SAND2007-7875P

Sandia National Laboratories

Carbon Nanotube Infrared Detectors

Xinjian Zhou, Alec Talin, *Andy Vance, *Alf Morales, François Léonard

Material Physics and *Material Chemistry

Sandia National Laboratories, Livermore CA

LOCKHEED MARTIN

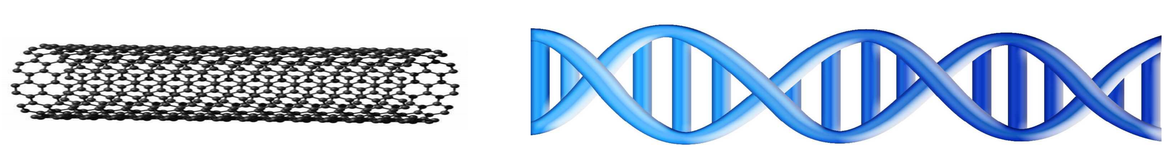
We never forget who we're working for™

Mission

To build a wideband (2μm-20μm) infrared detector using single-walled carbon nanotubes (SWNTs)

What are SWNTs

SWNTs are nanometer-sized seamless cylinders rolled up from single sheets of graphite. 2/3 of SWNTs are semiconductors and 1/3 are metals.



Why SWNTs

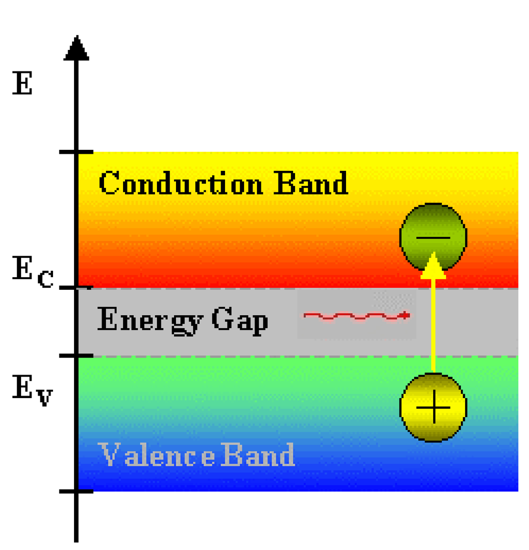
Current Material: HgCdTe

Not compatible with CMOS, bulky, requires cooling, low mobility, toxic, expensive

Advantages of SWNTs:

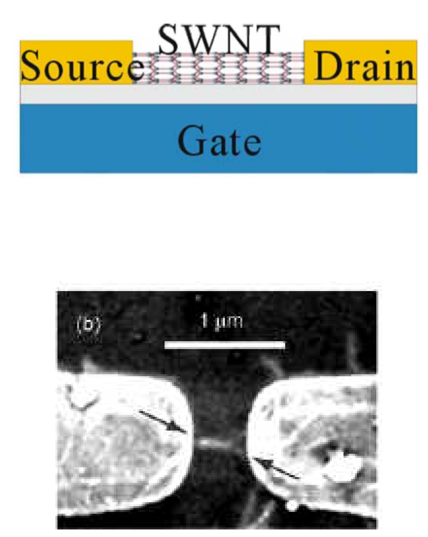
High mobility[1], non-toxic, potentially cheap tunable bandgap E_g = 700 meV/D[nm]

