Effect of the additive amount of nano carbon black on thermal insulating performance of fumed silica VIP

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VIP

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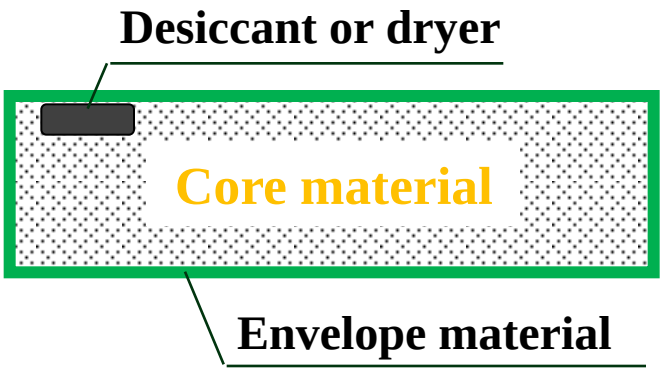
1. Introduction – Basic information



Novel and high-efficient thermal insulation material.

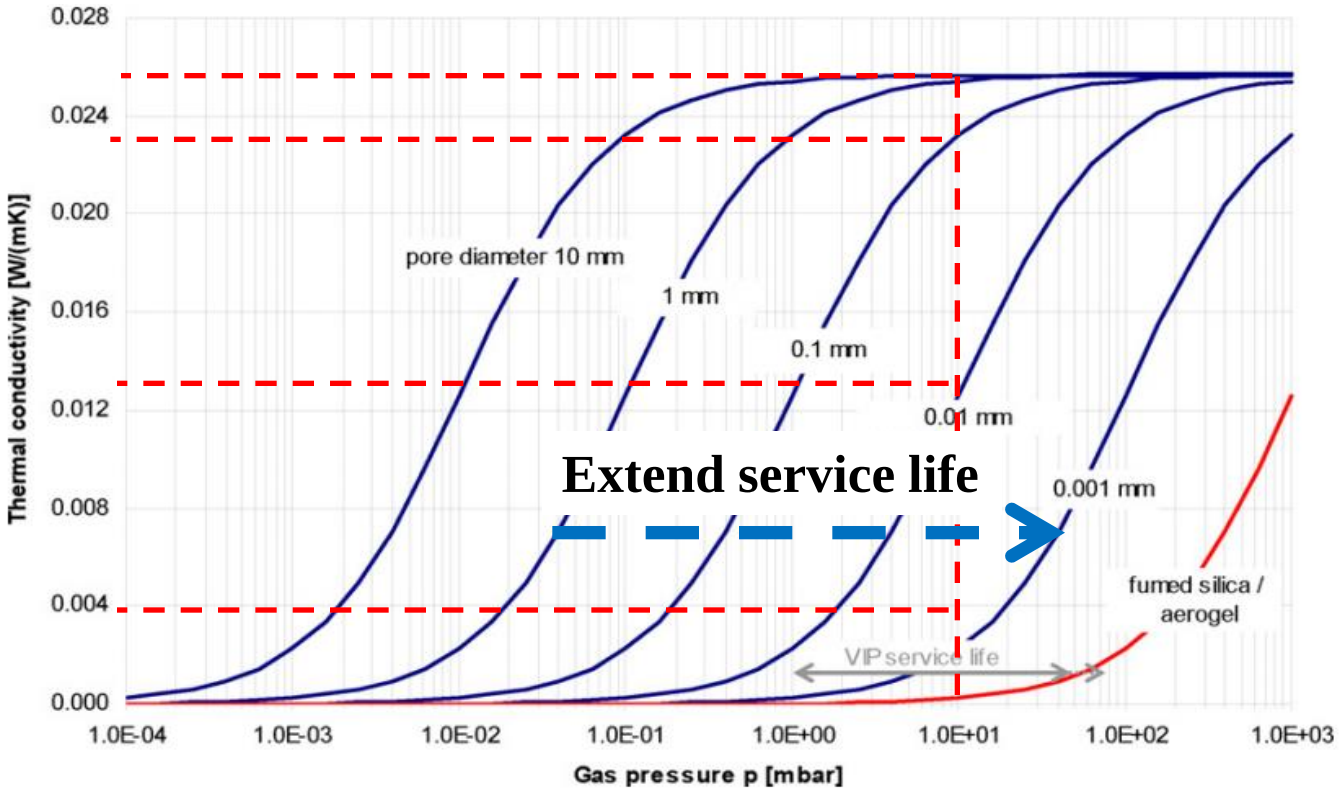
$$\lambda_{VIP} \leq \frac{1}{2}\lambda_{air}$$

High-quality VIP
- **Low thermal conductivity**
- **Long service life**

High-vacuum-state

Core material greatly influences the performance of VIP.

