m^{-1} K^{-1} for bulk [2];
  751 W m^{-1} K^{-1} for a single layer [3].
- **H-BN is usually included as a thermally conductive filler in polymers** [5]. Commercial heat-conductive dielectrics [6] usually have a thermal conductivity of 0.8 to 4.2 W m^{-1} K^{-1}.

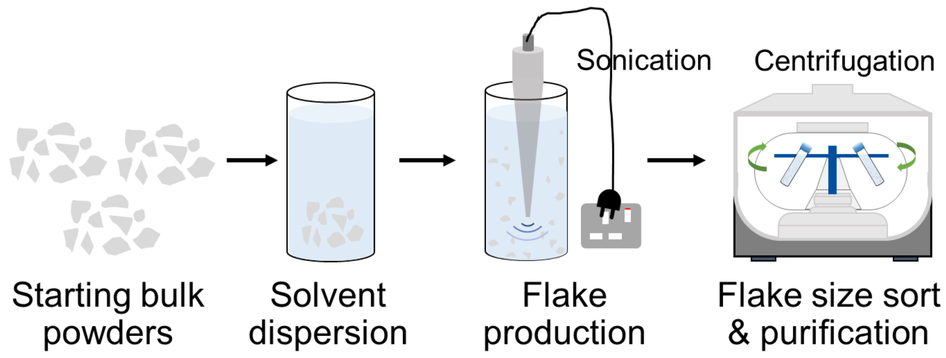

Figure 2: Step-by-step ultrasonication-assisted liquid phase exfoliation.

❑ 2D few-layer flakes of h-BN can be obtained by ultrasonication-assisted liquid phase exfoliation

Characterization

❑ Raman & AFM characterization show the successful exfoliation of bulk h-BN powders into few-layer flakes

The Raman shift of 1364 cm^{-1} showed our h-BN flakes are few-layer thick;

AFM statistical analysis: the lateral size and the thickness of the exfoliated h-BN flakes follow a log-normal distribution, which were peaked at 338 nm and 6.0 nm, respectively.

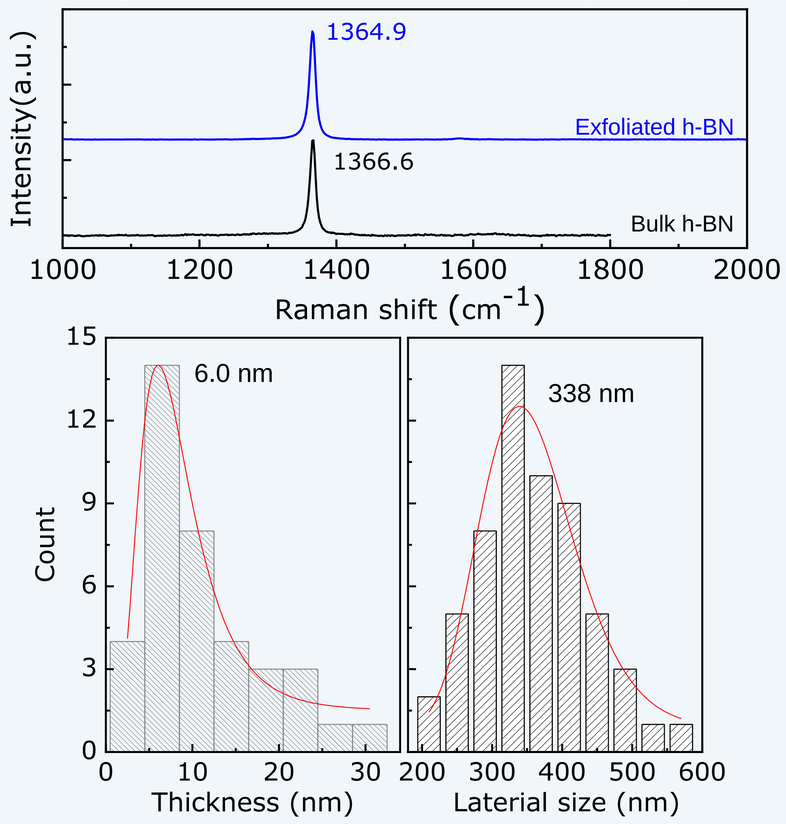

Figure 3: Raman (top) and AFM (bottom) characterization of exfoliated h-BN flakes.