How to detect IR light

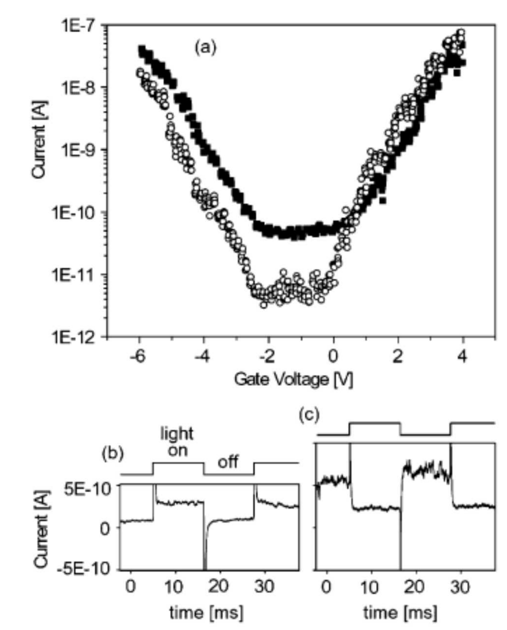


Photoconductivity

Transistor Approach

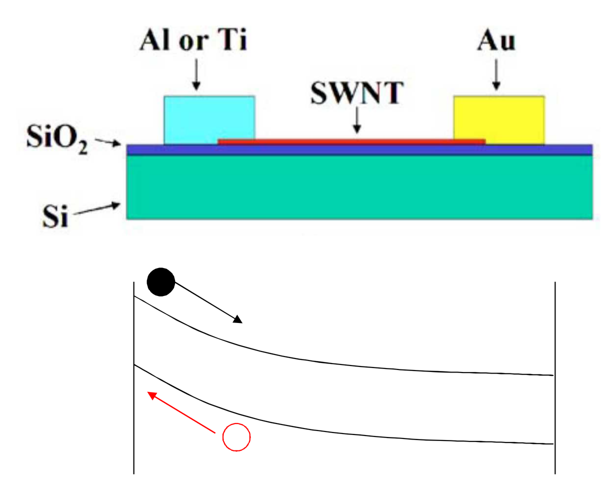


Device geometry



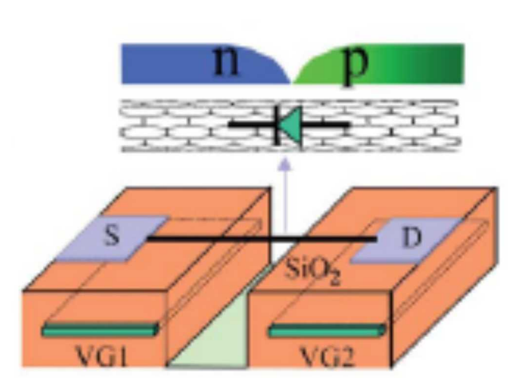
Current versus gate voltage when light is off (open circles) and on (solid squares)2

Our Design

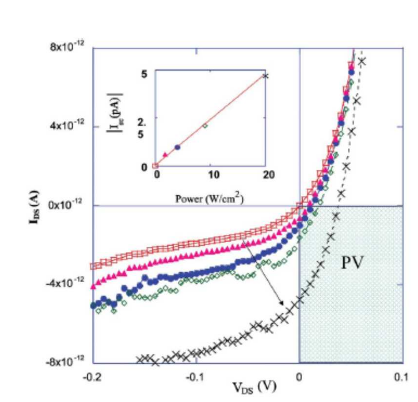


Zero power consumption device

Diode Approach



Device geometry



Current versus bias as a function of light intensity[3]

Performance Discussion

Performance=

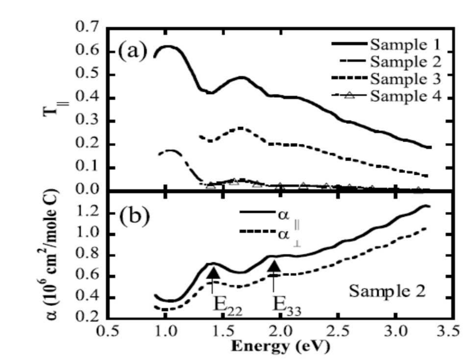
absorption

× quantum efficiency (Q.E.)

× collection efficiency (C.E.)

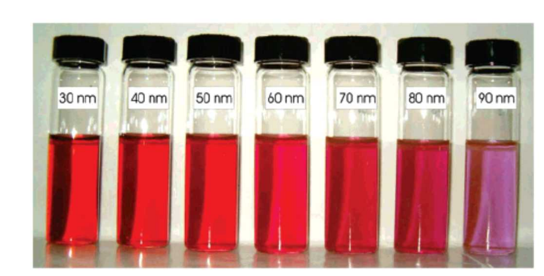
Q.E.~10-30%; C.E.~30-100%

Absorption from a single nanotube is low.



Absorption cross section of SWNTs[4]

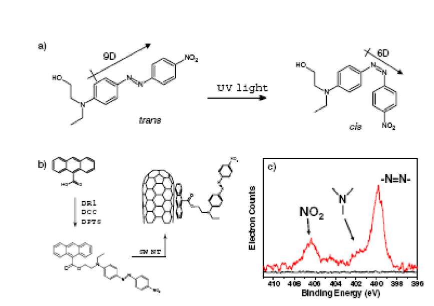
Surface plasmons could be used to concentrate light to the vicinity of nanotubes.



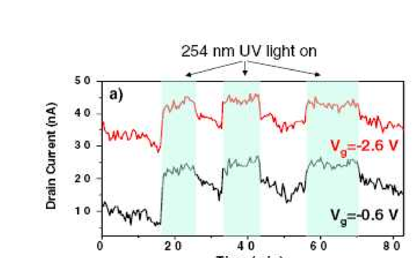
Solutions of gold nanoparticles of difference sizes. Color originates from surface plasmon resonance.