1. Introduction – Gas pressure vs. thermal conductivity



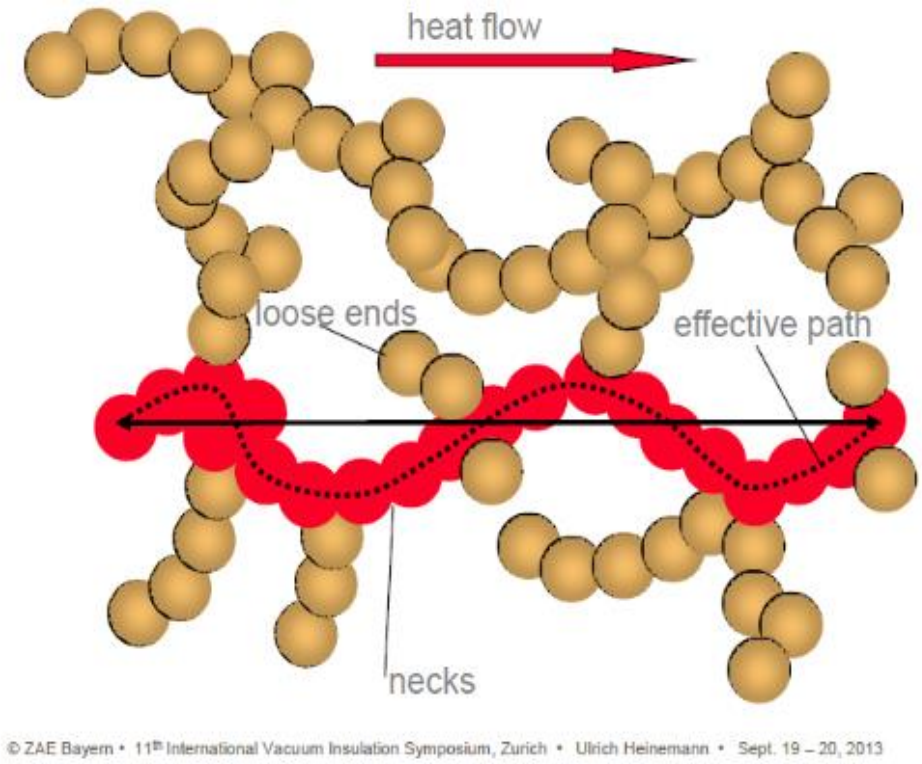
Decrease the pore size

Low thermal conductivity
at atmospheric pressure
and primary vacuum

Long service life
Building sectors
≥ 50 years

1. Introduction – Fumed silica

Fumed silica:



Characteristics:

Particle diameter: 5-50 nm;

Porosity: 80-99.9%;

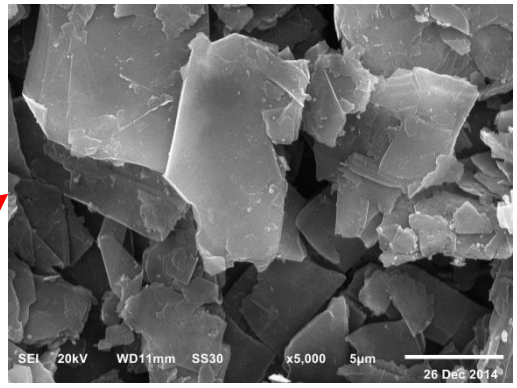
Thermal conductivity: 3-8 mW/(mK).

Disadvantage:

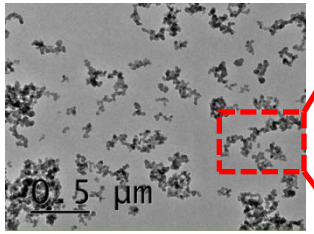
weak adsorption and scattering for infrared thermal radiation.

