NANO 112 Term Presentation - Thermally Insulative CNT Windows

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Motivation

Can’t see inside my refrigerator without opening it and letting heat in

To bring the fridge to regulated temperature, it’ll have to use a lot of energy to cool it back down.

Idea

THERMALLY INSULATIVE CNT WINDOWS

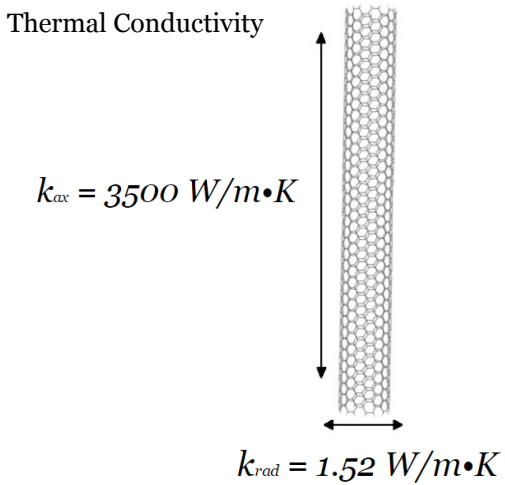
Aerogel (highly insulating) or silica (glass) substrate window, patterned with rows of CNTs.

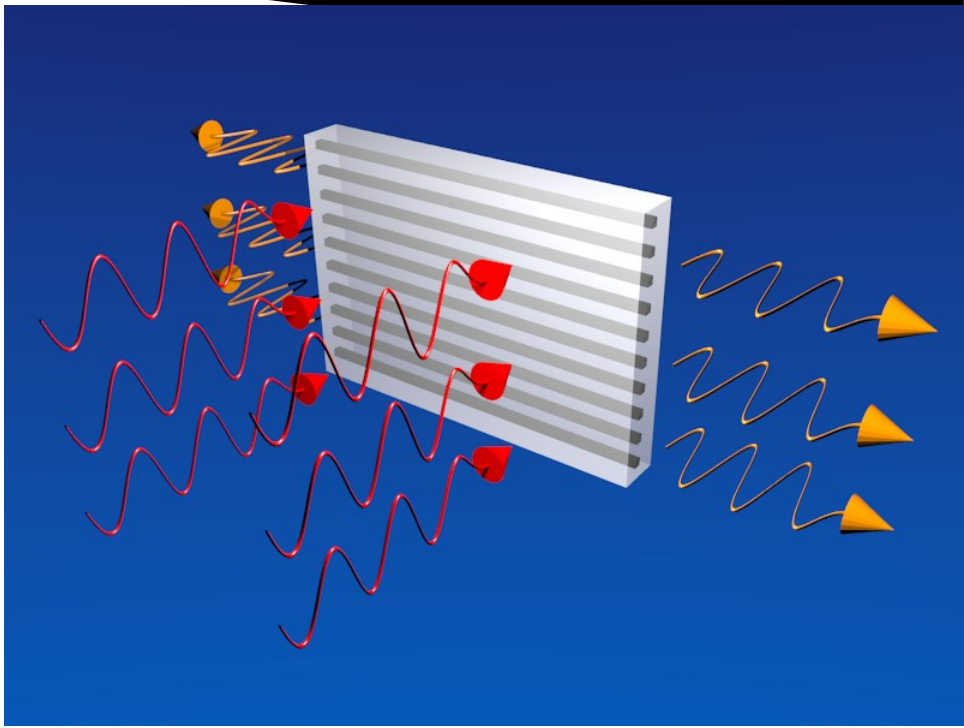
As long as they're spaced out larger than the wavelength light, we should be able to see through it

- Red has a wavelength of approx. 700 nm, so we space them at least 710 nm apart.
- Multiple light sources inside the fridge

