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Carbon nanotube thin film transistors on plastic films for printed electronics

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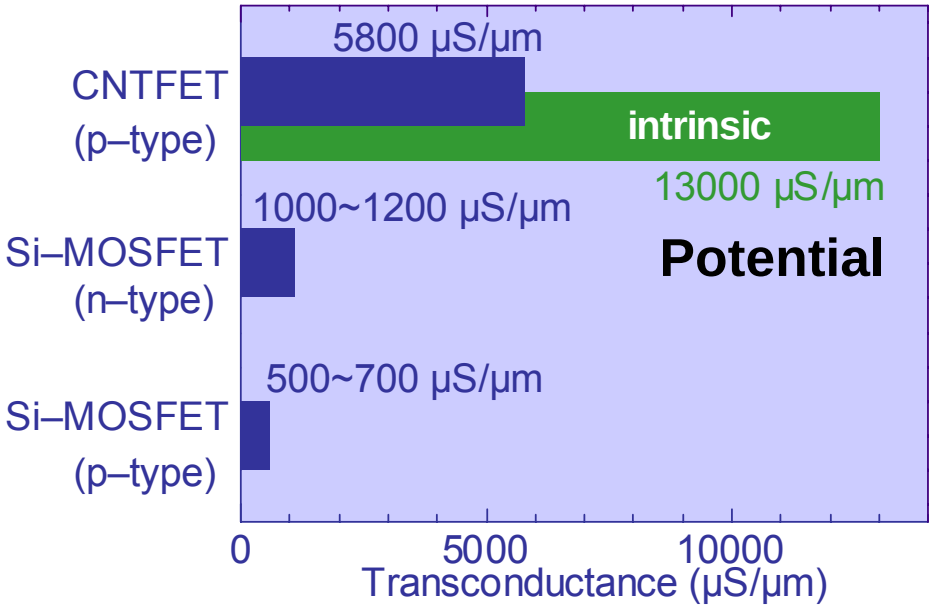
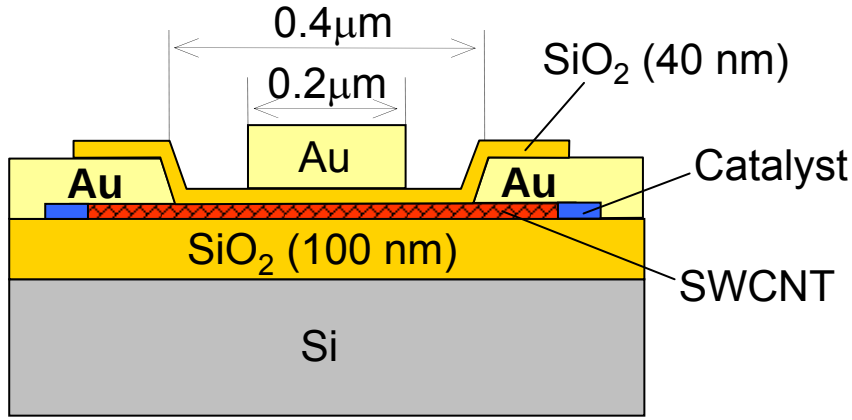
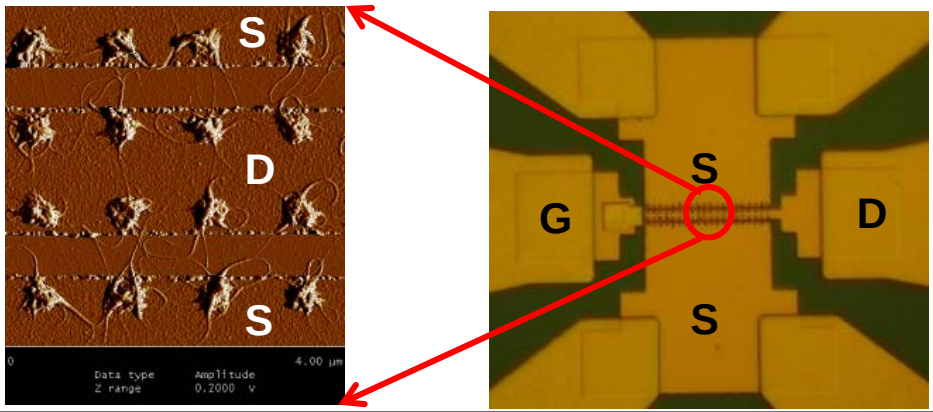
Carbon nanotube (CNT) transistor

Silicon-base CNT transistor shows very high electronical performance.