Another Avenue

Another approach modulates the electrical dipoles of chromophores with light. The resulting changes in the local electrostatic environments can be detected by SWNTs

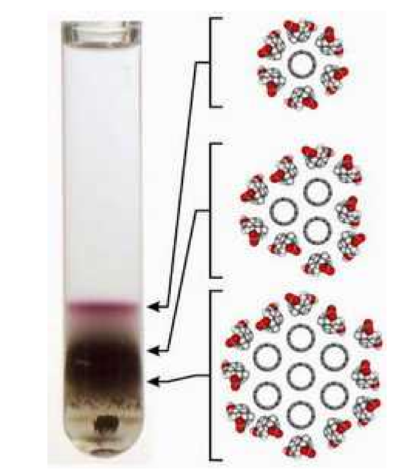


Under UV light, the chromophore isomerizes from the *trans* conformation to the *cis* conformation.

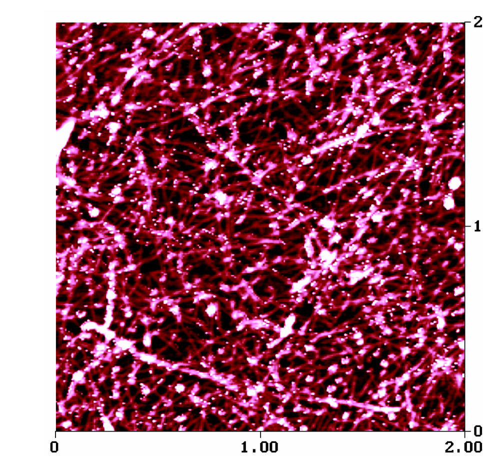


Time traces for a SWNT transistor showing multiple repeatable switching events under 254nm light.[5]

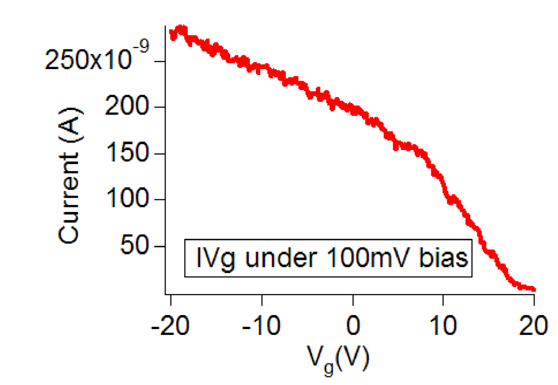
Current Status



SWNTs separated



Deposited



Network SWNT transistors fabricated

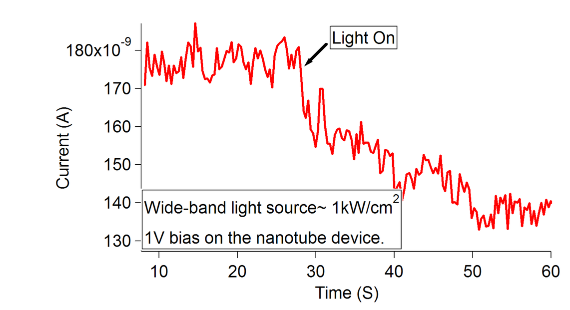


Photo response, related to oxygen desorption, observed

Conclusions

SWNTs are interesting candidate for IR detection. Two different approaches are promising and will be explored. Issues such as separating semiconducting SWNTs from metallic ones and controlling SWNTs assembly need to be solved.

Novel methods to concentrate light field around SWNTs will also be studied, as the device performance will be greatly enhanced.

SWNTs can detect light indirectly through functionalization with chromophores.

References

1.Zhou, X. J., Park, J. Y., Huang, S. M., Liu, J. & McEuen, P. L. Phys. Rev. Lett. 95, 146805 (2005).

2. Freitag, M.; Martin, Y.; Misewich, J. A.; Martel, R.; Avouris, Ph.Nano Lett. **3**, 1067 (2003).

3. J.U. Lee, Appl. Phys. Lett. **87**, 073101 (2005).

4. M. F. Islam, D. E. Milkie, C. L. Kane, A. G. Yodh, and J. M. Kikkawa, Phys. Rev. Lett. **93**, 037404 (2004).

5. J. M. Simmons, I. In, V. E. Campbell, T. J. Mark, F. Léonard, P. Gopalan, and M. A. Eriksson, Phys. Rev. Lett. **98**, 086802 (2007).