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A PATH FOR HORIZING YOUR INNOVATIVE WORK

MANUFACTURING OF ELECTRONICS COMPONENTS USING GRAPHENE

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Abstract: The richness of optical and electronic properties of graphene attracts enormous interest. Graphene has high mobility and optical transparency, in addition to flexibility, robustness and environmental stability. So far, the main focus has been on fundamental physics and electronic devices. However, its true potential lies in photonics and optoelectronics, where the combination of its unique optical and electronic properties can be fully exploited, even in the absence of a band Electronic segment, LEDs gap, and the linear dispersion of the Dirac electrons enables ultra wideband tenability. The rise of graphene in photonics and optoelectronics is shown by several recent results, ranging from solar cells and light-emitting devices to touch screens, photo detectors and ultrafast lasers.

Keywords: Optic Fiber, Opto-Electronic Devices.

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INTRODUCTION

1.1 Problems associated with existing technology:-

Silicon has provided the opto-electronics industry a solid base of favorable properties capitalizing on which various advancements in electronics have been made (in terms of speed and size). But now it seems that silicon is approaching its limits. Electroluminescent devices have still some way to go to meet the requirements of quantum efficiency, high operating frequency and lifetime necessary to compete with the hybrid solution using III-V optoelectronic systems. The speeds of silicon devices have stuck in the gigahertz range. Furthermore, it has become too difficult to increase the data rate in optical communication system.

1.2 Graphene:-

Graphene is a rising star in material science, which brought Nobel Prize to Andre Geim and Konstantin Novoselov for fabrication, identification and characterization of it in 2004. Since the start of the graphene revolution, numerous application concepts based on graphene have been demonstrated. In just a few years, high-frequency graphene transistors have reached performance that rivals that of the best semiconductor devices that have over sixty years research effort behind them; graphene electronics is still very much at its infancy and, extrapolating from recent progress, it is expected that graphene devices will break the 1 THz barrier in a matter of a few years [1–5]. The richness of optical and electronic properties of graphene attracts enormous interest. Graphene has high mobility and optical. Transparency, in addition to flexibility, robustness and environmental stability. In optoelectronics, the first graphene-based touch screen was recently demonstrated in a collaboration between SKK University and Samsung in Korea [6]. Graphene is being used to produce tunable lasers by exploiting the material's unusual electronic structure that guarantees a wide tunability range [3,7]. Graphene's properties also imply that the percentage of light absorbed decreases when the incoming light intensity increases, which can be exploited to fabricate very fast pulsed lasers that have great potential in optical communication [3,7].

The rise of graphene in photonics and optoelectronics is shown by several recent results, ranging from solar cells and light-emitting devices to touch screens, photo- detectors and ultrafast lasers. So keeping in view the limitations of Silicon based technology, Graphene can be a fanciful replacement to obtain high speed opto-electronic devices. In the subsequent chapters we will go through the literature (Existing fiber optics communication, Rise of graphene), graphene fabrication techniques, its various properties, applications and at last future aspects and conclusion.

II. LITERATURE REVIEW

2.1 The Optical Communication System The major characteristics of a telecommunication system are unquestionably its information carrying capacity, but there are many other important characteristics. For instance, for a bank network, security is probably more important than capacity. For a brokerage house, speed of transmission is most crucial feature of a network. In general, though capacity is priority one for most of the system users, we cannot increase it as much as we would like. The major limit is shown by the Shannon-Hartley theorem,