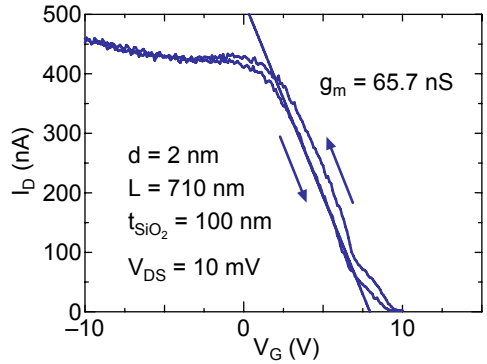




Cross Section



AFM Image **Optical Image**



Mobility

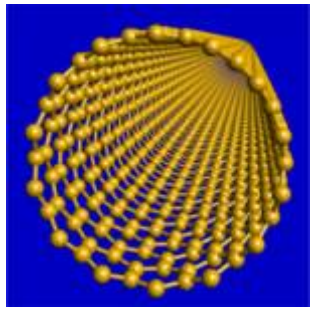
> 1,000 cm²/Vs

CNT for printed transistor

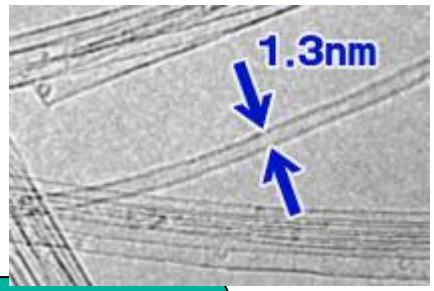
CNT has good features as a ink for printed electronics.

Structural characteristics

- Chemically stable
- Mechanically stable



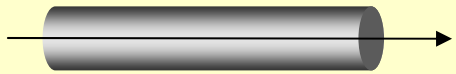
Handled in humid condition
No degradation in solvent



Suitable for making ink

Electronic Characteristics

- Large carrier mobility
  $\mu > 1{,}000\ cm^2/Vs$
- Large current capacity



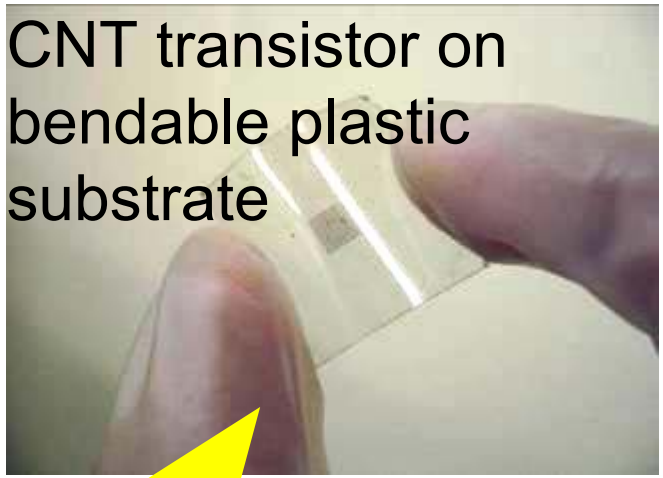
Ballistic conduction

Organic：hopping conduction

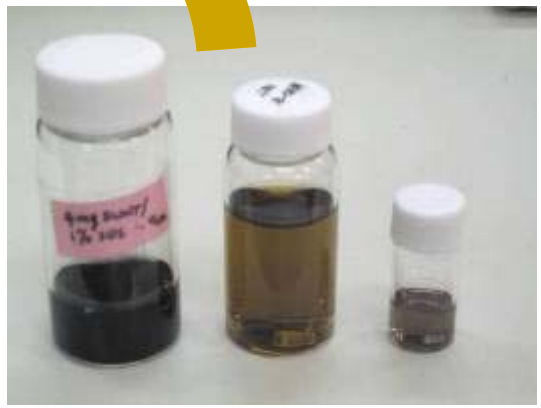
High-speed operation

Spin-coated CNT Transistors on Plastic Substrates

CNT transistor is fabricated by spin-coating "CNT ink" onto bendable plastic substrates.