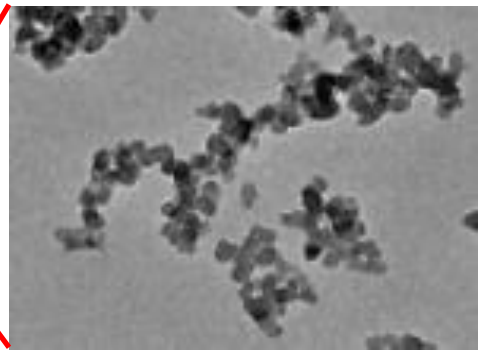
1. Introduction – Carbon black

Carbon black:



Micro carbon black





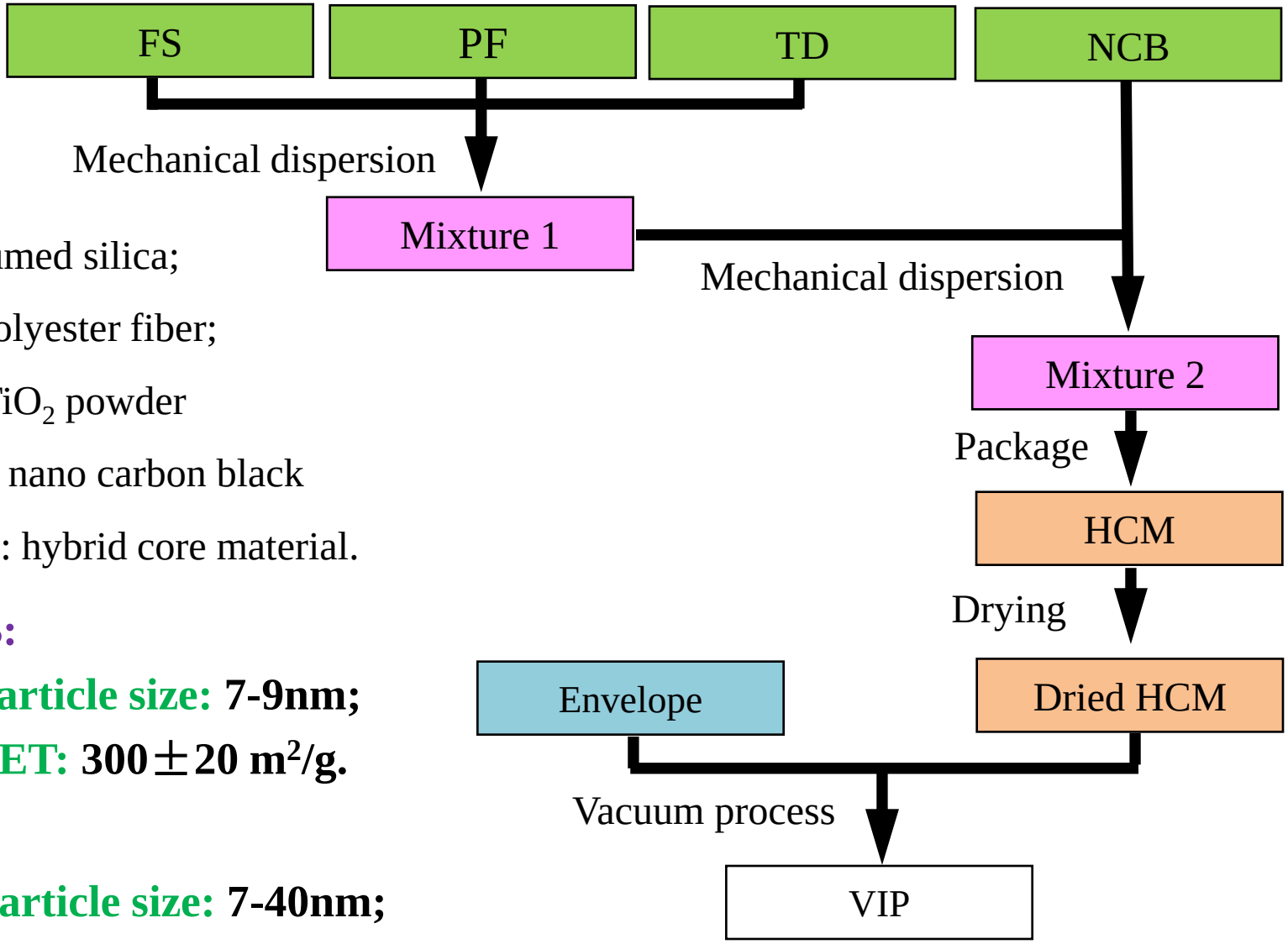
Nano carbon black

Function of carbon black:

(1) Opacifier: reduce the λ_{rad};

(2) Absorbent: absorb moistures and gases.

