# Applications of ‘GRAPHENE’ IN ELECTRONICS AND COMMUNICATIONS.

by

A.Sai Joshitha(17011A0423)

ECE reg.

# CONTENTS:

# MOTIVATION:

ScienceDaily

## Graphene: Increased market penetration by 2025

Now, researchers at Graphene Flagship partner The Fraunhofer Institute for ... just issued by IOP Publishing's journal 2D Materials, review the latest outcomes of ... "We are continuously analysing scientific and technological ...

25-Jan-2021

ScienceDaily

## Graphene 'nano-origami' creates tiniest microchips yet ...

This is the first time any researchers have done this, and it is covered in a paper published in the ACS Nano journal. By creating kinks in the ...

16-Feb-2021

Science News from research organizations

## Graphene and 2D materials could move electronics beyond 'Moore's Law'

Date: June 3, 2020

Source: University of Manchester

Summary: New developments in spintronics could lead to graphene being used as a building block for next-generation electronics.

SciTechDaily

## Progressing Electronics Beyond Moore's Law With Graphene and 2D Materials

Recent theoretical and experimental advances and phenomena in studies of electronic spin transport in graphene and related two-dimensional ...

07-Jun-2020

SciTechDaily

## Semiconducting Graphene Ribbons Developed for Electronics and Quantum Computing

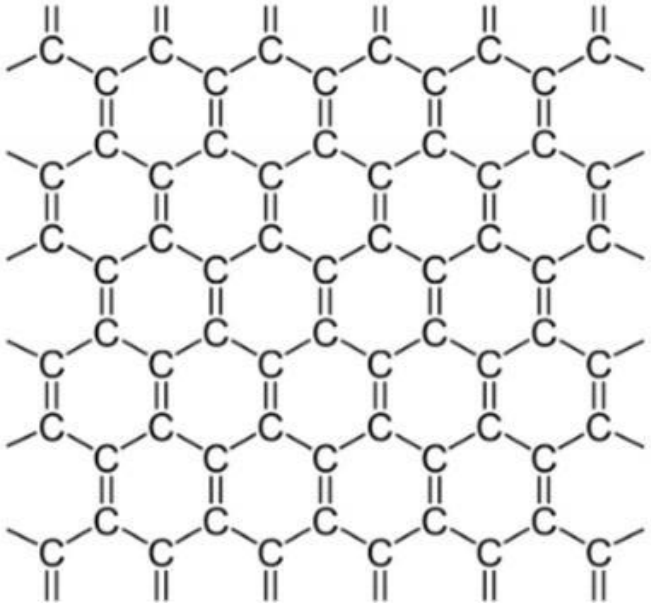
Graphene consists of a single layer of carbon atoms arranged in a ... Shi-Xia Liu and Ernst Meyer, 26 June 2020, Journal of the American ...

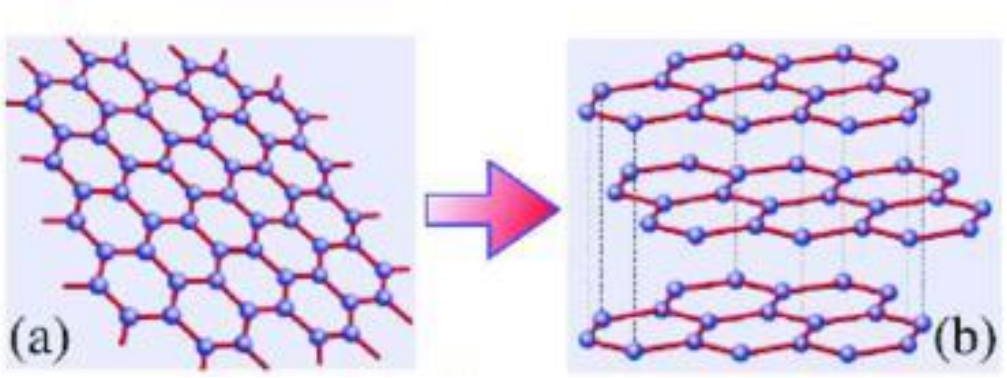
13-Jul-2020

News Collected from scientific news journals from google

# INTRODUCTION:

- Graphene is a single layer (monolayer) of carbon atoms, tightly bound in a hexagonal honeycomb lattice. It is an allotrope of carbon in the form of a plane of sp2-bonded atoms with a molecular bond length of 0.142 nanometers.