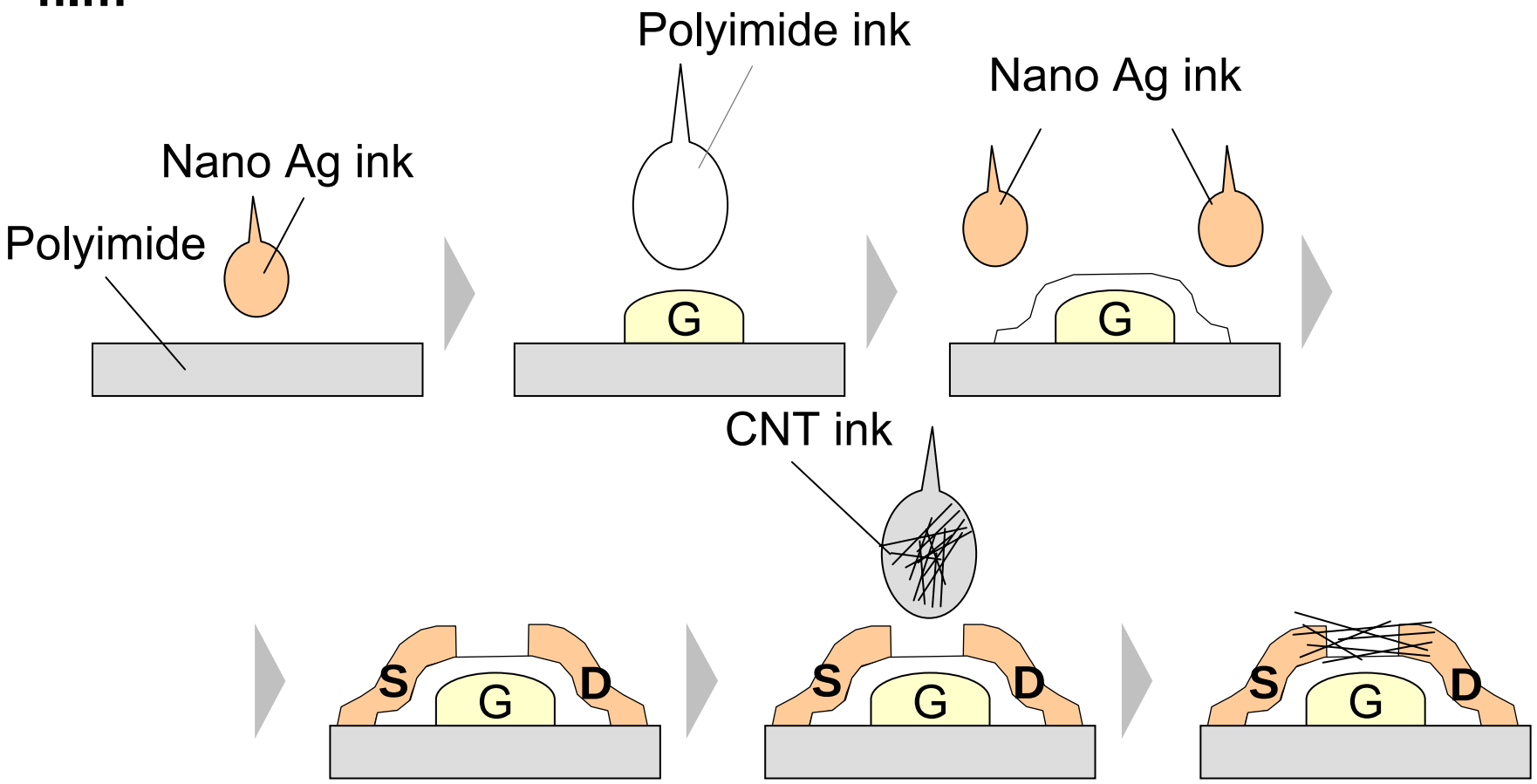
CNT Ink



CNT Transistor

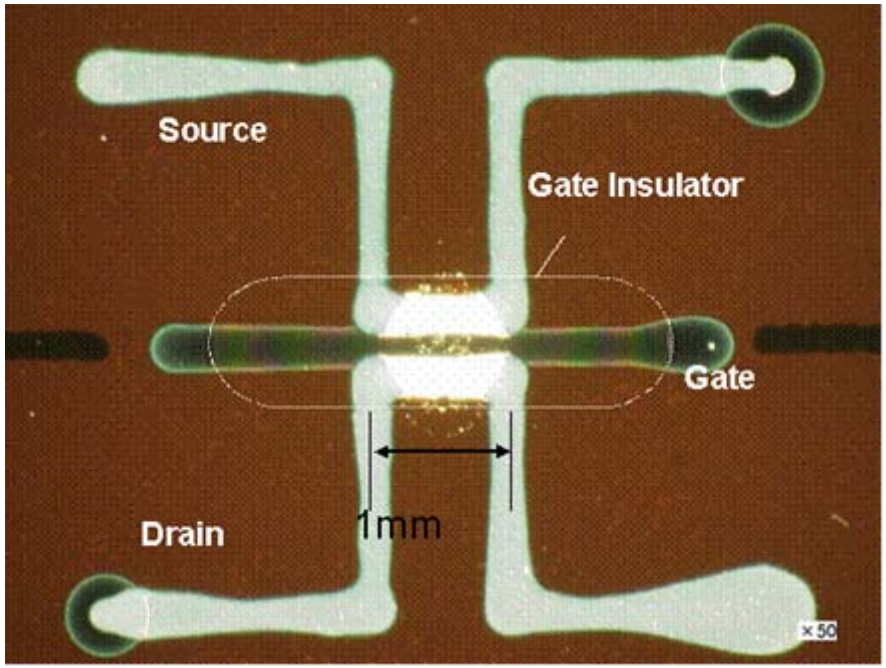
Fabrication process of the printed CNT transistor

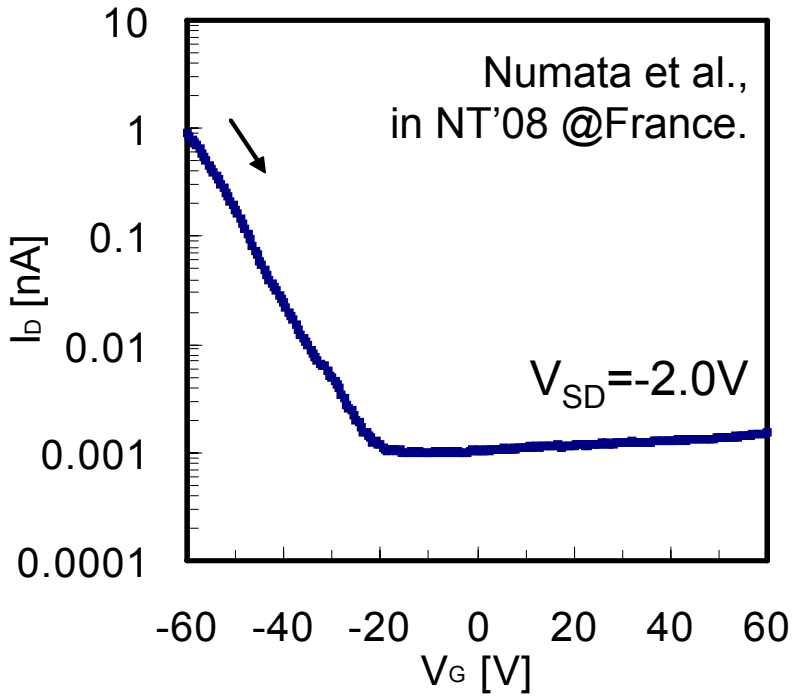
- **All parts of transistors (channel/insulator/electrodes) are printed.**