Thermal conductivities of h-BN composites

❑ Increasing the h-BN mass fraction increases the overall thermal conductivity value of the composite

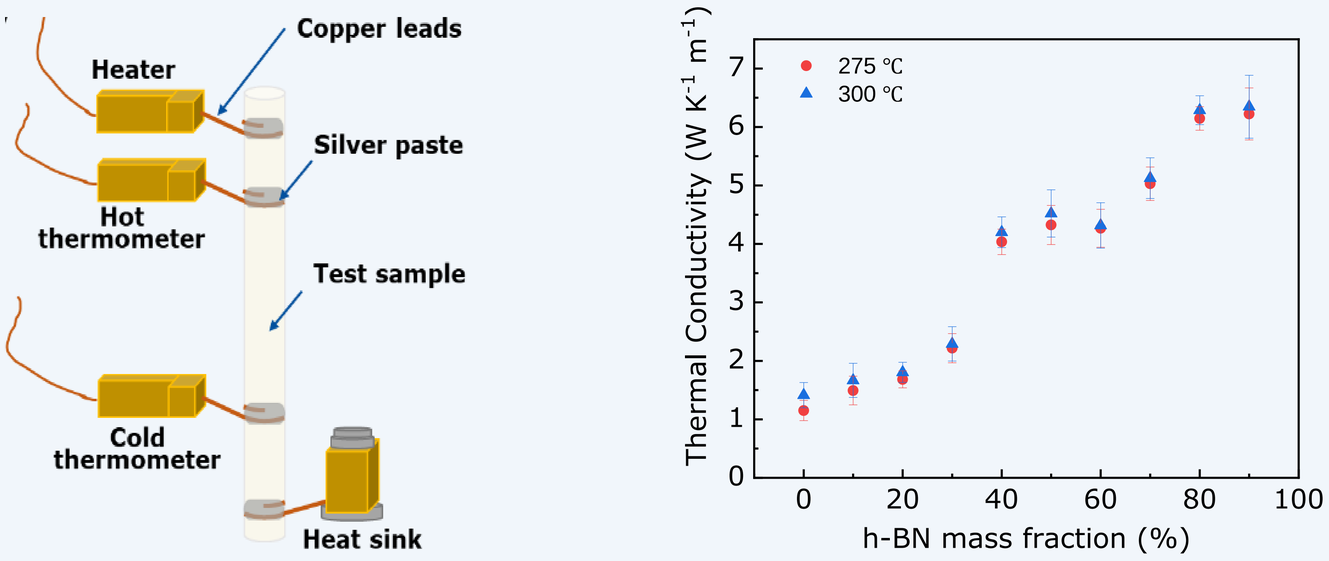

Figure 4: Left - illustration of the thermal experimental setup; Right - thermal conductivities of the composites with varying mass fractions of h-BN.

$$P_{\text{heater}} = P_{\text{cond}} + P_{\text{non-cond}}$$

$$P_{\text{non-cond}} = P_{\text{rad}} + \kappa_{\text{loss}} \Delta T_{\text{loss}}$$

$$P_{\text{cond}} = -\kappa A \frac{\mathrm{d}T}{\mathrm{d}x}$$

Sample	Thermal conductivity
60% Bulk BN	4.2 W m^{-1} K^{-1}
61% Exfoliated BN	21.7 W m^{-1} K^{-1}
Improvement	416.7%

Discussions:

1. The larger the mass fraction of thermally conductive h-BN is, the more the contact points and heat release paths among the fillers may be. Thus, the generation of heat can be released more efficiently.
2. Being added exfoliated h-BN flakes, the thermal conductivity of the composite was improved.

H-BN coated textile for thermal tests

❑ A h-BN coated textile: h-BN/polymer inks were drop casted on a textile

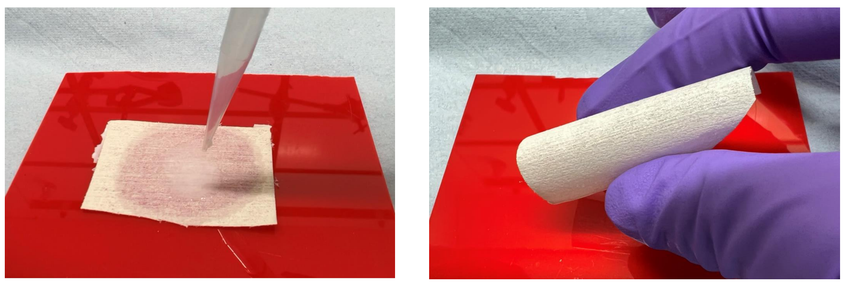

Figure 5: Left - h-BN/polymer ink was drop casted on a textile; Right - flexibility of the textile after being coated.

A textile was drop casted by the h-BN/polymer ink and dried overnight at the ambient temperature. The textile remains flexible after the coating. The successful coating of h-BN/polymer film may generate high thermally conductive paths, which will be tested by a customized temperature management setup in labs.

Conclusions & Reference

- The composites with bulk h-BN powders have improved thermal conductivities (up to 6.5 W m^{-1} K^{-1}) than the composites with only polymers (1.1 W m^{-1} K^{-1}) .
- The exfoliation of bulk h-BN powders into delaminated few-layer h-BN flakes further improves the overall thermal conductivity of the composite to 21.7 W m^{-1} K^{-1}.
- H-BN coating on the textile is successful and adds additional thermal conducting paths on the textile.

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