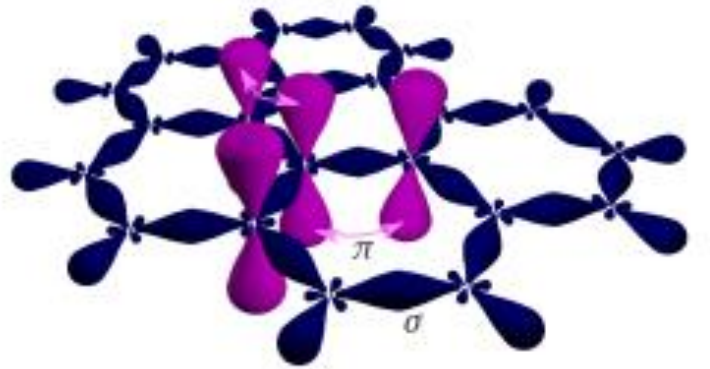

(a) Layer of graphene
(b) Layers of graphene stacked on top of each other form graphite, with an interplanar spacing of 0.335 nanometers.

Images are taken from www.graphene-info.com/graphene-structure-and-shape

# PROPERTIES OF GRAPHENE:

**Chemical Properties:**

- Graphene is a zero overlap semimetal.
- In Graphene carbon has sp2 hybridization. Each carbon atom has 3 sigma bonds and 2 pi electrons which travel with speed of light




**Mechanical properties:**

- High Young's Modulus (about 1TPa)
- High intrinsic strength (about 130GPa)
- High elasticity
- Ultimate tensile strength of 130,000,000,000 Pascals (or 130 gigapascals)

**Electrical Properties:**

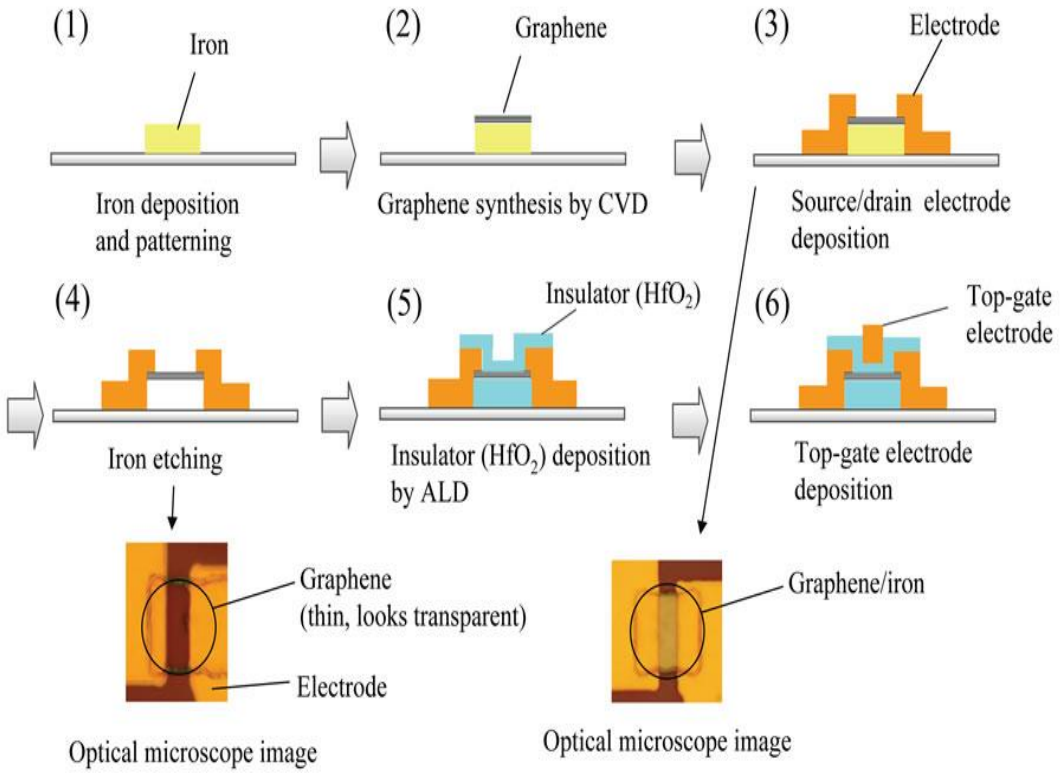
- The freely available electrons (pi-electrons) that do not get bonded are the reason for electrical conduction to take place.
- Graphene behaves as a semiconductor just like the Silicon, Germanium and GaAs. But since the cause of conduction in graphene is different from that of other semiconductor materials
- The electron mobility of graphene in its pristine form is more than 200,000 cm2 /Vs.
- The sheet resistance of graphene is about 30 ohms. Graphene is mainly a sheet resistance with a very high transmittance of about 90%.
- Graphene atoms are considered as massless, they behave much similar to photons.