- **Process temperatures are below 200˚, applicable for plastic film**



All printed CNT thin film transistor (TFT)

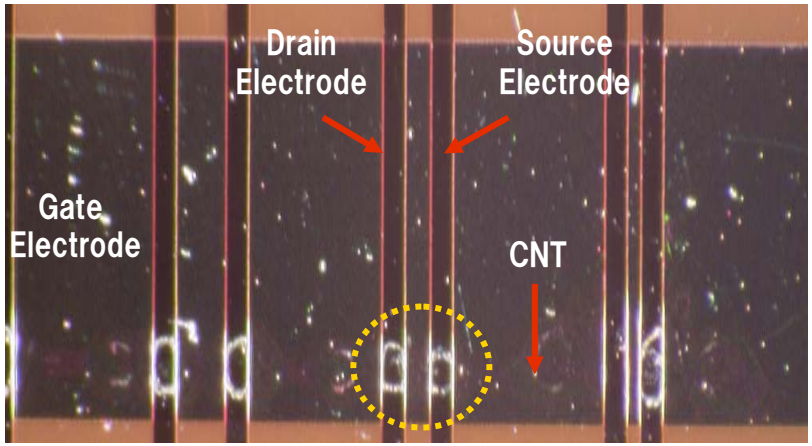
- dispenser system for printing
- CNT pattern diameter was about 1mm
- Device properties: μ =0.1cm^2/Vs and on/off ratio=1000