Idea

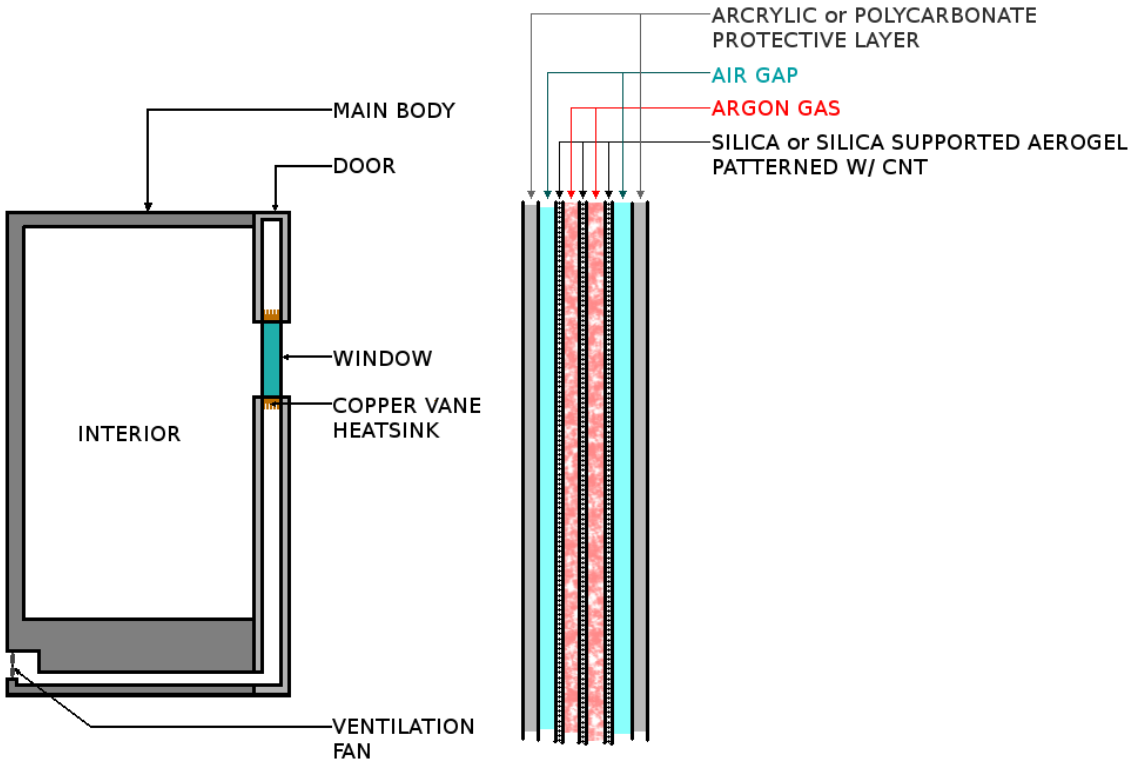
Incident heat that interacts with the CNT array is directed to the edges of window.





Design

- Low transmission of heat through the fridge door
  - Instead, the heat is conducted in plane with the door
  - Transmitted into copper heatsinks that border the window



Manufacturing

- Requirements
  - High throughput
  - Decent resolution (~700 nm)
    - Thinner trenches will need higher resolution
  - Autonomous manufacturing for production
  - Good alignment
    - Piezoelectric materials

Manufacturing

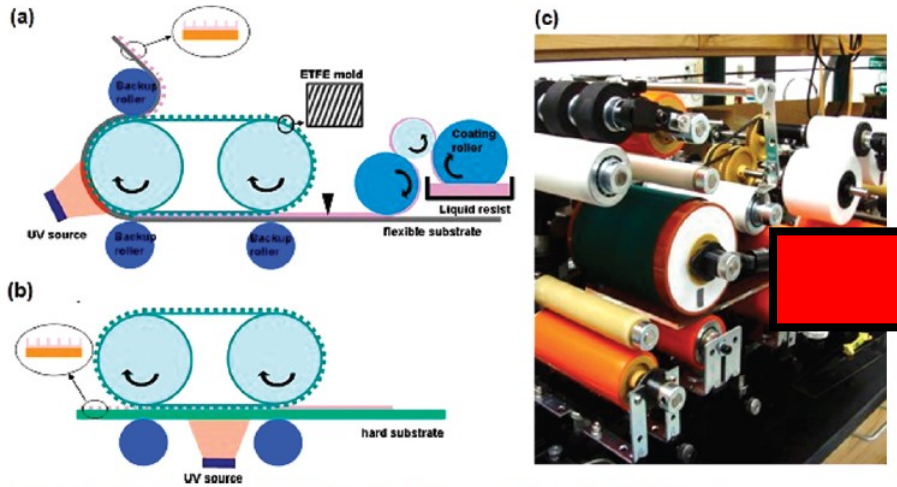


Figure 1. Schematics of (a) R2RNIL and (b) R2PNIL process. (c) Photograph of 6 in.-capable R2R/R2PNIL apparatus.

