



# Carbon Nanotube Electronics

2016 EE Research Festival



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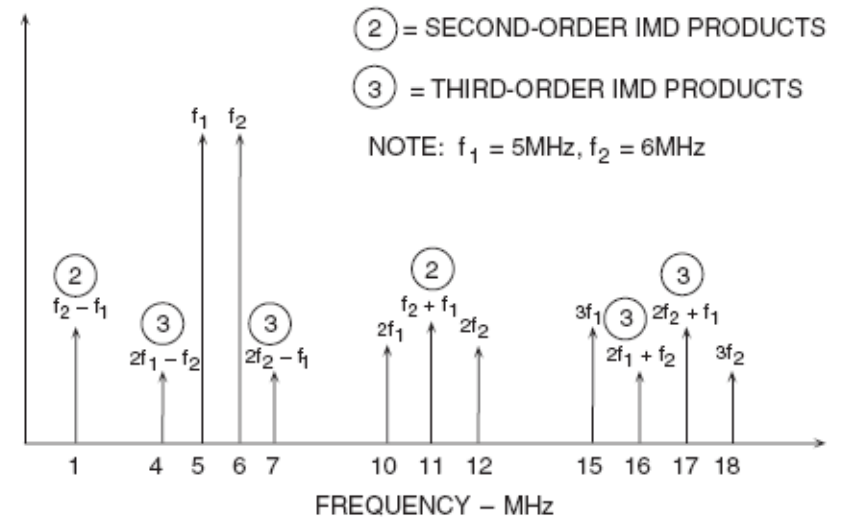
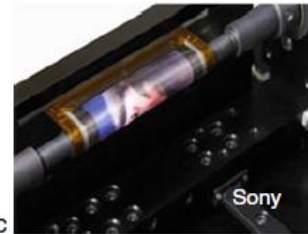
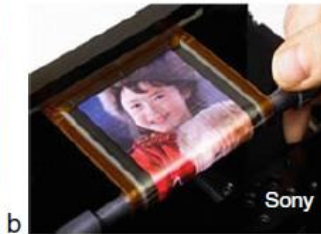
# Motivations



**Flexible, wearable & portable electronics**



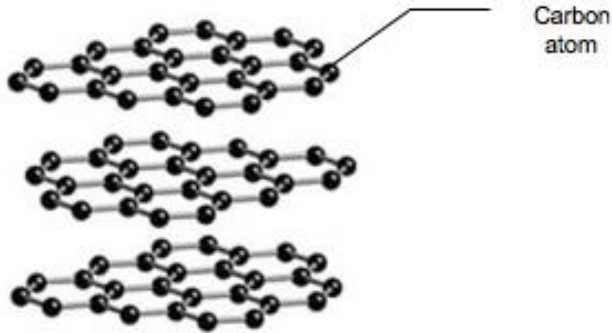
**Overcoming non-linear effects to use bandwidth more efficiently**



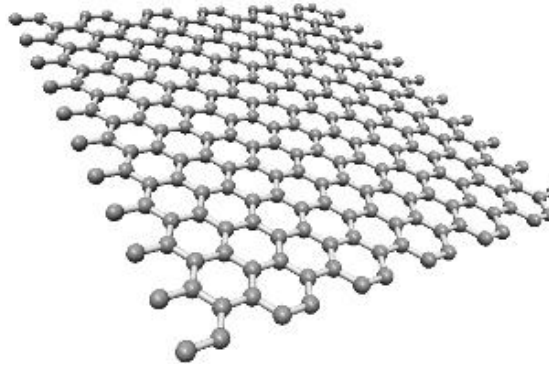
# Carbon Nanotubes



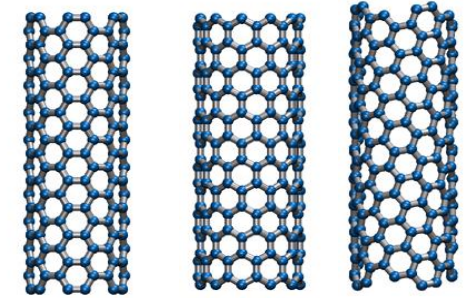
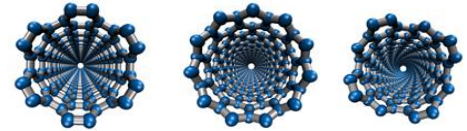
Graphite (3D)



