# The Darkest Manmade Material: Nanostructure and Randomness

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# Acknowledgment


| | | |
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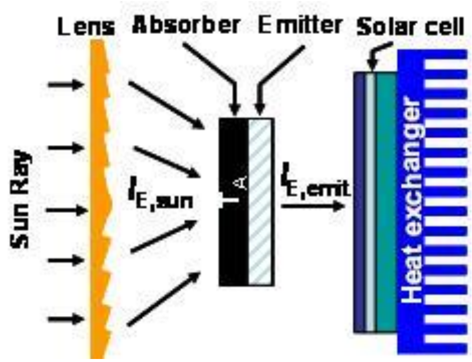
# Outlines

- Introduction
- Our approach and sample structure
- Measurement setup and results
- Summary

# Some Possible Applications of black materials

- As a sunlight absorber of thermophotovoltaics
- As an infrared absorber of infrared detector
- As a stray light absorber for astronomical observation




A propose design of optical absorber for solar energy conservation

A picture of Hubble space telescope

http://hubble.nasa.gov/

# Requirement of optical absorber and Our approach

**Reflection of normal incidence:**

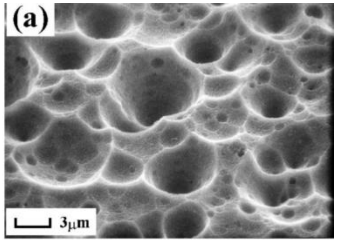
$$R = \frac{(n-1)^2 + k^2}{(n+1)^2 + k^2}$$

**Requirement of optical absorber:**

- low Reflection
- high absorption
- wide spectrum range absorption
- wide incident angle absorption

**Conventional methods:**

- Black paint (R=5-10%)
- Micro-surface-structure NiP ($R_{total}$=0.16%)