**Optical Properties:**

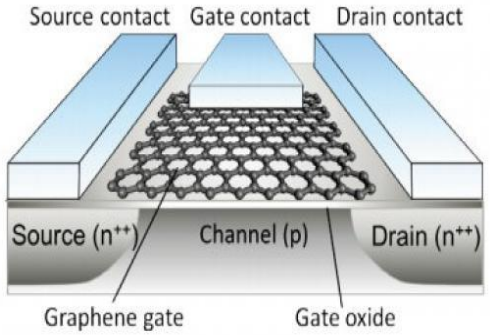
- Graphene has very good absorption capacity.
- Even though graphene in pristine form is just 1 atom thick, it has ability to absorb 2.3% of white light.

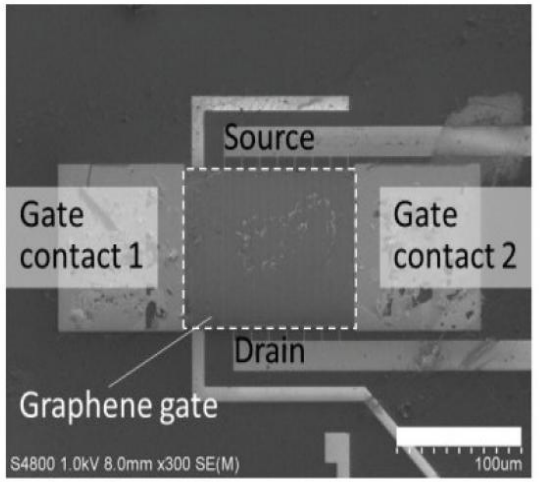
**Lets see…**
**where these properties are applied**
**and how it is revolutionizing silicon era**