Graphene (2D)



Carbon Nanotubes (1D)

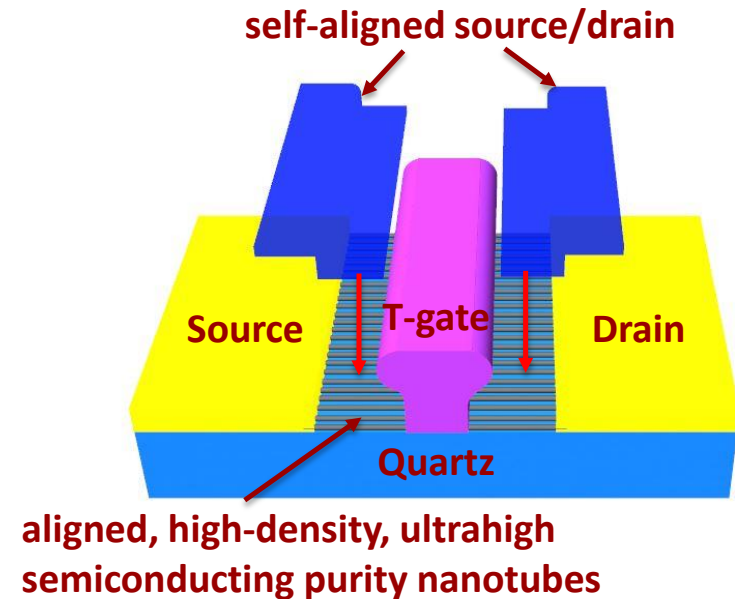
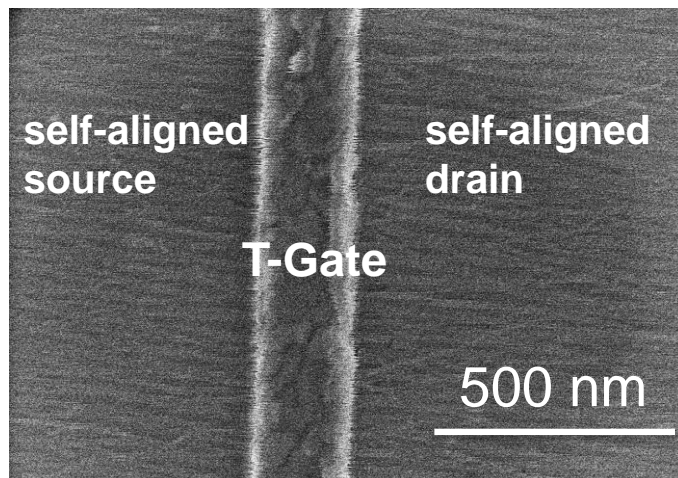
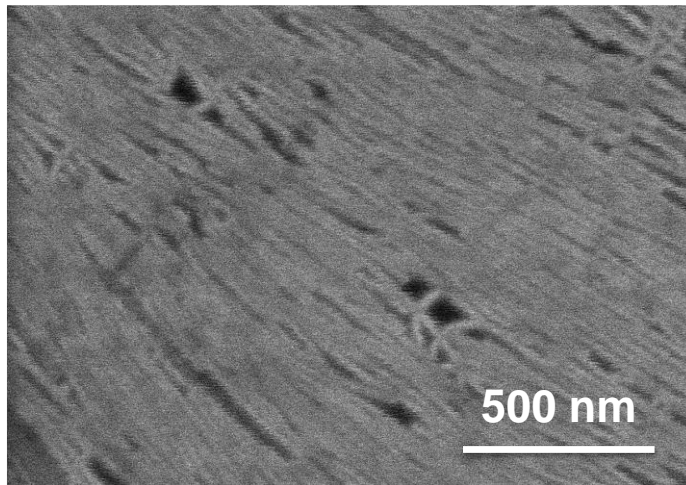


