



# Architectural Effects for Transfer-Printed Carbon Nanotube Mat Transistors



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## Motivation

The motivation of our research is to make logic and sensor circuits using carbon nanotube mat transistors on flexible substrates

Logic gates –encapsulated for stability



Top gate

Sensors –exposed to environment

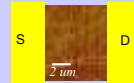


Bottom gate

## Carbon Nanotube

- CNTs – can have high mobility and can be functionalized
- CNT mat devices – easier to fabricate than single tube devices

CVD: Flow  $H_2$ ,  $CH_4$  and  $C_2H_2$  at  $900^\circ C$  over  $SiO_2$  substrate covered with  $(Fe(NO_3)_3)$  nanoparticle catalyst



- ➔ Density controlled by catalyst concentration
- ➔ Length controlled by growth time

30% metallic CNT; 70% semiconducting CNT

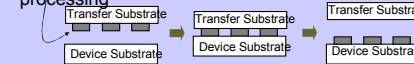
## Transfer Printing

- Enables fabrication of high quality organic devices

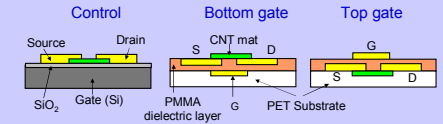
(Hines et al, APL, 86, 163101, 2005)

- Large area, flexible substrates
- Processes nanometer scale features
- Layer-to-layer alignment
- High throughput with low temperature

Printable layer processing



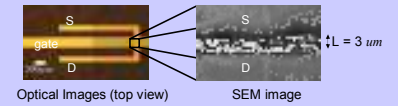
## Device Configurations



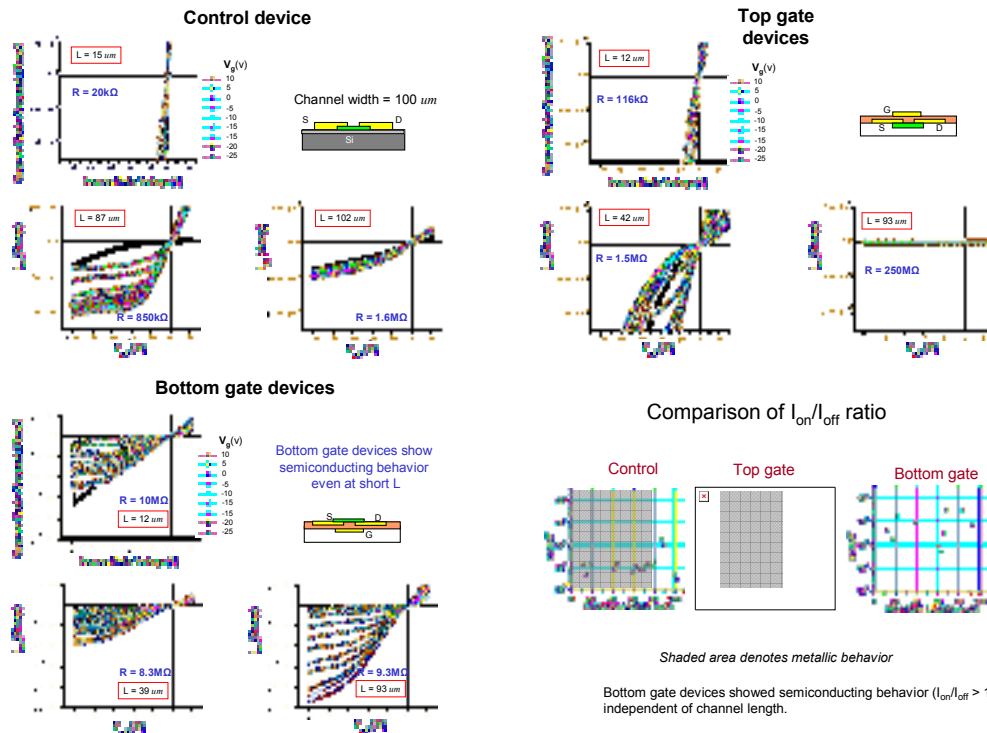
PET polyethylene terephthalate

PMMA poly(methyl methacrylate) spin coated and baked

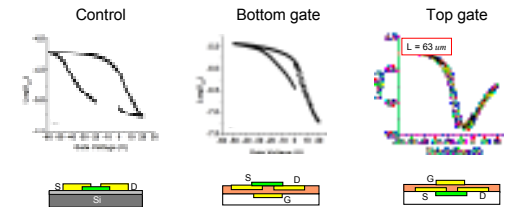
Electrode (Au) patterns grown by standard photo-lithography



## Channel length dependent output characteristics



## Transfer Characteristics



Top gate devices:

- show less hysteresis compared to control and bottom gate device
- show ambipolar behavior as opposed to p-type behavior of control and bottom gate devices

## Conclusion

- Channel length dependent characteristics of devices were studied
  - Semiconducting behavior for:  $L > 80 \mu m$  -Control
  - $L > 63 \mu m$  -Top gate
  - $L > 12 \mu m$  -Bottom gate
- Device characteristics vary with device architecture
  - Control and bottom gate – p type, hysteresis
  - Top gate – ambipolar, no hysteresis
- $I_{on}/I_{off}$  ratio
  - $\sim 10^1$  – Control and top gate (below a critical L)
  - $\sim 10^3$  – Bottom gate

## Future Work

- ❖ Fabrication of patterned and transfer printable carbon nanotube mats
- ❖ Investigation of percolation issues through carbon nanotube density dependent characteristics