# GRAPHENE TRANSISTORS



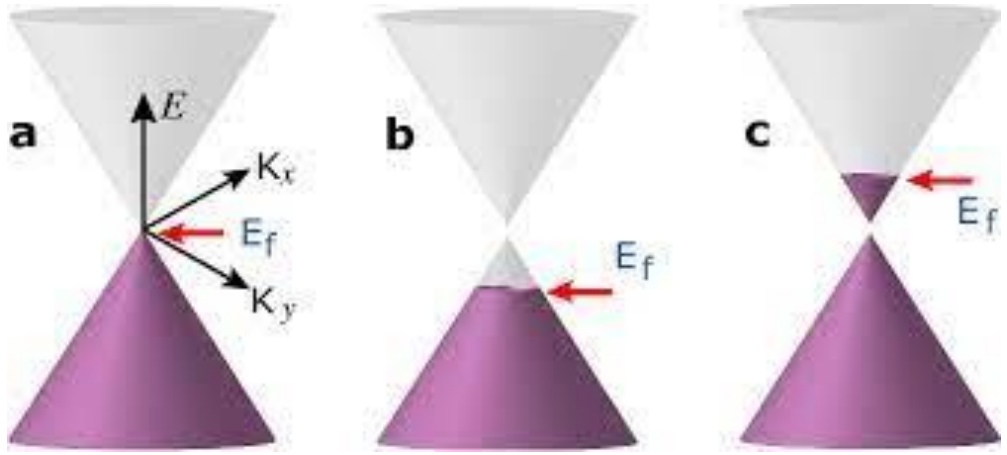

Fujitsu process of making graphene transistor




Images are taken from Javad Bavaghar Chahardeh "A Review on Graphene Transistors" International Journal of Advanced Research in Computer and Communication Engineering, June 2012

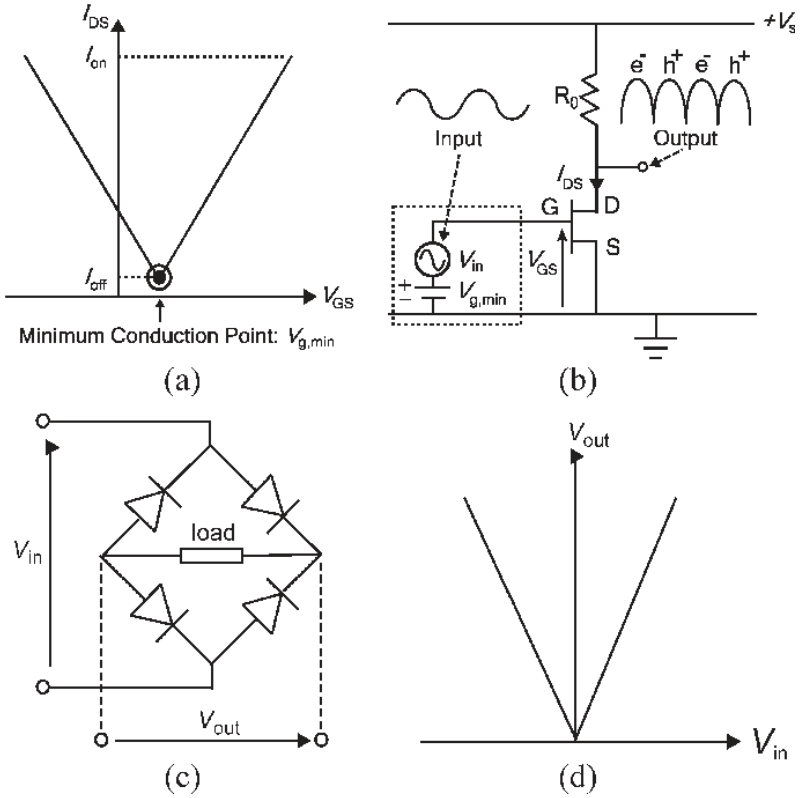
- Hetero atom doping, chemical modification, Electrostatic field tuning methods are used to adjust fermi level.




Schematic band structures of graphene.

(a) Band structure of pristine graphene with zero-bandgap. Ef is at the cross-over point.
(b) p-type ,Ef lies in valence band
(c) n-type graphene with the bandgap. Ef lies in conduction band

# GRAPHENE FREQUENCY MULTIPLIERS(DOUBLERS)



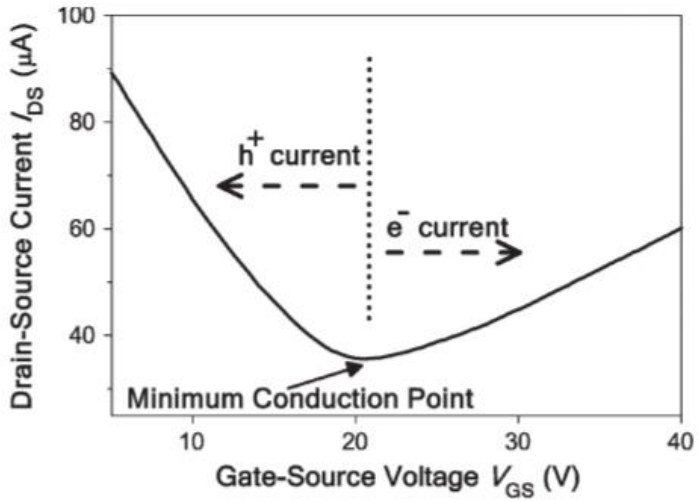

a) Piecewise linear approximation of the transfer characteristic of ambipolar G-FETs.