2. Fabrication method



- **FS**: fumed silica;
- **PF**: polyester fiber;
- **TD**: TiO_2 powder
- **NCB**: nano carbon black
- **HCM**: hybrid core material.

NCB:

(1) Particle size: 7-9nm;

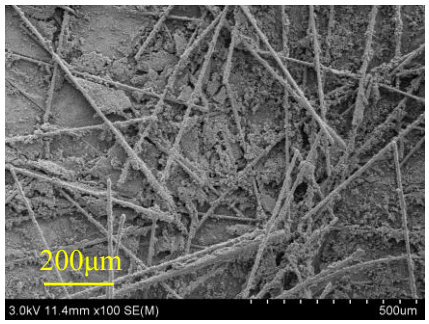
(2) BET: 300±20 m^2/g.

FS:

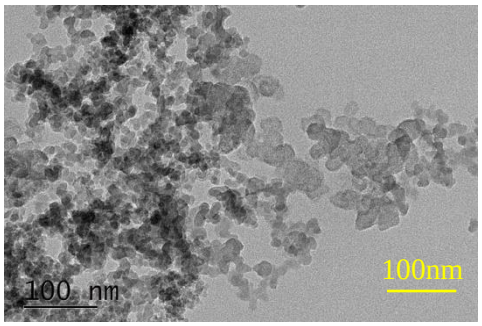
(1) Particle size: 7-40nm;

(2) BET: 150±10 m^2/g.

3. Microstructure – Microscopic photos and BET analysis



(a) SEM, ×100



(b) TEM

Fig.1 Microstructure of core material

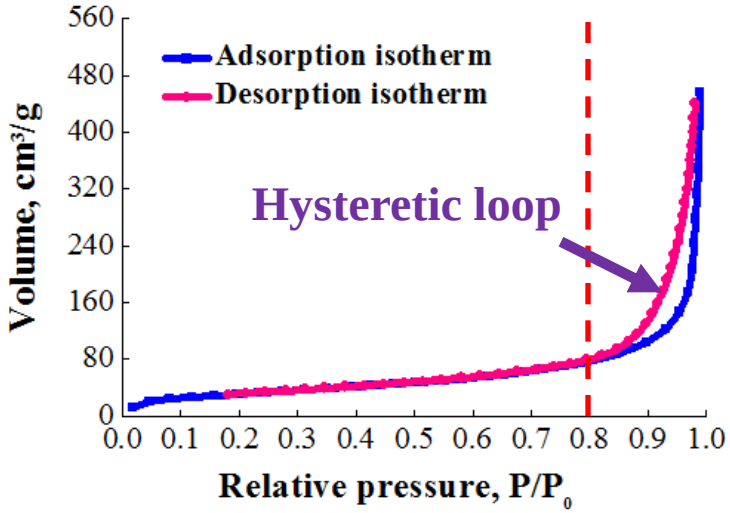


Fig. 2 Nitrogen adsorption and desorption isotherms of HCM.

Typical type-IV curve: indicating a large amount of mesopores.

