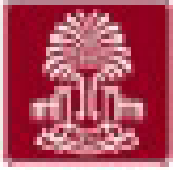


USC Department of Physics
Graduate Seminar

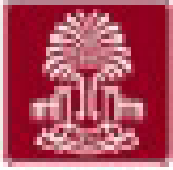


**GRAPHENE
NANORIBBONS**

Nahid Shayesteh,



- Carbon based material
- Discovery and innovation of graphen
- Graphene nanoribbons structure and...



□ Carbon-based nanoelectronics....

1. Replace silicon-based micro electronics
2. Exhibit superior physical properties in many aspects.
3. Industrial applications



□ The term *graphene*

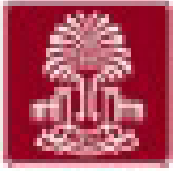
- ✓ 1962—Hanns-Peter Boehm coined graphene as a combination of graphite and the suffix –ene to describe single-layer carbon foils.

□ Hanns-Peter Boehm: Born January 9, 1928 in Paris

German Chemist

Professor Emeritus in Ludwig-Maximilians University in
Munich, Germany

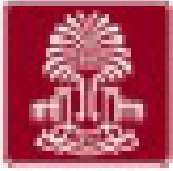
Pioneer of graphene research



- ❑ **Mitsutaka Fujita** (藤田 光孝 *Fujita Mitsutaka*)
 - ✓ Introduced graphene nanoribbons as a theory model to examine the edge and nanoscale size effect in graphene.
 - ✓ Japanese Physicist
 - ✓ Born: August 16, 1959
 - ✓ Died: March 18, 1998



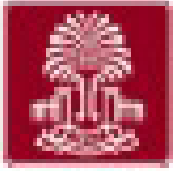
Nahid Shayesteh, Department of Physics



□ Definition: thin strips of graphene

- ✓ **Graphene nanoribbons**
- ✓ GNR's
- ✓ **Nano-graphene ribbons**

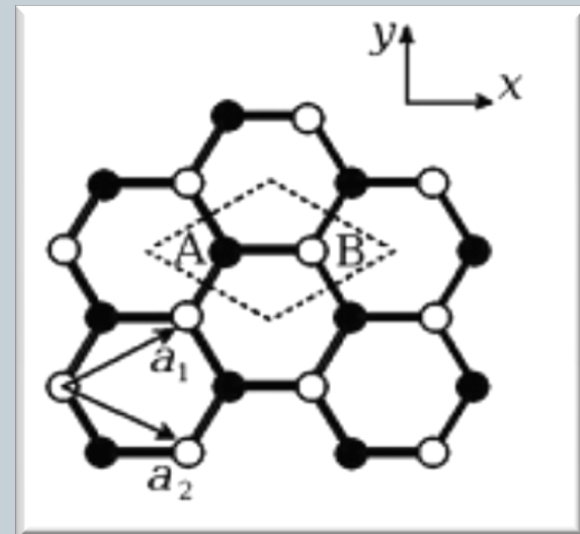
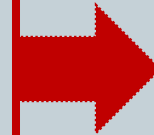




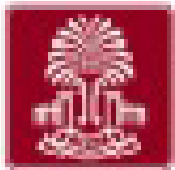
□ The structure of Graphene consists of...

- ❖ Honeycomb Lattice
- ❖ 2 Dimension thin layer of Carbon atoms

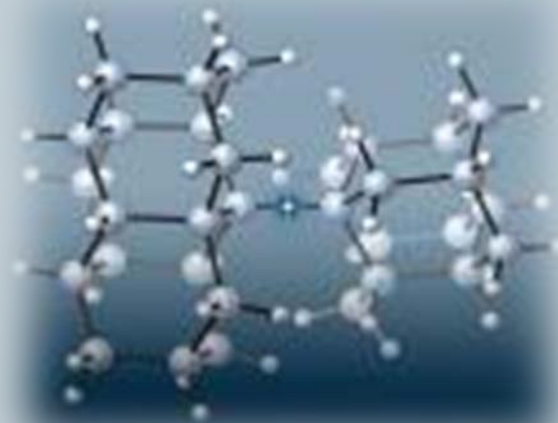
Basic structure of
carbon hexagon of
graphene