Ahn and Guo, ACS Nano 3(8):2304-2310, 2009.

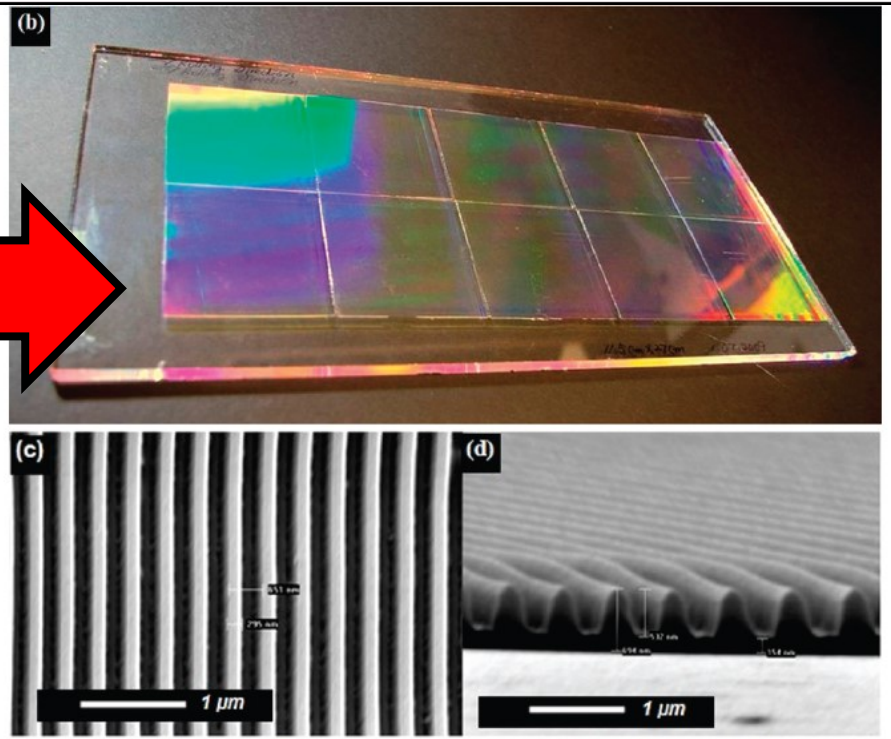
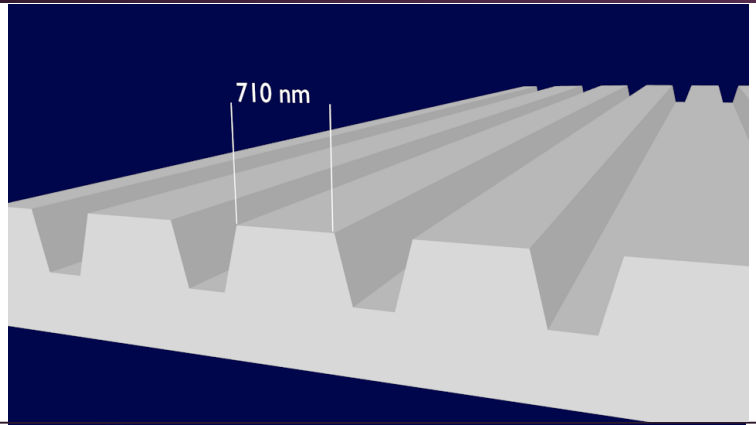


Figure 2. (a) A 4 in. wide, 12 in. long 700 nm period epoxysilicone pattern on flexible PET substrate by R2RNIL process and (b) a 4 in. wide, 10.5 in. long 700 nm period grating pattern on glass substrate. (c,d) SEM images of the patterned grating structure.

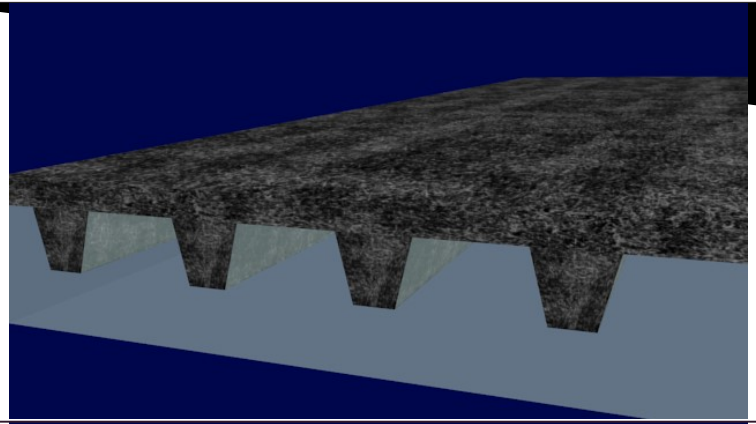
Ahn and Guo, ACS Nano 3(8):2304-2310, 2009.