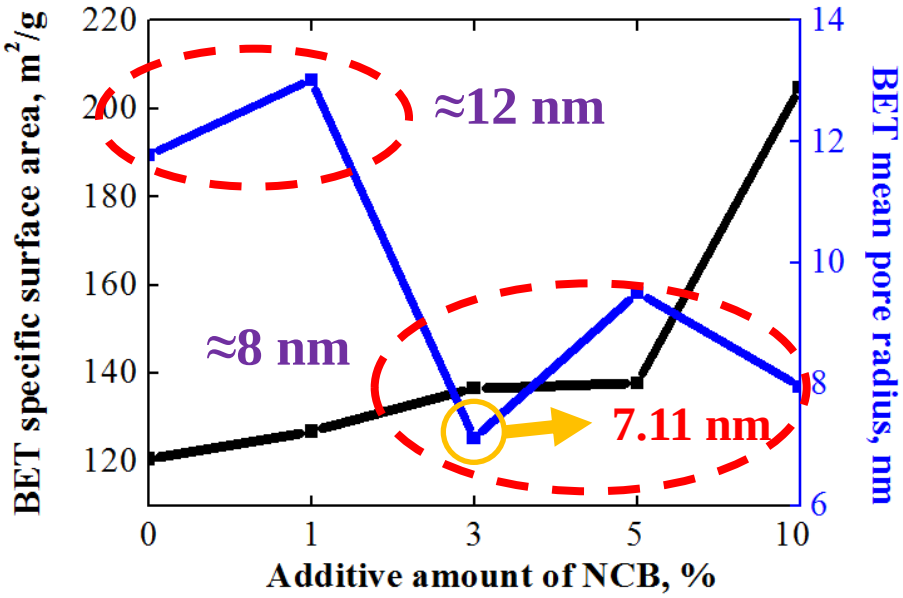


Fig. 3 BET specific surface area and pore radius of HCMs.