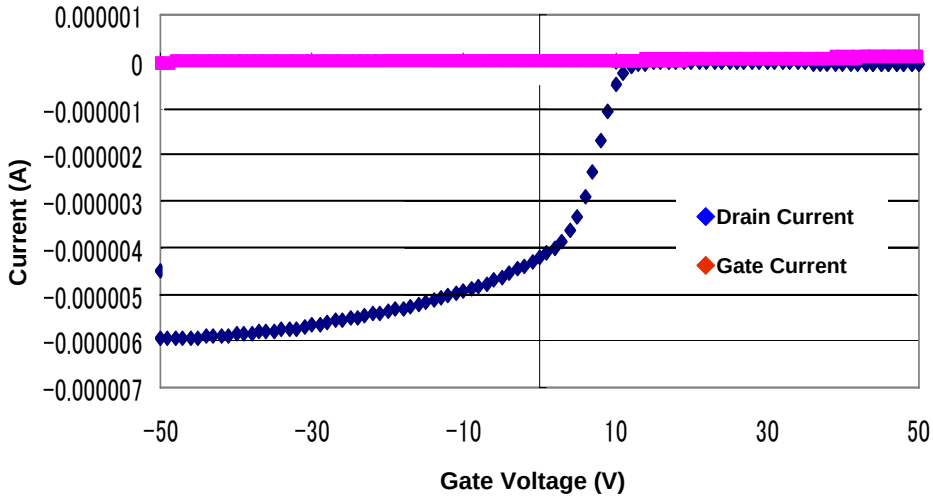




To improve the definition of the pattern, and increase CNT density, we applied to ink-jet printing method

Ink-jet printed CNT-TFT



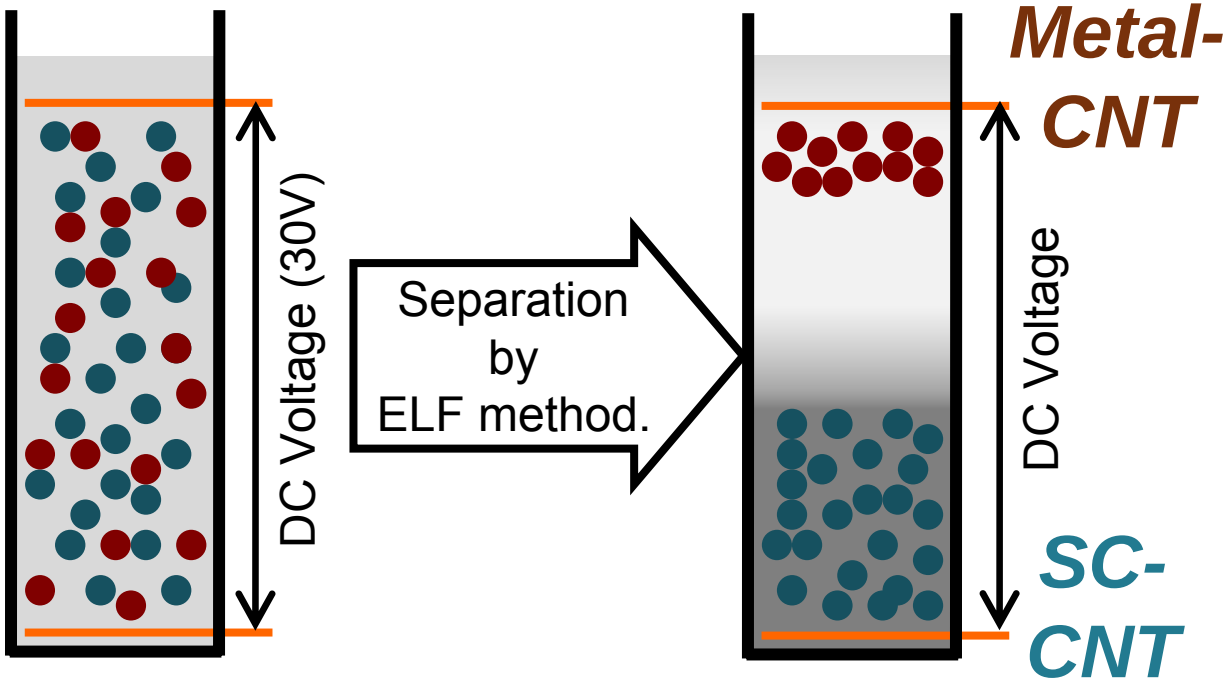


- ink formulation : Water(~100%), Surfactants(100ppm), CNT(10ppm)
- droplet pitch : 50 μ m, 3 times overcoats
- TFT characteristics : on/off ratio = 4000
  mobility = 0.8cm^2/Vs

→ For more high mobility, we developed CNT Metal Semiconductor separation technology.

