SCANNING PHOTOCURRENT SPECTROSCOPY OF ALIGNED SINGLE-WALLED CARBON NANOTUBE FILMS

S. Mineshige[1,2], J. M. Lloyd[2], S. Nanot[2], J. Kono[2]

1. NanoJapan Program and Information Science and Technology, Hokkaido University

2. Department of Electrical and Computer Engineering, Rice University

Scanning photocurrent measurements of aligned single-walled carbon nanotube films (SWCNTs) provide local information about electron-light interaction in macroscopic ensembles of SWCNTs. Photocurrent and photovoltage in random networks of SWCNTs have been reported previously, but there is no consensus about the origin: thermal or Schottky barrier induced. However, this mechanism is the basis for photodetection using carbon nanotubes, and understanding it is necessary to design optical devices based on SWCNTs such as solar cells or photodetectors. In this research, we measure the temperature dependence of the local and global photocurrent and photovoltage of highly aligned SWCNTs films. The samples are contacted with two different metallic electrodes to induce asymmetric Schottky barrier energies. These measurements provide precise information about the relative contribution of thermal and electrostatic effects in the photocurrent generation in such films.

SCANNING PHOTOCURRENT MICROSCOPY OF ALIGNED SINGLE-WALLED CARBON NANOTUBE FILMS

S. Mineshige[1,2,†], J. M. Lloyd[2], S. Nanot[2,‡], R. H. Hauge[3], J. Kono[2]

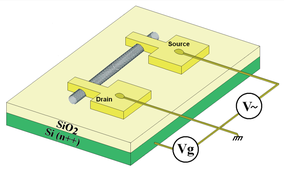
[1] NanoJapan Program and Information Science and Technology, Hokkaido University, Sapporo, Japan, †(mineshige@nano.ist.hokudai.ac.jp)

[2] Department of Electrical & Computer Engineering and Depertment of Physics & Astronomy, Rice University, Houston, TX 77005, USA, ‡(sn14@rice.edu)

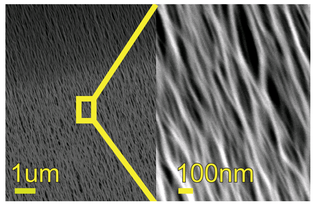
[3] Chemistry Department, Rice University, Houston, TX 77005, U.S.A

Introduction & Methods

Motivation: Why we use Carbon Nanotube (CNT) Films



Individual CNTs Transistors[1]
- Efficient
- Photovoltaic detections butdifficult or time consuming
- Difficult to make



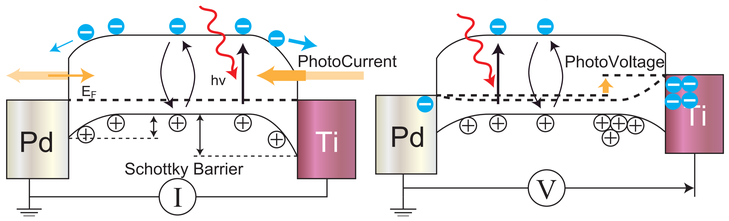
[1] A. Jorio, *et al*., Topics in Applied Physics, Volume 111, 2008, Springer

Can we extend it to macroscopic ensemble (films) ?
- Easy to make
- Large area detection
- Useful for photo detecting application

SEM image
- Highly aligned CNT films
- Synthesized by chemical vapor deposition

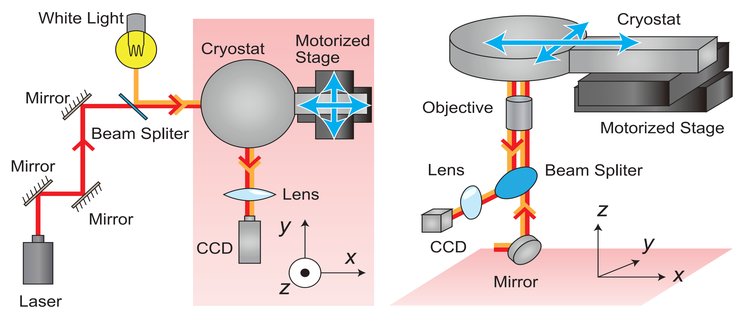
Schottky Barrier Model

- One of the model to explain photovoltage effect on CNT
- Different schottky barrier makes different photovoltage



- Closed Circuit (Left): different metals will induce different Schottky barriers --> different photoresponse
- Open Circuit (Right): charges move where bands are bended--> photocurrent, charge accumulation --> band bending modified-->photovoltage