4. Thermo-physical property – Density

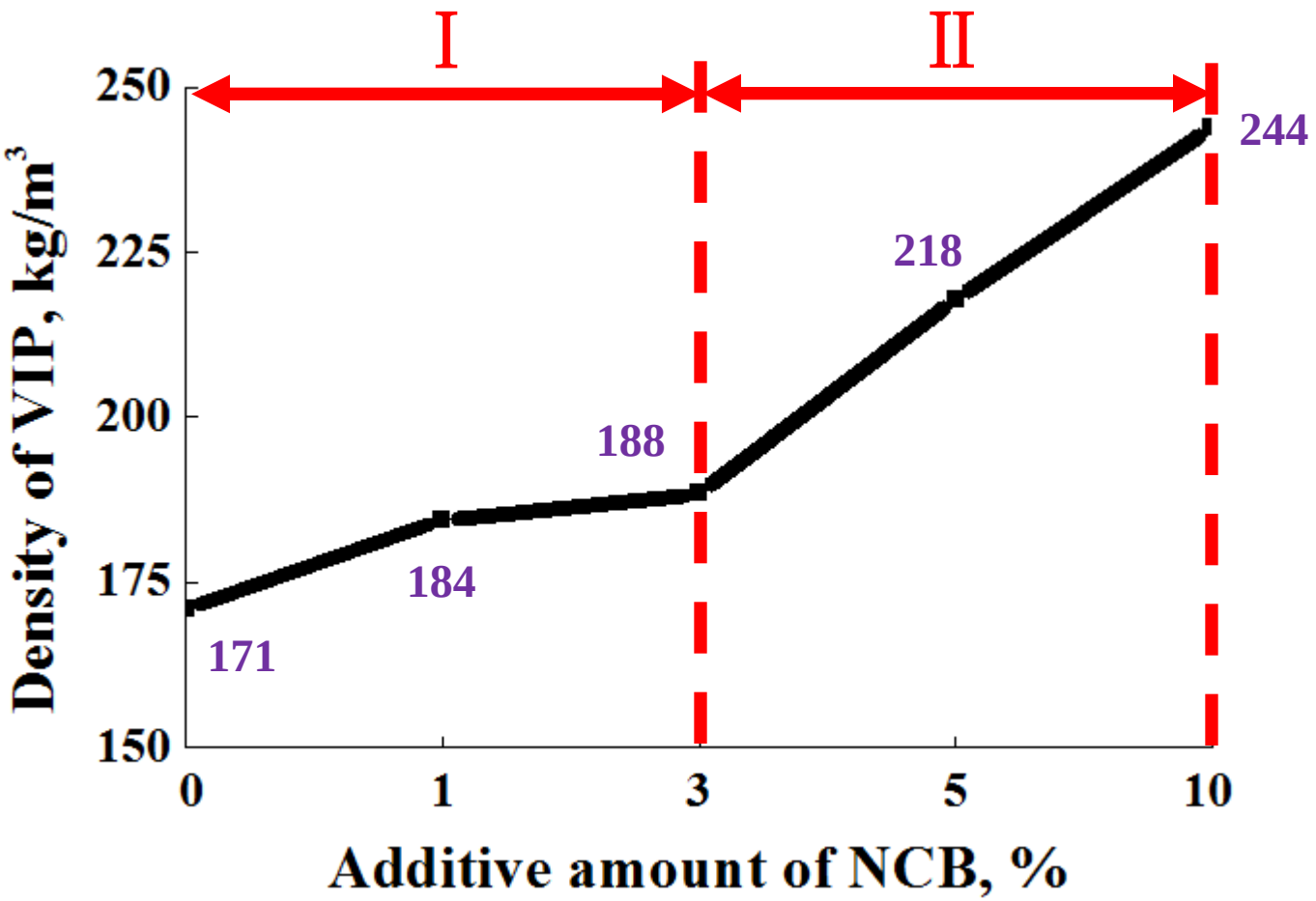
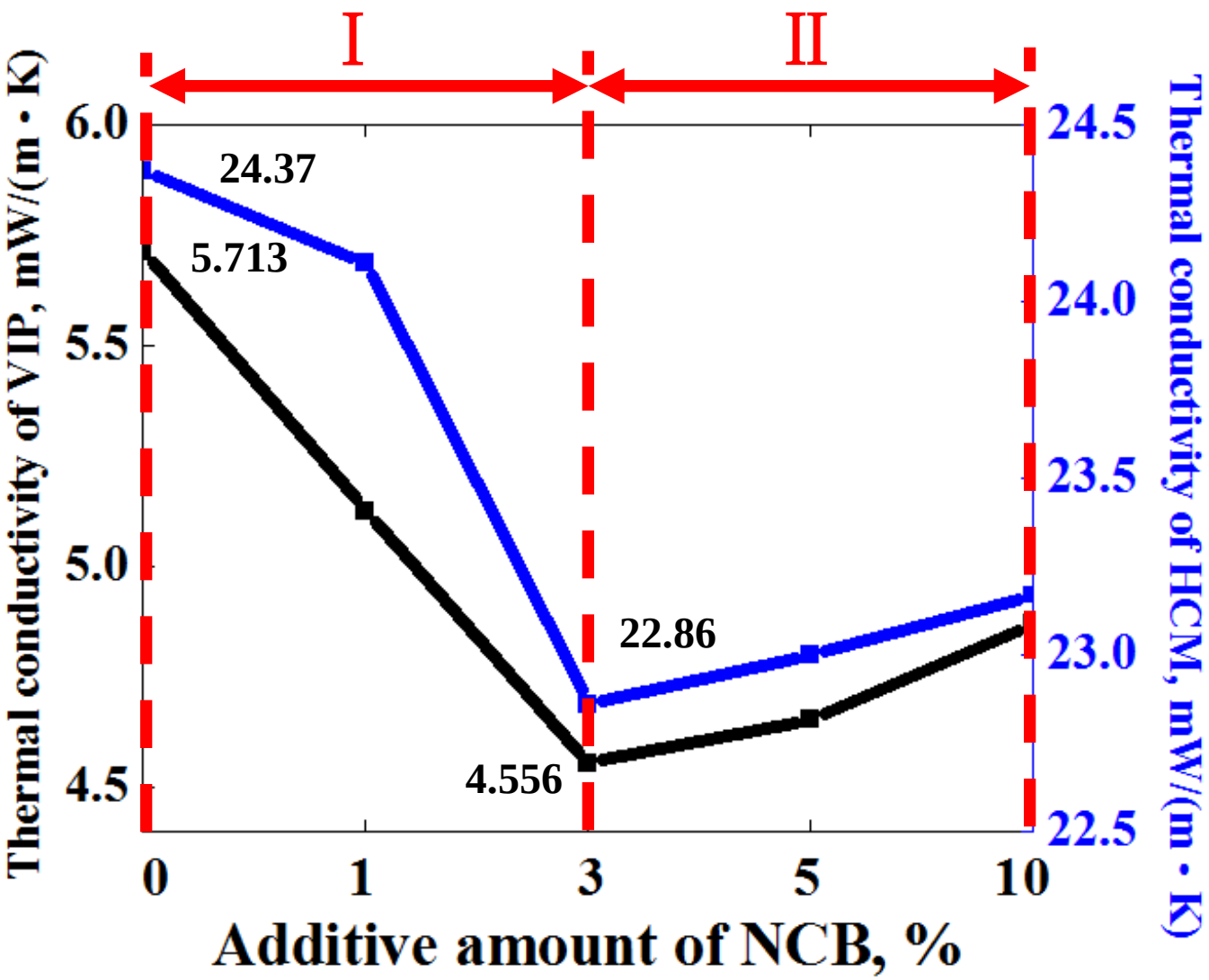


Fig. 4 Density of VIPs as a function of additive amount of NCB.

