Glass fiber reinforced hollow silica nanospheres for thermal insulation applications

Tao Gao

Department of Civil and Transport Engineering
Norwegian University of Science and Technology (NTNU)
Outline

➢ Background
  o Buildings & energy efficiency
  o Superinsulation materials/solutions

➢ Nano insulation materials
  o Silica aerogels
  o Hollow silica nanospheres (HSNSs)

➢ Fiber reinforced HSNSs
  o Synthesis
  o Properties

➢ Conclusions
Energy & buildings

U.S. Energy Consumption by Sector

- Buildings: 49%
- Industry: 23%
- Transportation: 28%

Source: US Energy Information Administration (2011)
Energy use in buildings

Residential Buildings
Primary Energy End Use Splits (2010)

Commercial Buildings
Primary Energy End Use Splits (2010)
Factors influencing the energy use

- Climate
- Building envelope
- Building equipment

+ Operation & Maintenance
- Occupant behavior
- Indoor environmental conditions
Energy transfer through the building envelope

It is important to improve the energy performance of building envelope (wall, window, roof, etc.).
Thermal insulation is very important!

Thermal insulation materials/components are critical to building’s energy efficiency.
Thermal insulation materials/solutions

- U-value: 0.1 W/m²K
- Stone facade panel; well-ventilated air gap; low-lambda EPS; VIP; low-lambda EPS; solid concrete wall; plaster
- Brickwork; mineral wool insulation; lightweight blockwork; cavity + dabs; plasterboard
Thermal insulation of today

- **Traditional Insulation**
  - ~ 36 mW/(mK)

- **Vacuum Insulation Panels (VIPs)**
  - ~ 4 mW/(mK)  fresh
  - ~ 20 mW/(mK)  perforated

- **Gas-Filled Panels (GFPs)**
  - ~ 40 mW/(mK)

- **Aerogels**
  - ~ 15 mW/(mK)  (monolithic)

- **New materials and solutions**
Nano insulation materials

NIM

D

L

0.5 μm

IVIS2015, Nanjing, China
Nano insulation materials - synthesis

Nano insulation materials - synthesis

Polystyrene nanoparticles

Hollow SiO$_2$ nanospheres

coated with SiO$_2$

remove PS cores
Nano insulation materials - synthesis

Dimension

Surface
## Nano insulation materials - property

<table>
<thead>
<tr>
<th>Material</th>
<th>Outer diameter (nm)</th>
<th>Layer thickness (nm)</th>
<th>Thermal conductivity (W/mK)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid SiO₂</td>
<td>~ 300</td>
<td>-</td>
<td>0.089</td>
</tr>
<tr>
<td>Hollow SiO₂-Etching</td>
<td>~ 300</td>
<td>~ 50</td>
<td>0.067</td>
</tr>
<tr>
<td>Hollow SiO₂-PAA</td>
<td>~ 50 – 300</td>
<td>~ 10</td>
<td>0.045</td>
</tr>
<tr>
<td>Hollow SiO₂-PS</td>
<td>~ 150</td>
<td>~ 15</td>
<td>0.020</td>
</tr>
<tr>
<td>Aerogel</td>
<td>-</td>
<td>-</td>
<td>0.015</td>
</tr>
</tbody>
</table>
Nano insulation materials - improvement

HSNS powder

Fiber reinforced HSNS NIM

Glass wool

IVIS2015, Nanjing, China
Fiber reinforced HSNS NIM

<table>
<thead>
<tr>
<th></th>
<th>effective conductivity (mW/(mK))</th>
</tr>
</thead>
<tbody>
<tr>
<td>glass fibers</td>
<td>68</td>
</tr>
<tr>
<td>PS/SiO2-glass fibers</td>
<td>73</td>
</tr>
<tr>
<td>HSNSs-glass fibers (20 wt.%)</td>
<td>55</td>
</tr>
<tr>
<td>HSNSs</td>
<td>~ 37</td>
</tr>
</tbody>
</table>
Fiber reinforced HSNS NIM

Control of the fiber content, surface, diameter

Control of the HSNSs
Fiber reinforced HSNS NIM

1. Thermal insulation product

2. Core materials for vacuum insulation panels

Fumed silica \textit{(expensive)}

Glass fibers \textit{(high thermal conductivity)}
Conclusions

1. The HSNS NIM represents an interesting material system for thermal insulation applications.

2. Adding glass fiber reinforcement improves the workability of HSNS NIMs, also increases the thermal conductivity.

3. The performance of glass fiber reinforced HSNS NIMs needs to be further enhanced, e.g., by modifying the synthetic parameters.
Thank you!