J. Mater. Chem. **12**,p2749 (2002)

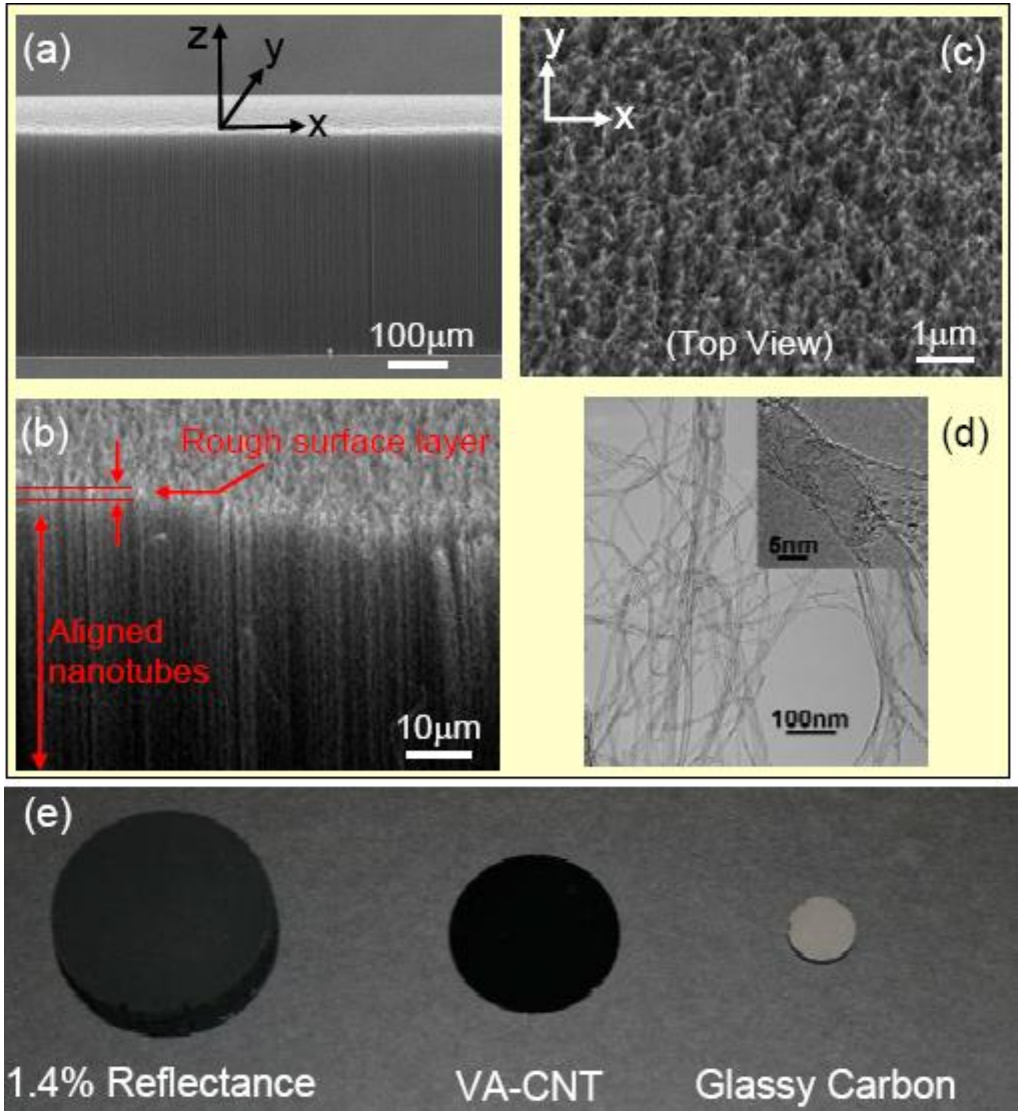
**Our Approach:**

**(vertically aligned carbon nanotube (VA-CNT))**

Porous nanomaterial + Surface randomness

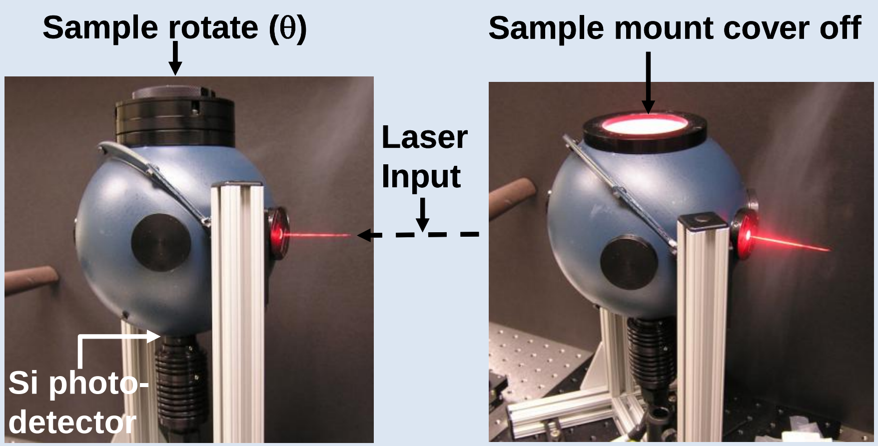
Shows total reflectance $R_{total}$=0.05%