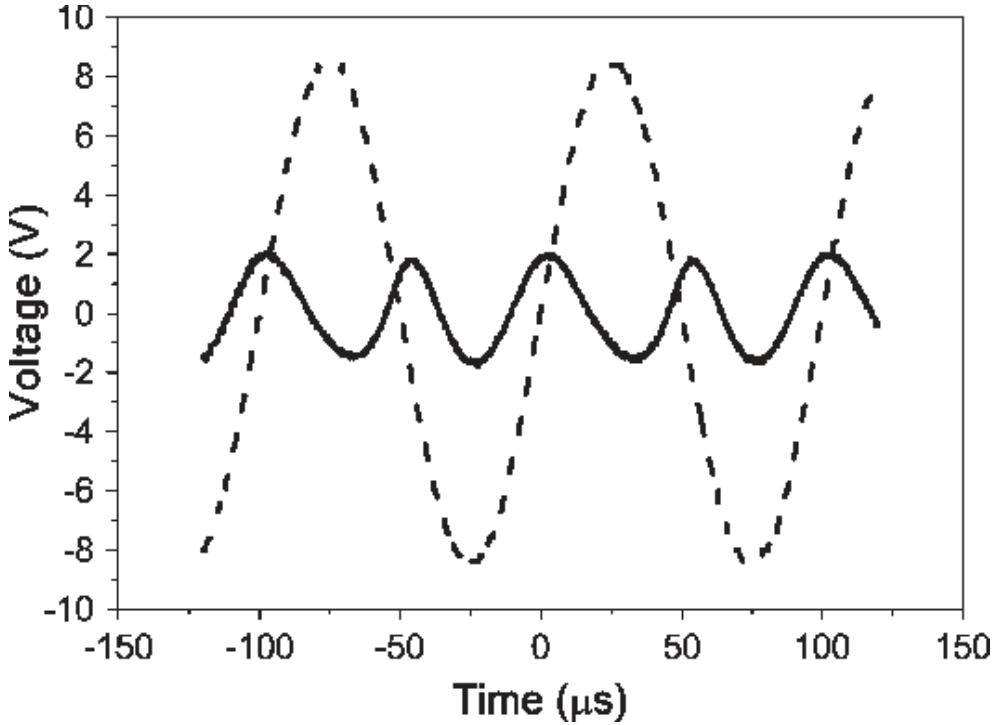
b) Graphene-based circuit for frequency multiplication of the input signal Vin.

c) Typical full-wave rectifier circuit.

d) Ideal input–output characteristics of a full-wave rectifier.

Images are taken from Han Wang, Nezich, D., Jing Kong, & Palacios, T. (2009). Graphene Frequency Multipliers. IEEE Electron Device Letters,2009




- Using semiconductor parameter analyser, series resistance taken as 5.03kohms, drain bias of 2.87v, Vgmin of 20.1v.
- Agilent oscilloscope is used to observe input and output graphs.

# SLOT ANTENNA

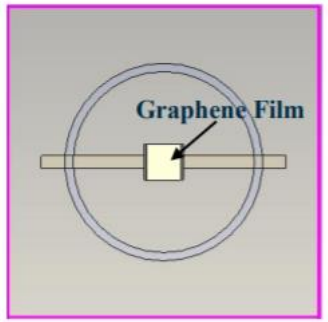



Fig 1.Slot Antenna with Graphene loading.