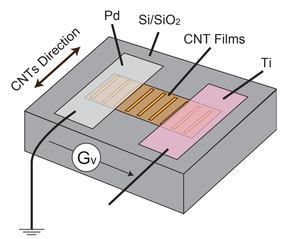
Scanning Photovoltage Microscopy

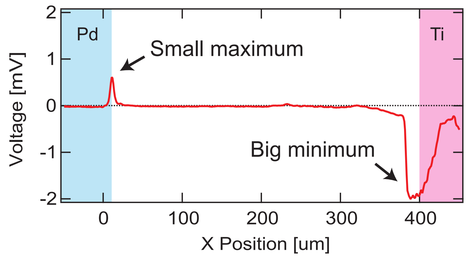


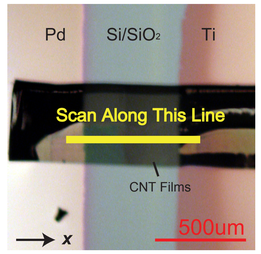
- Laser is focused 1μm spot size by objective lens
- CCD, white light and laser allow us to focus laser and image the sample

Sample A: CNTs are parallel to contact

Scanning Photovoltage Microscopy







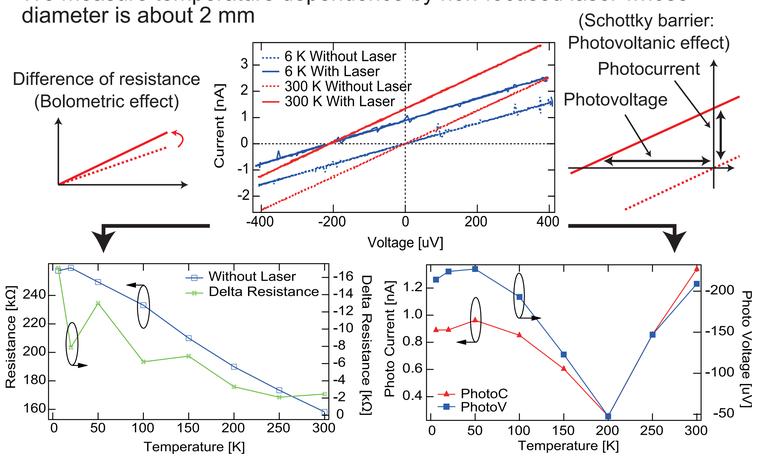
On Pd (Small Schottky barrier): Small maximum
On Ti (Big Schettky barrier): Big minimum

Opposite polarity of photovoltage

The result supports Schottky barrier model

Temperature Dependence

We measure temperature dependence by non-focused laser whose diameter is about 2 mm



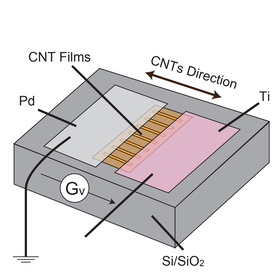
Increasing Temperature
Decresing Resistance → Photoresistance: Decreasing
Photovoltage: Decreasing & Increasing
Photocurrent: Decreasing & Increasing

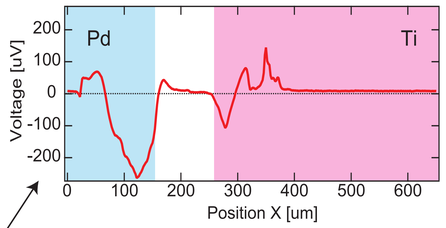
Photoresistance: Bolometric effect is very small & negligible at hight T

Photovoltage & current don't come from thermal effect

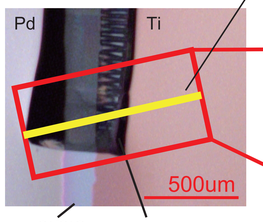
Sample B: CNTs are mis-aligned

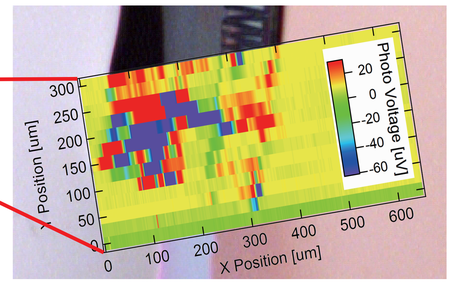
Scanning Photovoltage Microscopy





- No clear Schottky barrier





Photovoltage map
- Photovoltage maxima correlate with bended regions
- Small edge from Ti

Conclusion & Aknowledgement

Clear evidences of Schottky barrier effect:
- Local scan shows different photovoltage for different metal
- Photovoltage independent of heating by laser

Importance of alignment:
- CNT-CNT contacts dominate in miss-aligned films

HOKKAIDO UNIVERSITY
RICE
NSF
NanoJapan
International Research Experience for Undergraduates