# Sample Structure of VA-CNT

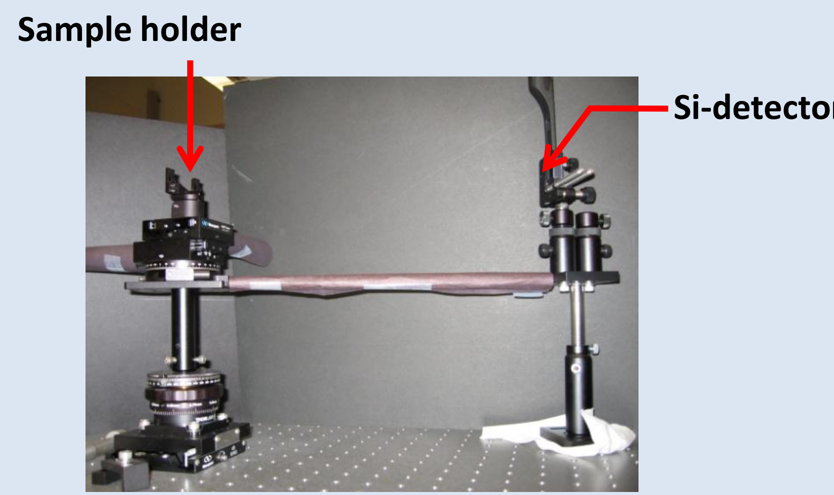


# Equipment Setups

## Setup of total reflection measurement




## Setup of diffuse profile measurement

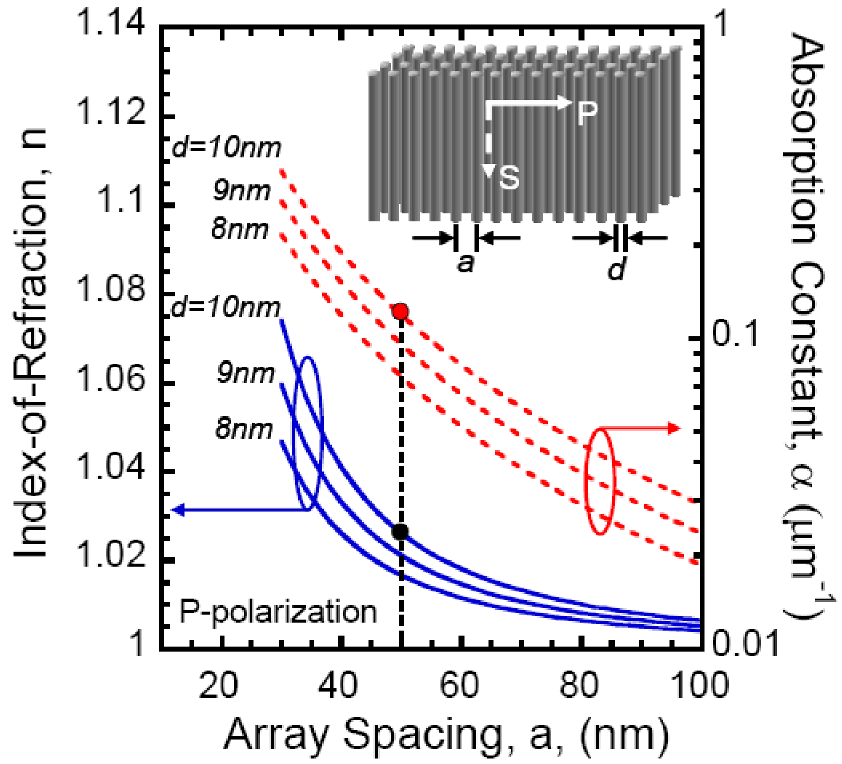


# Porosity Consideration: Maxwell-Garnett Mean Field Approximation (Theory)

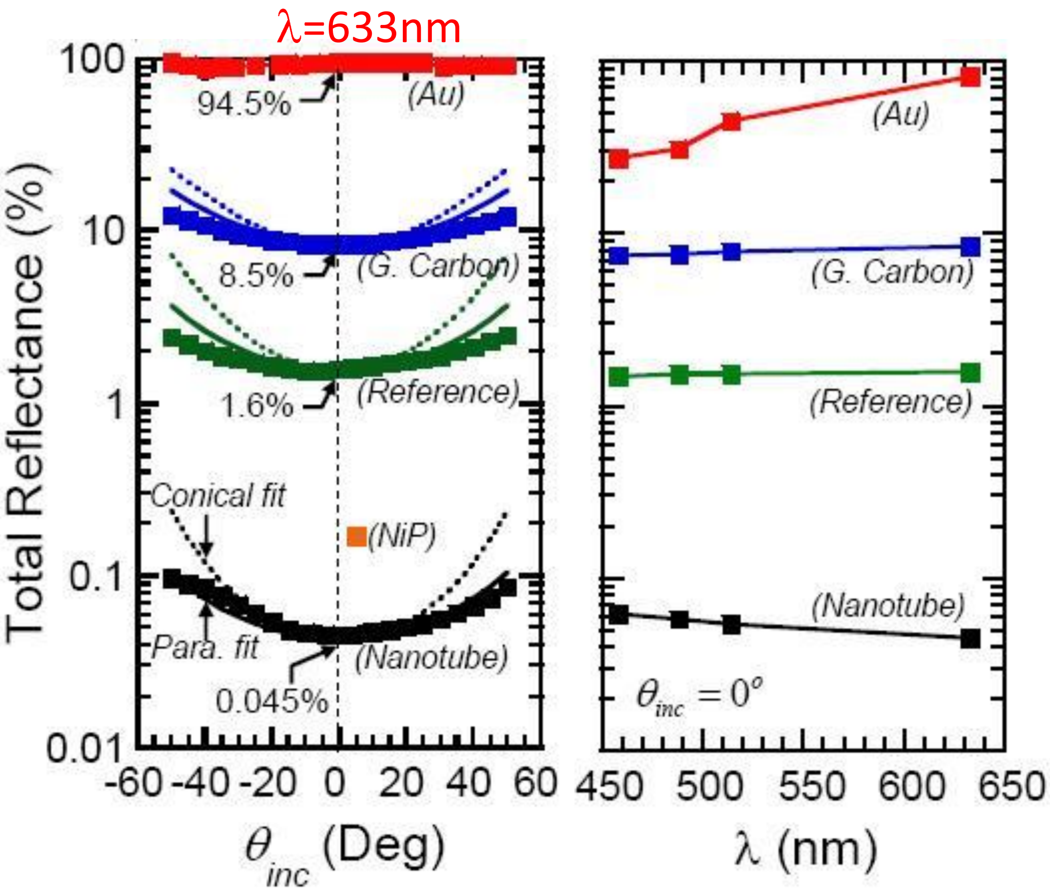
Our CNT samples:

a=50±10nm, d=8-10nm

Filling fraction=2-3%

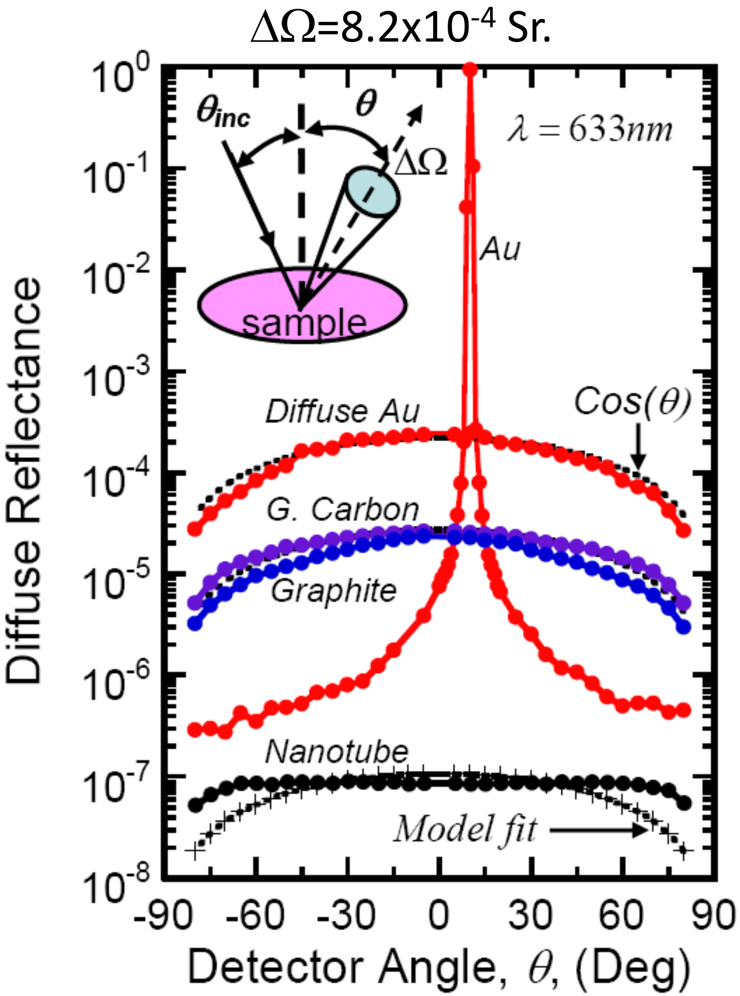


# Total Reflection measurements (Experiment)




- VA-CNT shows extremely low total reflectance $R_{total}$=0.05% @ 633nm
- VA-CNT has very low total reflectance in visible range
- VA-CNT still has very low total reflectance (<0.1%) at large incident angle

# Surface Randomness: Diffuse Profile Measurements




- Our VA-CNT has no specular reflectance and strong diffuse reflectance profile
- A strong diffuse model proposed by Shirley and George (App. Opt. 27, p1850 (1988)) was used to fit the diffuse profile.

# Summary

- We demonstrate that the VA-CNT is the darkest manmade material based on porous nanostructure and surface randomness
- VA-CNT is the best candidate of the ***wide-spectrum-window***, ***wide-incident-angle*** optical absorber