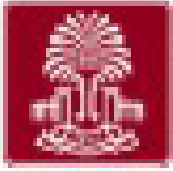


Nahid Shayesteh, Department of Physics



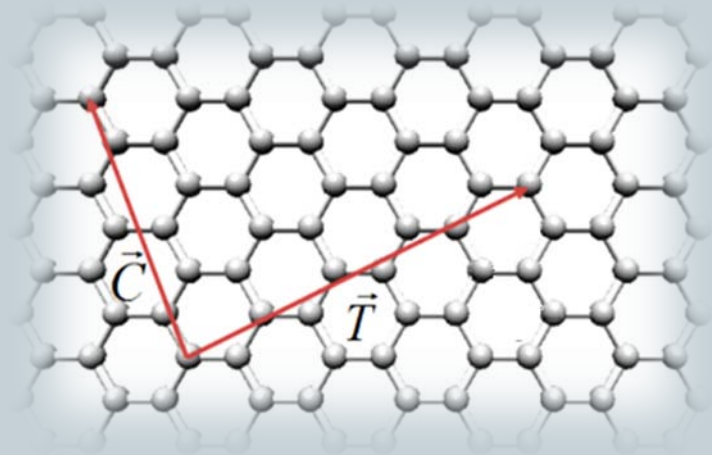
- ❑ The carbon-carbon bond length in graphene is about 0.142 nanometers.
- ❑ Graphene sheets stack to form graphite.
- ❑ One stack of 3 million sheets = 1 millimeter thick.
- ❑ Graphene is the basic structural element of some carbon allotropes including...
 - ✓ Graphite
 - ✓ Charcoal
 - ✓ Carbon Nanotubes
 - ✓ Fullerence



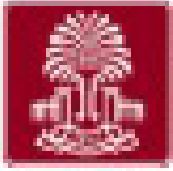


□ The *Energy* gap of the 1 dimensional graphene nanoribbons (GNRs), can be...

- ✓ Produced lithographically by patterning 2 dimensional graphene through a chemical route
- ✓ Different crystallographic orientations
- ✓ Tuned with varying widths



Nahid Shayesteh, PhD Candidate, M.S.C., B.S.

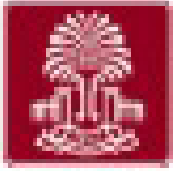


□ Graphene projections...

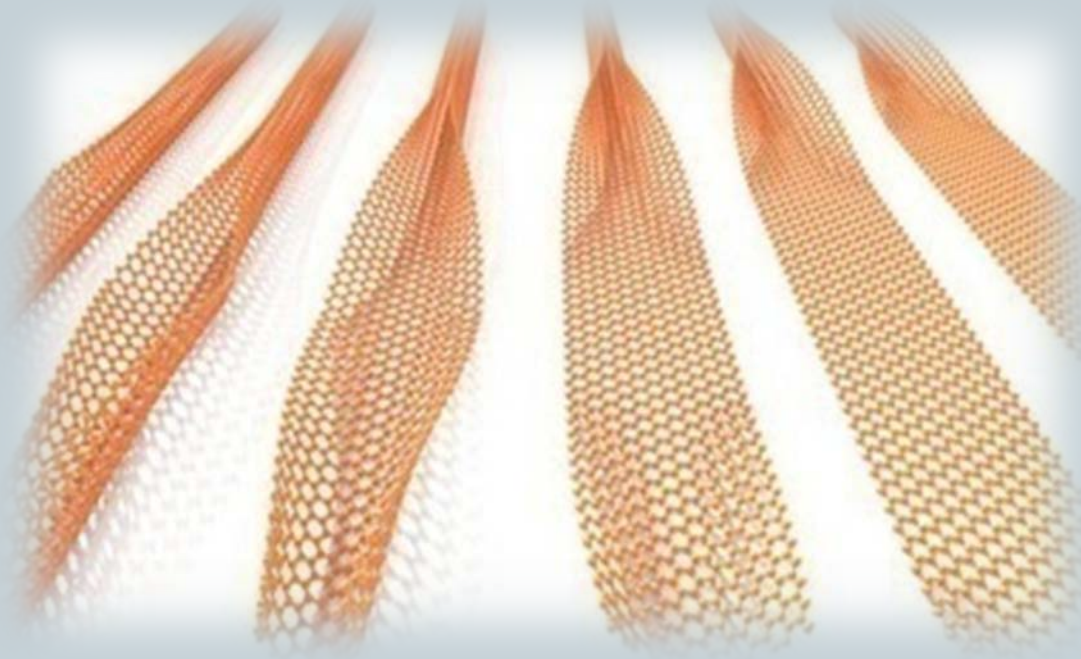
- ✓ Display hopeful electronic properties.
- ✓ Possess very high electron or hole mobility
(comparable to the properties observed in CNTs)

□ Graphene is considered a semimetal, because...

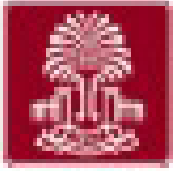
- ✓ There is no present band gap (band gap is zero),
- ✓ There is a narrow channel width (transverse direction) & a band gap can be provided.



- Graphenenanoribbons (GNRs) can be obtained by unzipping the single wall carbon nanotubes.