Armchair Zigzag Chiral

- ☐ Mechanically flexible
- ☐ Inherently linear
- ☐ High mobility (up to  $10,000 \text{ cm}^2/\text{Vs}$ )
- ☐ High current carrying capability
- ☐ Small dimension & intrinsic capacitance

Excellent materials for  
flexible electronics and  
radio-frequency  
electronics

# Carbon Nanotube Radio-Frequency (RF) Electronics

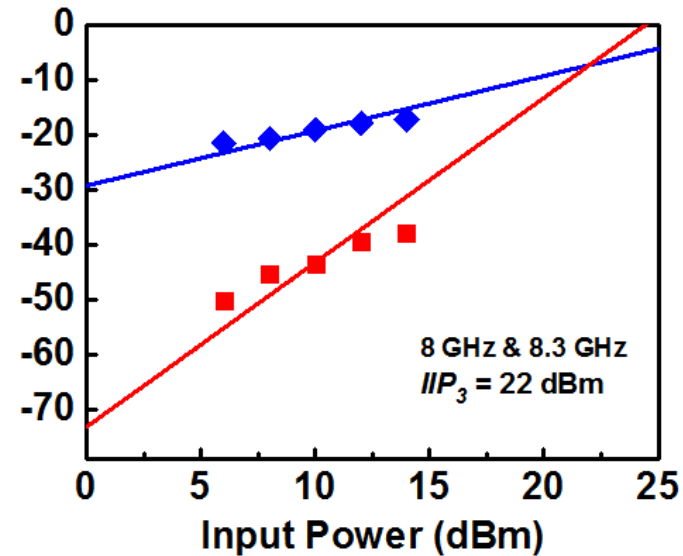
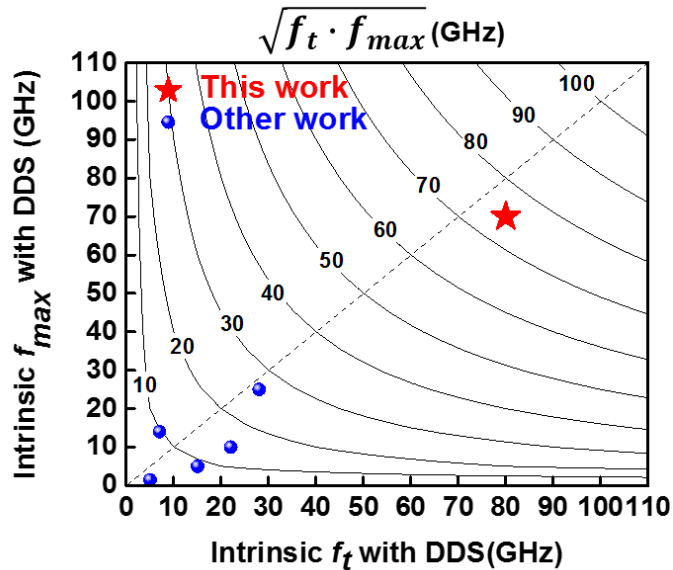
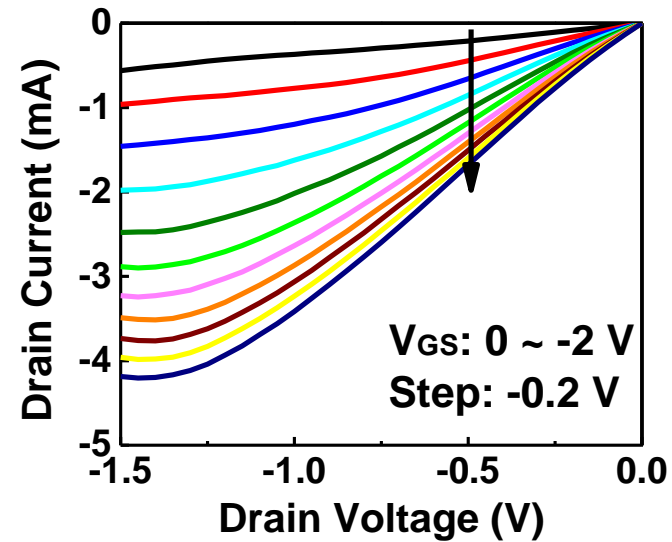
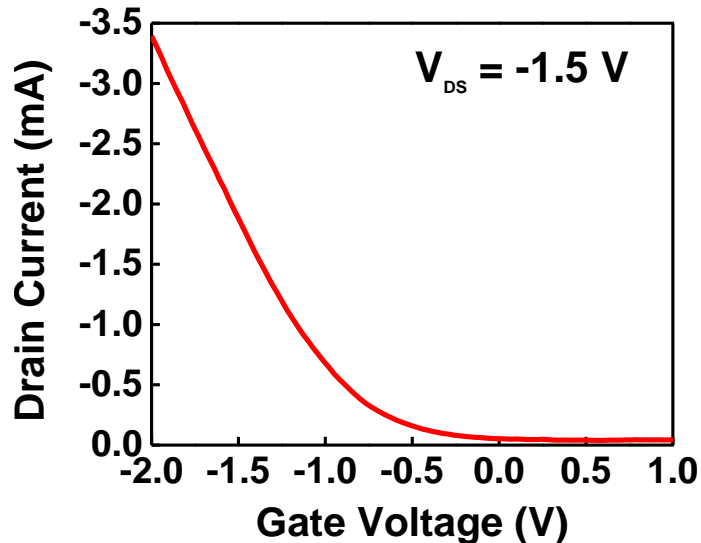