Manufacturing

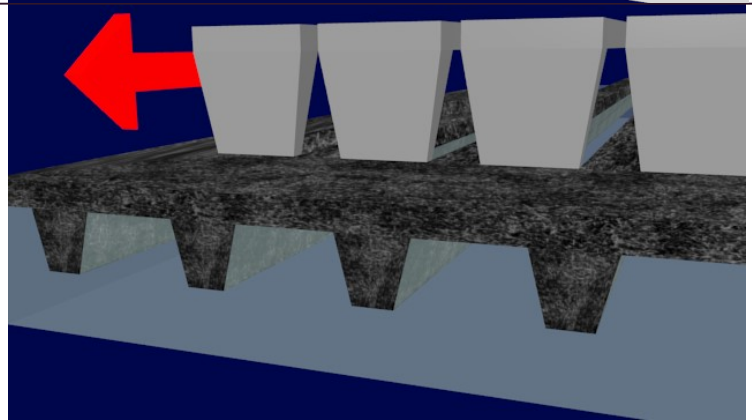
a.



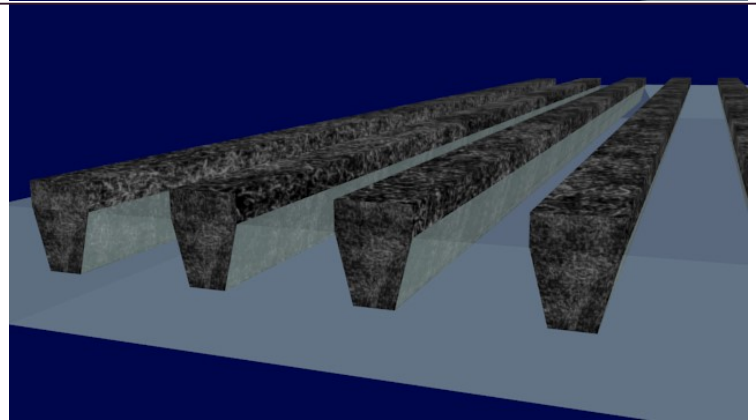
b.



c.



d.



Preliminary Calculations

Fourier's Law in 1-D: $q = kAdT/s\ [W]$

- q = *heat transfer*
- k = *thermal conductivity of the material*
- A = *area*
- dT = *temperature gradient*
- s = *thickness of material*

For glass: $k = 1.05\ W/m{\cdot}K$

For CNT (axial direction): $k_{ax} = 3500\ W/m{\cdot}K$

For CNT (radial direction): $k_{rad} = 1.52\ W/m{\cdot}K$

Comparable to glass

Results (Costs)

Volume Estimate: *15.24 cm x 20.32 cm x 0.5 cm → 154.838 cm^3*

Cost of Glass substrate:

~$61.47 for tempered glass with these dimensions

DullesGlassandMirror

Cost of Aerogel:

$60 for a single *2.5 cm x 2.5 cm x 1.0 cm* block

BuyAerogel

→ $1486.44 worth of aerogel

Very expensive compared to glass

Results (Costs)

- Carbon Nanotube Costs
  - $10/g
    - Density = 1.6 g•cm^{-3}
    - Estimated Volume of CNTs
      - *710 nm x 710 nm x 20.32 • 10^7 nm • 107,500 trenches = 0.11 cm^3*
    - Finding Mass using p = M/V
      - Total mass = *0.0175 g*
      - → *$0.175 per window*

Conclusions

Possible issues

- Need to find a reliable method of aligning CNTs
- Too much heat transmission through tubes
  - Alternatively use graphene sheet instead
- Unwanted light diffraction
  - Spacing with the trenches
  - Multiple internal light sources

Other potential uses

- Anything that requires insulation and visibility
  - Painting/art storage
  - Housing in cold climates