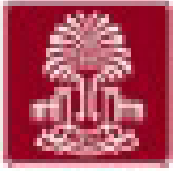
Nahid Shayesteh, PhD Candidate, M.S.C., B.S.



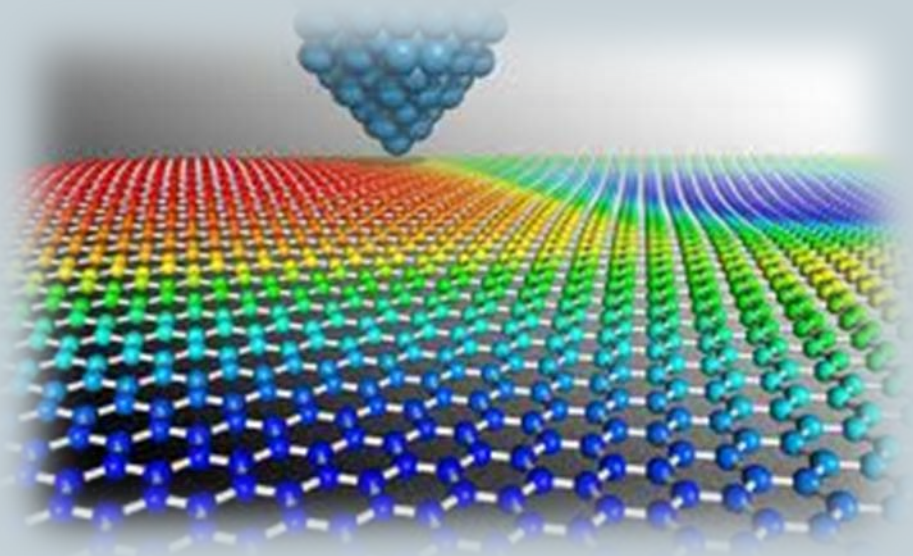
- ❑ The ribbon form of graphene (GNR)
 - ✓ Inherited almost all of the attractive properties of the carbon nanotube and graphene.
 - ✓ Additional benefit of a tunable band gap.
 - ✓ Tunable semiconducting behaviors vis a vis changing ribbon width.

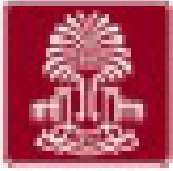
 - ❑ The first bandgap measurements are made by...
 - Phaedon Avouris.
 - Philip Kim

 - ❑ Opening of energy gaps...
 - Reported: 0.5 eV in a 2.5 nm wide armchair ribbon
- Nahid Shayesteh, Department of Physics*



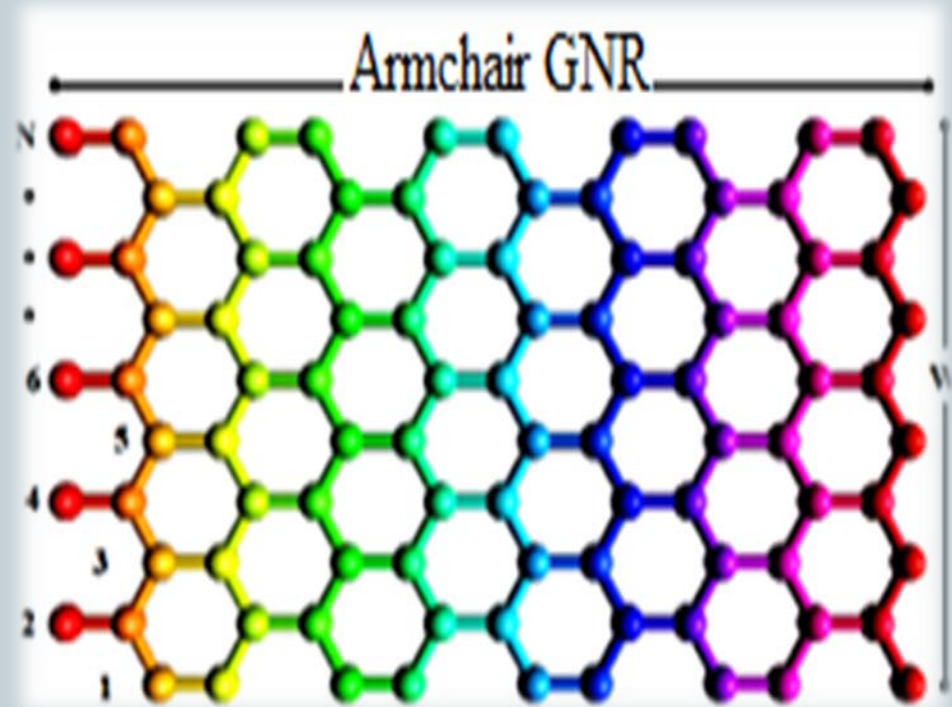
- ❑ Zigzag & Armchair GNRs are metallic or semiconducting electronic properties that depends on the width of the nanoribbon.
- ❑ Electronic properties depend on...
 - the edge shape
 1. armchair
 2. zigzag

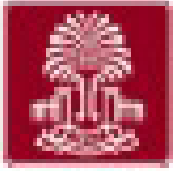




Armchair GNR's...