- Well-aligned, high-density (40 tubes/ $\mu\text{m}$ ), and ultrahigh semiconducting purity carbon nanotubes.
- Channel length: 100–150 nm.

Yu Cao, et al, *ACS Nano* 2016, 10 (7), pp 6782–6790

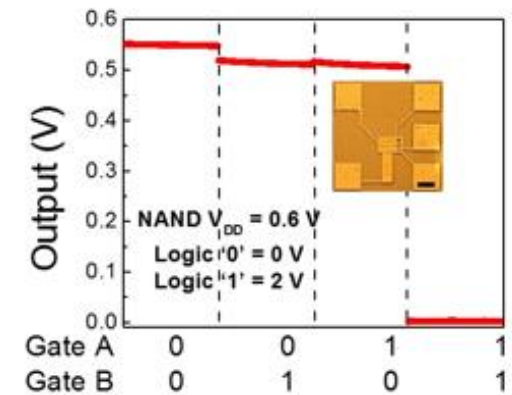
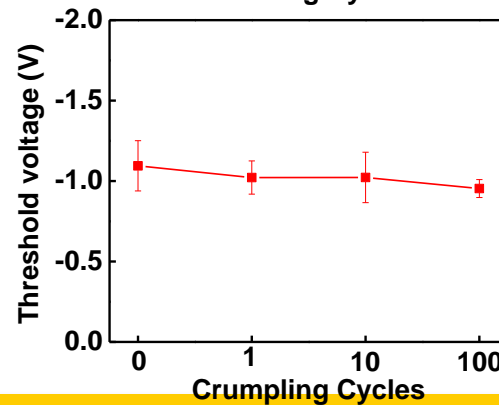
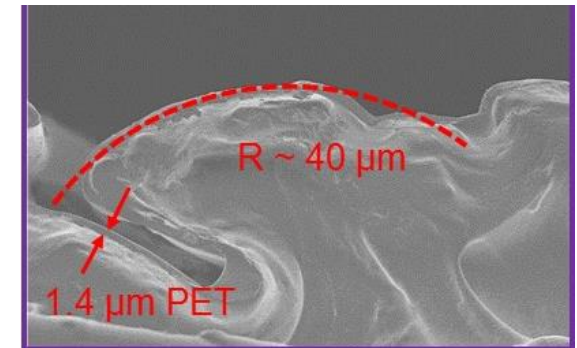