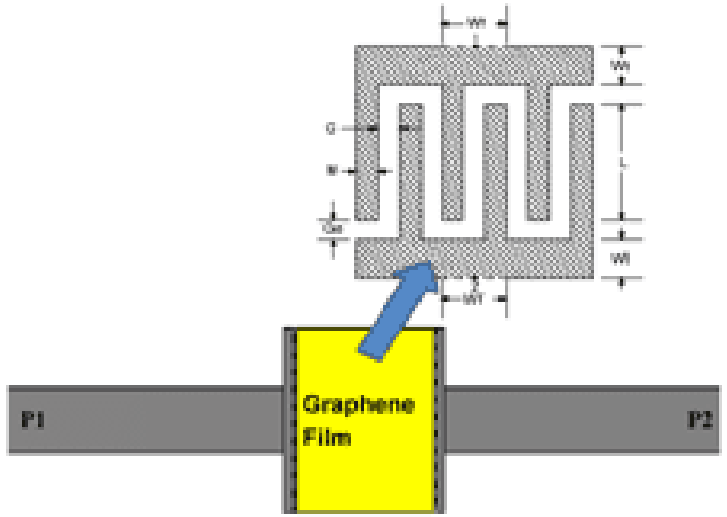
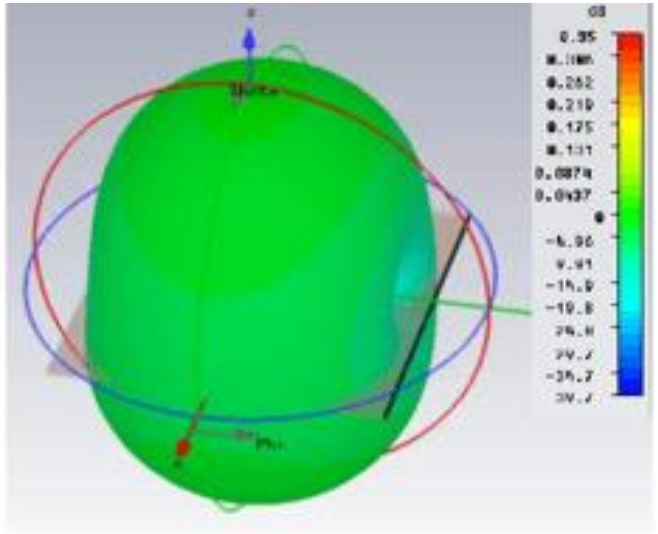



Fig 2. Geometry of an interdigitated capacitor (IDC) with a graphene film overlaid on the fingers.

L=4mm,G=0.1mm,Ge=0.1mm,Wt=1.52mm,N=11.

Images are taken from Krishna Naishadham ,Design of a Graphene Loaded Slot Antenna with 100:1 Bandwidth for Wireless Sensor Applications ; Antennas and Propagation Society International Symposium (APSURSI), published by IEEE ,2014

Radiation pattern at 3.46 GHz showing gain of 0.35 dBi using CST Microwave studio.

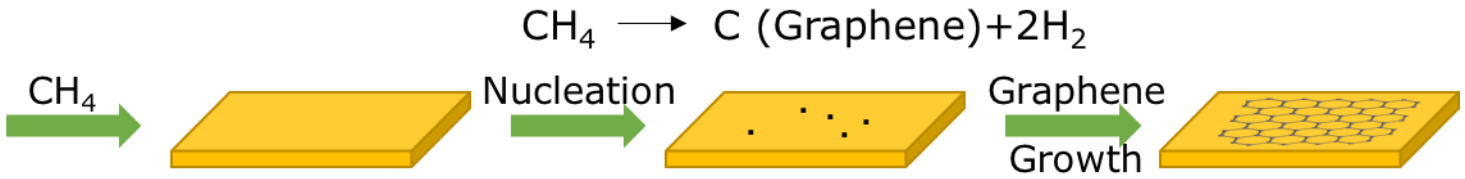


- If Entire surface of the Antenna is covered with graphene, return loss of almost 0 dB is achieved but radiation efficiency is compromised which is only 6%.
- There is trade off between radiation efficiency and losses.
- In order to increase the radiation efficiency, IDC with graphene film is placed now radiation efficiency of 44% is achieved with return loss of <20db.