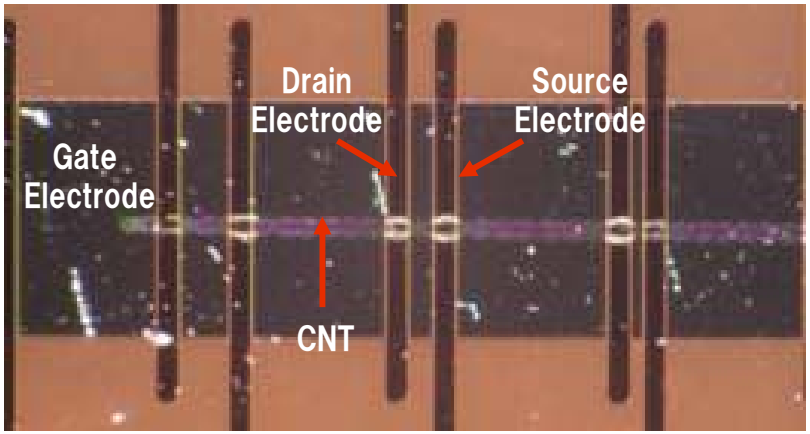
CNT Metal-Semiconducor separation technology

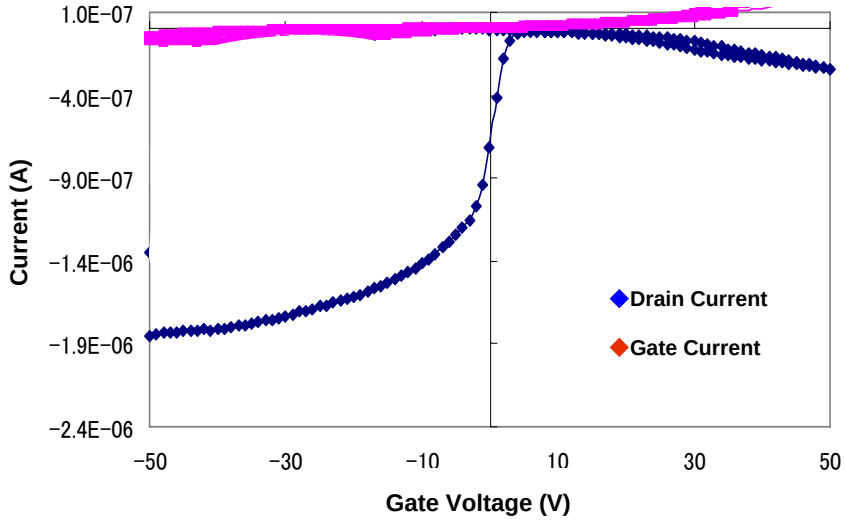
- As for synthesized CNT, Semiconductor : Metal = 2 : 1
- We developed an original separation technology to get better semiconductor sample. (Electric-field inducing Layer Formation)
  - Simple apparatus and Easy purification protocol
  - Applicable for wide diameter range (1.0-2.2 nm)
  - Ion-free process



We successfully obtained high purity semiconductor CNT.

CNT-TFT using high-purity semiconductive-CNT





- ink formulation : Water(~100%), Surfactants(100ppm), CNT(10ppm)
- droplet pitch : 50 μ m, 3 times overcoats
- TFT characteristics : on/off ratio = 9700
  mobility = 5.1cm^2/Vs

Improvement of both mobility and on-off ratio were achieved.

Summary

Carbon Nanotubes as Printed Electronic Materials

- Large carrier mobility

  → expect for high performance TFT

- Chemical and mechanical stability

  → suitable for ink manufacturing

Printed CNT Transistors

- CNT-TFT using high purity CNT and water-based ink

  mobility = 5.1cm^2/Vs and on/off ratio = 10000

- Spreads decrease dramatically.

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