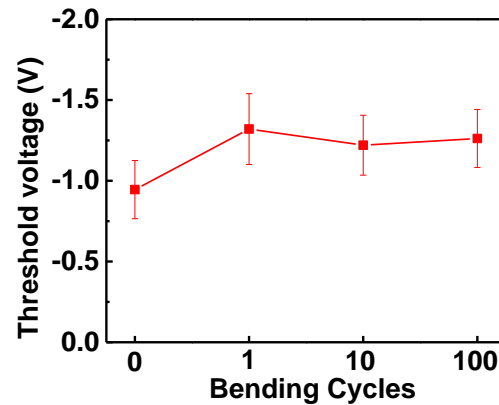
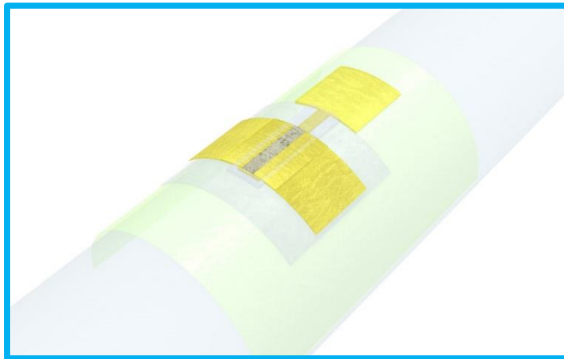
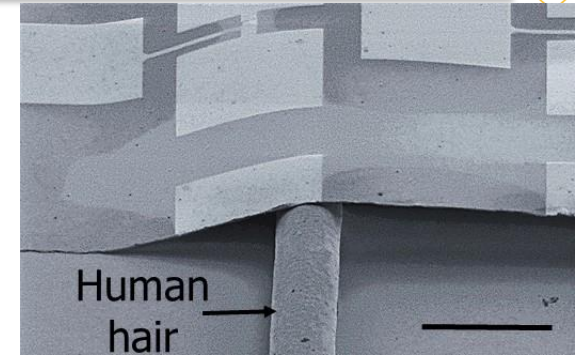
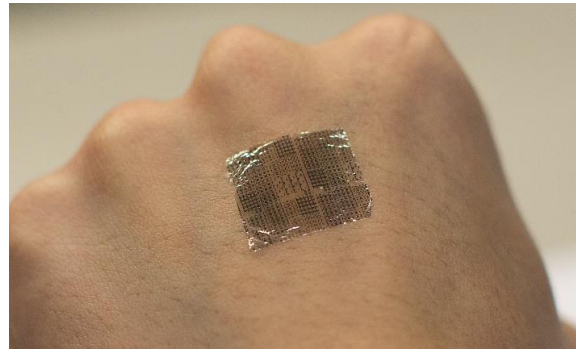
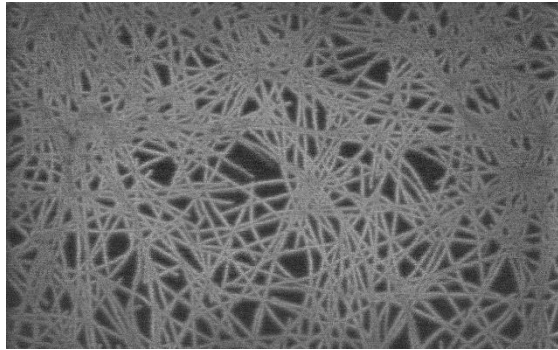


# Excellent RF Performance with High Linearity

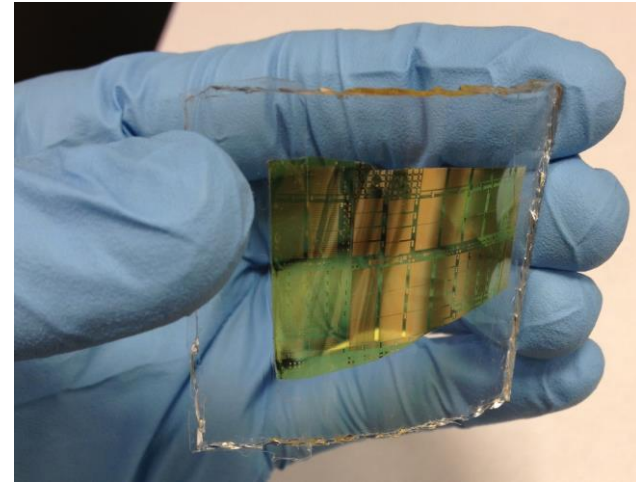
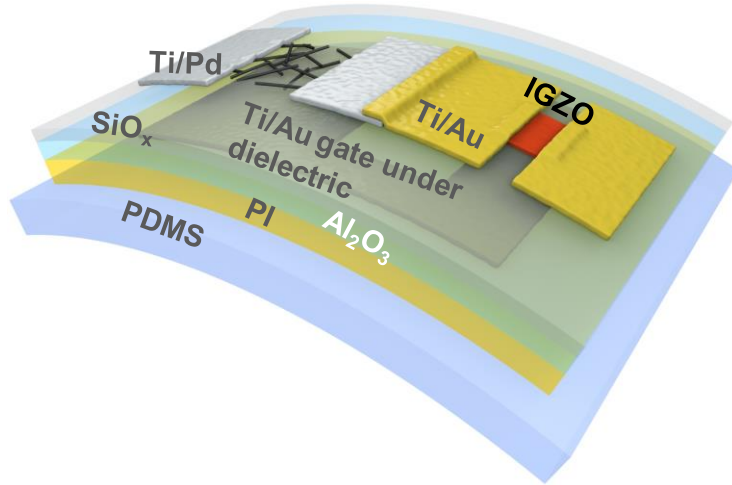




