Photocurrent measurement in thin-film single-walled carbon nanotube field-effect transistors

WEERAPAD DUMNERNPANICH
FACULTY OF SCIENCE DEPARTMENT OF PHYSICS
MAHIDOL UNIVERSITY
OUTLINE

- Introduction
- Objectives
- Experiment
  - Electrode structure
  - Fabrication process
  - Measurement setup
- Results and Discussion
- Conclusion
- References


OBJECTIVES

- Fabricate single-walled carbon nanotube thin film for a field-effect transistor device by a solution process technique using dielectrophoresis (DEP) method.
- Study electrical transport characteristics of the device prepared in Objective 1 with a single conducting channel and dual conducting channel schemes at room temperature under broadwavelength (200-2500 nm) light illumination.
EXPERIMENT
ELECTRODE STRUCTURES

- Aluminum electrode material (Al: 60nm)
- Adhesion material (Ti/TiN: 40nm)
- Insulation layer (SiO₂: 160nm)
- Substrate: Si

Source  Drain
ELECTRODE STRUCTURES

Top view of single conductive channel

Source (Al)

SiO₂ Substrate

5 µm channel gap

Drain (Al)

120 µm

Top view of parallel conductive channel

First channel

Second channel

Source

Drain

S

D

S

D
FABRICATION
$\vec{F}_{DEP} = 2\pi r^3 \varepsilon_m \text{Re}[K^*(\omega)]\nabla |\vec{E}|^2$

\( \varepsilon_m \) is electric permittivity of medium
\( K^*(\omega) \) is Clausius-Mossotti coefficient
\( \nabla |\vec{E}|^2 \) is gradient of electric field strength
MEASUREMENT SETUP

Broad wavelength 200-2500nm
Power mode = 0W-250W
RESULTS AND DISCUSSION
ELECTRICAL TRANSPORT (single-channel)

![Graph showing electrical transport over time with different power levels.]

- Single channel at \( V_{ds} = 2.0V \)
- Current values: 1.840e-6 A and 1.237e-6 A

---

12
ELECTRICAL TRANSPORT (single-channel)

Mobility $\propto$ Trans-conductance

Trans-conductance = 1.064 µS

Trans-conductance = 1.168 µS
ELECTRICAL TRANSPORT (parallel channels)

Measured current of parallel conductive channels is not equal to 2x of single conductive channel
ELECTRICAL TRANSPORT (parallel channels)

Mobility \propto \text{Trans-conductance}  
Trans-conductance = 0.781 \mu S  
Trans-conductance = 0.922 \mu S
DISCUSSION

<table>
<thead>
<tr>
<th></th>
<th>Measured current at 200W (µA) Vds = 2.0V</th>
<th>Increasing of Measured current from 0W to 200W (µA) Vds = 2.0V</th>
<th>Transconductance at 0W (µS) Vds = 2.0V</th>
<th>Transconductance at 200W (µS) Vds = 2.0V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single channel</td>
<td>4.11</td>
<td>1.84</td>
<td>1.06</td>
<td>1.17</td>
</tr>
<tr>
<td>Parallel channels</td>
<td>3.13</td>
<td>1.83</td>
<td>0.781</td>
<td>0.922</td>
</tr>
</tbody>
</table>
DISCUSSION

- Scattering
- Unconventional Schottky barrier
- loss energy by heat dissipation
CONCLUSION

- The excited charge carriers in the SWCNTs by increasing light emission power up to 200 W was found linearly dependence of the power.

- In a comparison with a parallel conductive FET channels, the measured single conductive FET channel exhibits a higher trans-conductance.

- The measured current of both devices shows small increases with light powers when applying gate biases and saturates at a high power.

- We demonstrated that the carbon nanotube materials can be used for light sensor application or energy harvesting materials for low-power consumption technology.
REFERENCES

ACKNOWLEDGE

DR. YODCHAY JOMPOL
FACULTY OF SCIENCE
DEPARTMENT OF PHYSICS
MAHIDOL UNIVERSITY
THANK YOU FOR YOUR ATTENTION