| Application | General Lead | Requirements |
|---|---|---|
| **Slot Antenna** | **To avoid radiation losses but need to be compromised in terms of radiation efficiency** | **Its one layer atom and small structure** |
| **Transistors(GFETs)** | **To achieve high mobility of electrons** | **Due to zero band gap property and free, fast pi electrons** |
| Organic Light Emitting Diode(OLEDs)Graphene | Can be used in wearable technologies and can be folded to a radius of <5mm | A better control over sheet resistance is required |
| Touch screens | Easy to implement compared to ITO(Indium Titanium Oxide) and nano ribbons | Requires Flexibility and control over contact resistance |
| **Frequency multiplier** | **Output signal has harmonics of Fundamental frequency of input signal** | **Ambipolar GFETS with mobility of hole rate equal to mobility of electron.** |
| Batteries | Graphene electrodes are useful due to their ultra thin size and flexibility. | High Thermal Conductivity. It shouldn't susceptible to oxidation |
| Supercapacitors | Holds large amount of charge for long time and charging time is also less | Due to high electron mobility |
| Biosensors(In Medical) | Drug delivery and precise targeting of cancer cells. | This is done by simply keeping the graphene oxide layer in a solution of appropriate pH and then applying electric field .These droplets reach the active affected site and then open up. |

# AVAILABILITY AND MANUFACTURING OF GRAPHENE

- For more than 60 years Graphene has been studied by various scientists. But since graphene was not available in Free State it was not considered as a practical material that can be used. More specifically it was being referred to Academic Material.
- Graphene was properly isolated and characterized in 2004 by Andre Geim and Konstantin Novoselov at the University of Manchester. For this work they were awarded with Nobel Prize. Later Graphene CVD was first reported in 2008 and 2009, using Ni and Cu substrates.


A single layer of graphene is deposited onto a copper substrate and then etched.

Images are taken from wikipedia.org/wiki/Graphene, acs material 2017

# LIMITATIONS:

- Graphene acts as a catalyst gets prone to oxidative environments.
- Also it has been found that graphene inhibits some toxicity too.
- Being a great conductor of electricity, and due to its zero band gap ,it can't be switched off.
- Till now we saw many applications of Graphene but the major drawback of graphene is ‘it could not be produced easily in large industrial scales’.

# CONCLUSION

- Graphene is the trending material on which lots of research are taking place.
- Graphene is a wonder material with low mass, high strength, more conductivity, more flexible and with very high sheet resistance.
- Due to its exotic properties it can used in various fields and helps in revolutionising the world.


Image is taken from Chaitoglou, Stefanos.” Growth Study and Characterization of Single Layer Graphene Structures Deposited on Copper Substrate by Chemical Vapor Deposition”,2016

# FUTURE SCOPE

- If Graphene could be produced on large scales ,then In next 20-30 years the key component of electronics industry will be graphene.

  Graphene can be used as flexible screen for smartphones.
  Graphene in aviation, Satellites.
  Graphene can be used in ultrafiltering of sea water( Any toxic materials in sea water).
  Double Graphene sheet as  an Armour shield…etc.

# REFERENCES


- A. Dubey, S. Dave, M. Lakhani and A. Sharma, "**Applications of graphene for communication, electronics** and medical fields: A review," International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT), 2016.
- Krishna Naishadham ,Design of a **Graphene Loaded Slot Antenna** with 100:1 Bandwidth for Wireless Sensor Applications ; Antennas and Propagation Society International Symposium (APSURSI), published by IEEE ,2014.
- Javad Bavaghar Chahardeh "**A Review on Graphene Transistors**" International Journal of Advanced Research in Computer and Communication Engineering,June 2012 .
- Han Wang, Nezich, D., Jing Kong, & Palacios, "**Graphene Frequency Multipliers"**. IEEE Electron Device Letters,2009 .

# THANK YOU