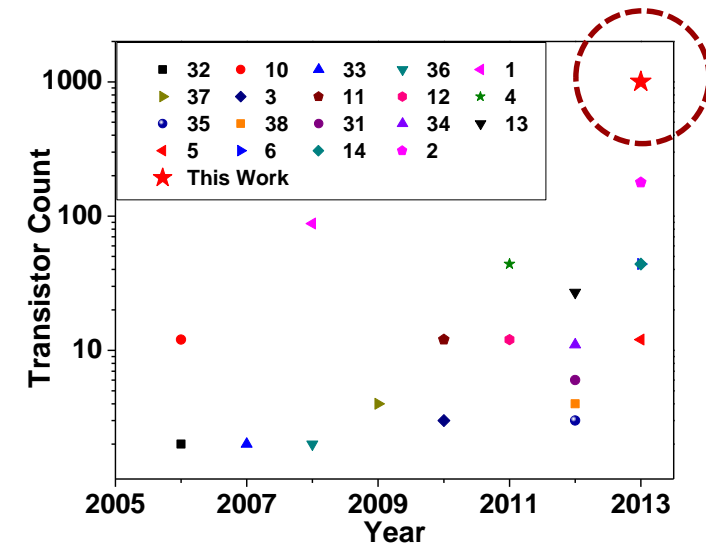
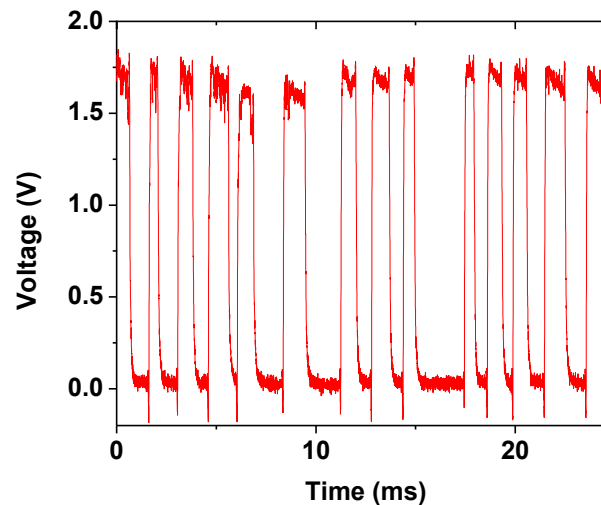
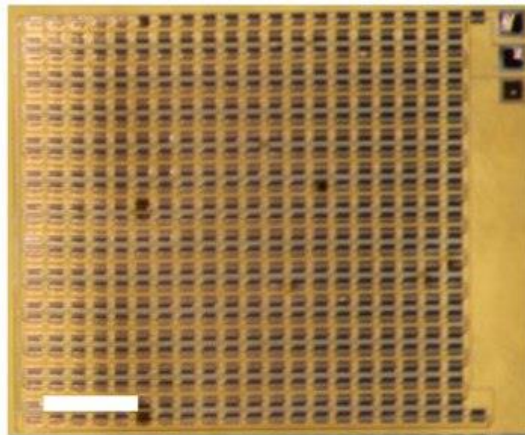
# Carbon Nanotube Ultra-Flexible Electronics