- ❑ Liang work shows certain armchair GNRs can display semiconducting behavior.
- ❑ Armchair ribbon is semiconducting when
 - ✓ $N=3p$ or
 - ✓ $N=3p+1$
 - ✓ #of dimer lines $N=3p+2$ is semimetal behavior (p is integer).





Zigzag GNR's...

15

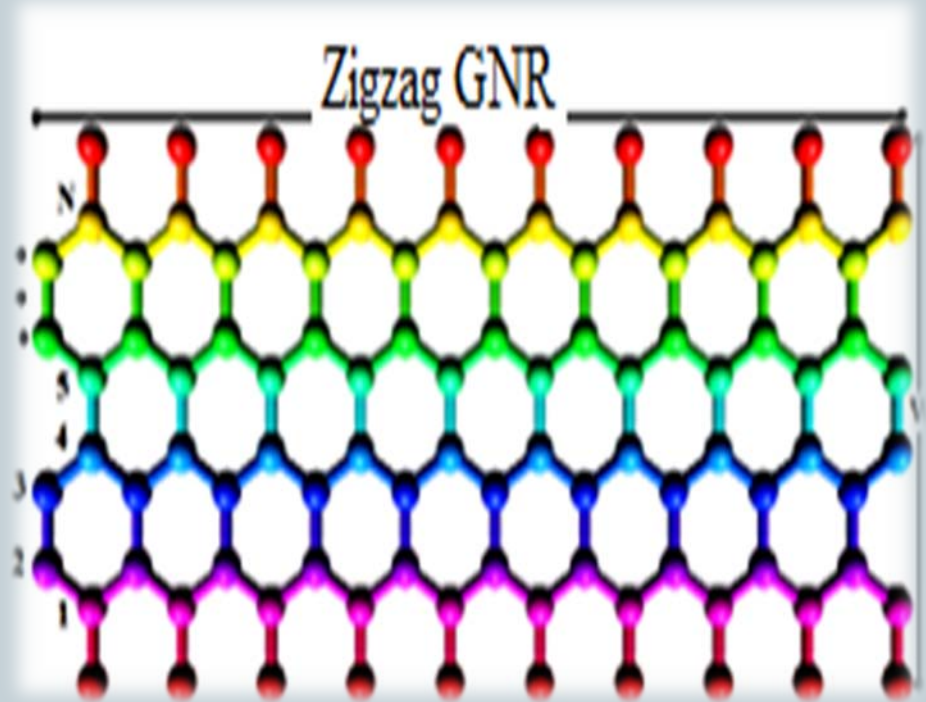
□ Zigzag GNRs are either...

1. Semiconducting

2. Metallic

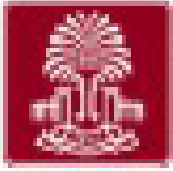
And

Expected to be more
conductive

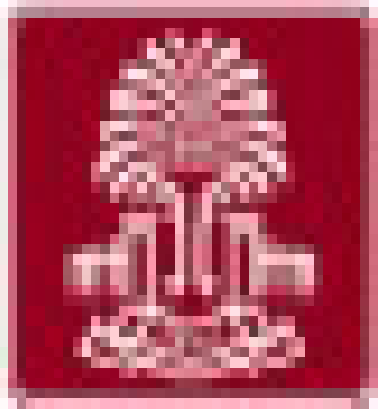




- ❑ New types of the graphene base material can be achieved.
- ❑ Carbon based material have different application depend on their structure



1. Bu, H., et al., *Atomistic simulations of mechanical properties of graphene nanoribbons*. Physics Letters A, 2009. **373**(37): p. 3359-3362.
2. Eduardo V Castro¹, N.M.R.P., J M B Lopes dos Santos¹, and F.G.a.A.H.C. Neto⁴, *Bilayer graphene: gap tunability and edge properties*. Journal of Physics, 2010. **129**(1): p. 012002(8).
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4. Group, C.M., *Moore's Law: More or Less*. www.cmg.org/measureits/issues/mit41/m_41_2.html, 2010.
5. Novoselov, K.S., *Electronic properties of graphene*. phys. stat. sol. , 2007. **244**(11 / DOI 10.1002/pssb.200776208): p. 4106-4111.



U N I V E R S I T Y O F
SOUTH CAROLINA.

Thank you for your time and consideration. I will be more than happy to answer any questions or concerns that you may have at this time.