(1) When NCB content ≤ 3%, the density of VIPs was 170-190 kg/m^3.

(2) When NCB content > 3%, the density of VIPs increased significantly.

4. Thermo-physical property – Thermal conductivity



NCB

(1) Absorb and scatter infrared thermal radiation.

(2) Further adsorb the gases and moisture.

(3) Increase the solid thermal conduction.

Fig. 5 Thermal conductivity of HCM and VIP.

4. Thermo-physical property – Ageing

Ageing condition: 80 °C and 80% R.H.

Panel size: 350 mm × 190 mm × 15 mm

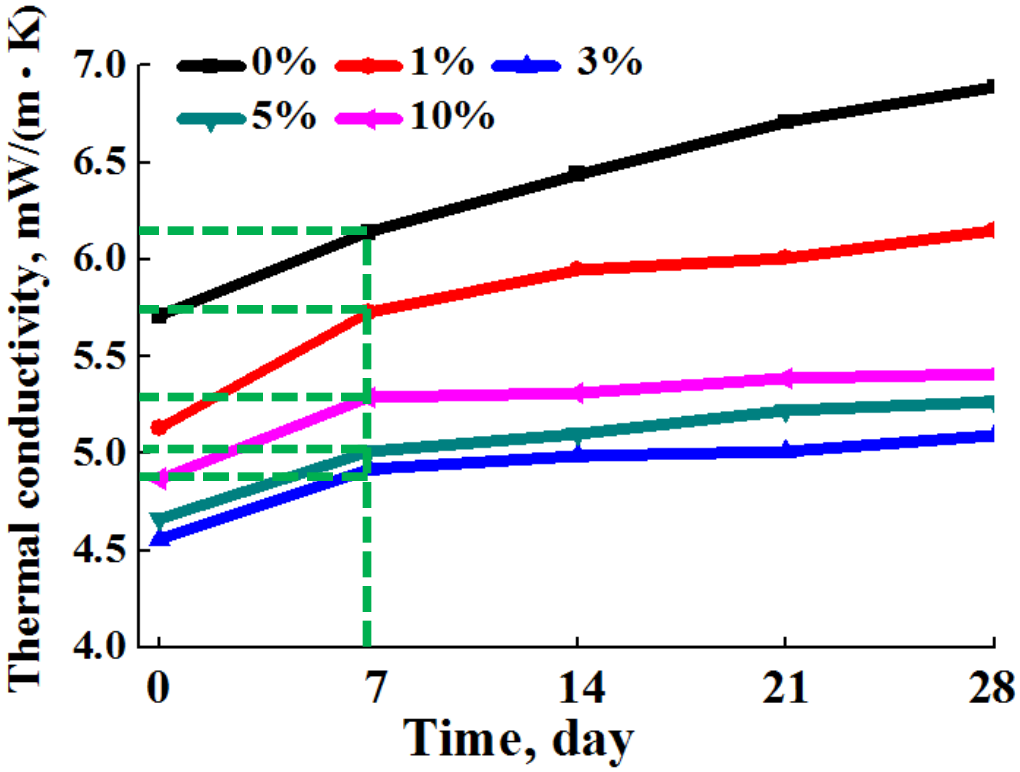


Fig. 6 Ageing curve of VIPs.

❖ **Reason of deterioration in λ_{tot} :**

Pressure increase and moisture accumulation in core material.

❖ **NCB absorb the moisture and gases inside the VIP.**

(1) Maintain λ_{tot} of aged VIP in a low value;

(2) Slow down the ageing process.

5. Conclusions & outlooks

Conclusions:

(1) The addition of NCB modified the pore structure of HCMs; the smallest average pore size was reached when NCB content was 3%.

(2) NCB content was ≤ 3%: density slightly increased; NCB content was > 3%: density dramatically increased.

(3) In order to decrease the thermal conductivity and extend service life of the VIPs, the optimum additive amount of NCB was 3%.

Outlooks:

(1) The effect of NCB with different particle size and aggregation state on thermo-physical properties and moisture adsorption rate of HCMs should be further investigated.

(2) The thermal transport mechanism within the multi-component HCMs should be well investigated.

Reference

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Thank You