# Carbon Nanotube & IGZO for CMOS Flexible Electronics

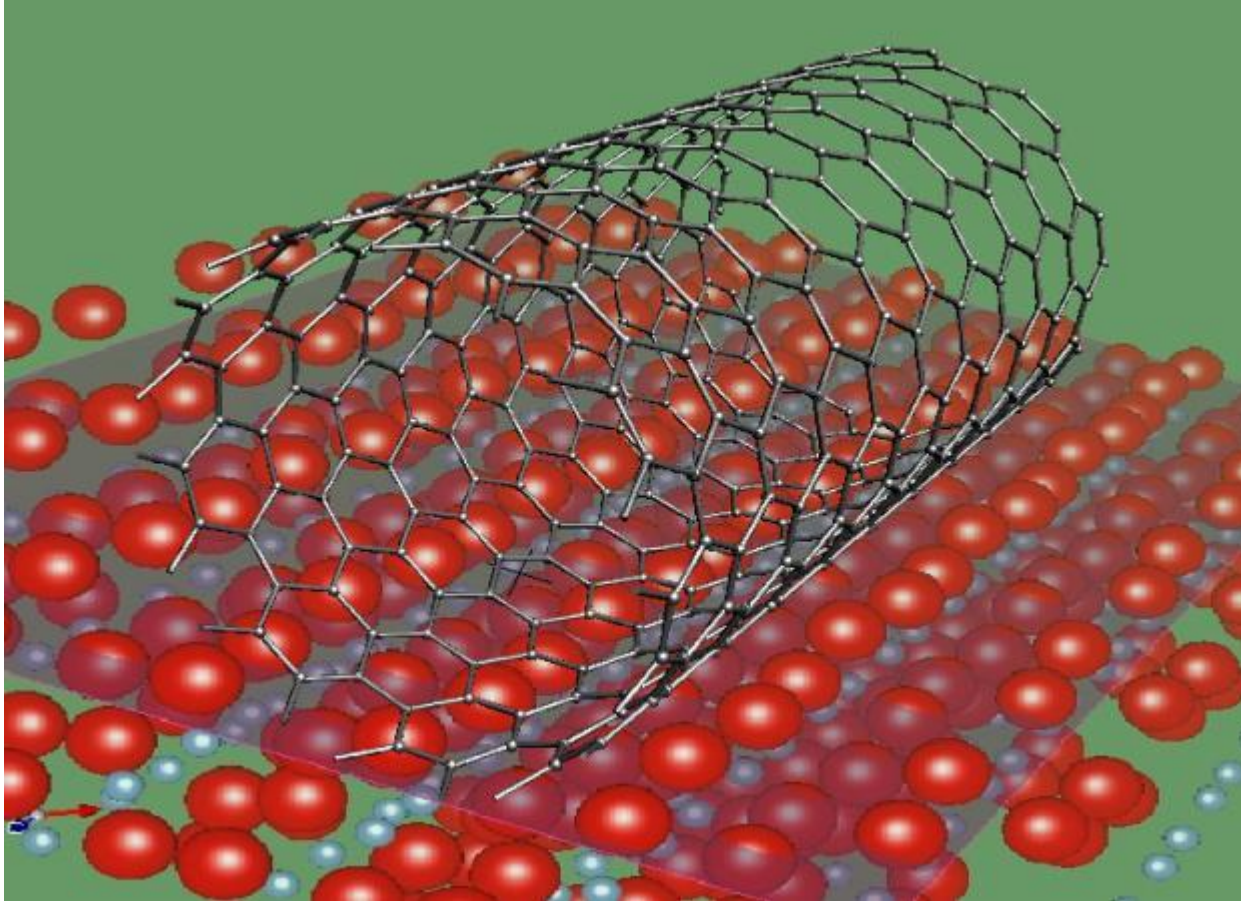


## 501-stage ring oscillator



Yu Cao, et al, *Nature Communications* 2014, 5, 4097

# Thanks for your attention!



<http://nanolab.usc.edu/>