$$C = BW \times \log_2(1+SNR) \quad (2.1)$$

where C is the information-carrying capacity (bits/sec), BW is the link bandwidth (Hz), SNR is the signal to noise ratio. Thus the information-carrying capacity is proportional to channel bandwidth, the range of frequencies within which the signals can be transmitted without substantial attenuation (eq.2.1). What limits the channel bandwidth? The frequency of the signal carrier. The higher the carrier's frequency, the greater the channel bandwidth and the higher the information-carrying capacity of the system. Fiber optic communication system use light as the signal carrier; light frequency is between 100 and 1000 THz; hence we can estimate the bandwidth of a single fiber-optic communication link as 50 THz or above. An optical communication system consists of an electronic segment and optical segment. The devices in the electronic segment are generally fabricated on Si chips. These devices convert information into electrical form, modulated and multiplexed. Then the signal moves to the optical transmitter, where it is converted into optical form by optical transmitter. The optical sources such as LEDs and LDs are heart and soul of the transmitters. They are usually made up of semiconductor materials such as Si, Ge, GaAs, etc. The modulation bandwidth (BW range of frequencies within which the signal can be transmitted without substantial attenuation) of the optical sources (LED) is given by,

$$BW = 0.35/tr \quad (2.2)$$

Where t_r is the rise time of the device, which is proportional to the mobility of the charge carriers (recombination lifetime). As the mobility of charge carriers are fixed, further increase in speed of the devices is very difficult to achieve (limited bandwidth). Most of the engineers and scientists think that it will eventually become too complex and expensive to reduce the size of silicon chips. Also, the speeds of silicon chips have stuck in the gigahertz range. Hence the enormous bandwidth of the fiber optic cable is limited due to the limitations of the electronics involved. So as the electronics world is looking for new candidate materials, Graphene seems to offers an exceptional choice [20].

2.2 Graphene

Graphene is single layer of carbon atoms arranged in a hexagonal lattice with a host of properties ideal for applications, see Fig.2.2. One of the commonly occurring forms of carbon, graphite, is a stack of graphene layers, and has been used in a number of applications for hundreds of years. The current focus on graphene followed the ground-breaking experiments by A.K. Geim and K. Novoselov in 2004 that were acknowledged with the Nobel Prize in Physics in 2010 [1]. The huge interest in graphene is driven by the considerable and tantalizing potential that this material offers in conventional as well as radically new fields of information and communication technology (ICT) applications [2,3]. The electronic structure of graphene is very unusual – the electrons behave more like massless, relativistic particles than like the charge carriers in everyday electronics – which leads to higher device speeds and potential for electronics that is much faster than what we have today [4,5]. Graphene is almost transparent, absorbing only 2.3% of incident light [8], and very well suited for photovoltaic applications in optoelectronics, touch screens and solar cells [3]. Due to its ultimate thinness, graphene is very flexible, but at the same time graphene is the strongest material we know (about 300 stronger than steel with the same weight) [9] as well as the best conductor of heat [10], which enables not only flexible electronics but many applications outside ICT as, e.g., strong lightweight composites. Some of graphene's superlative properties are given in Fig. 2.2

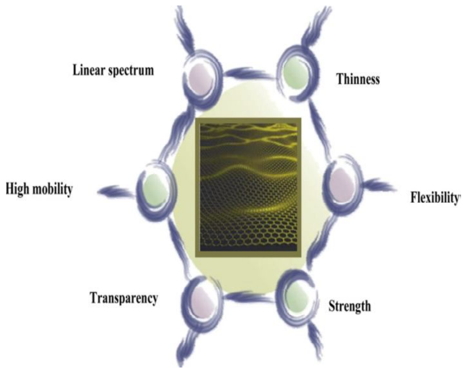

Fig. 2.2 The unique properties of graphene [21]

2.3 2D Materials That Should Not Exist

More than 70 years ago, Landau and Peierls argued that strictly 2D crystals were thermodynamically unstable and could not exist. Their theory pointed out that a divergent contribution of thermal fluctuations in low-dimensional crystal lattices should lead to such displacements of atoms that they become comparable to inter atomic distances at any finite temperature. For this reason, atomic mono layers have so far been known only as an integral part of larger 3D structures, usually grown epitaxially on top of mono crystals with matching crystal lattices. Without such a 3D base, 2D materials were presumed not to exist, until 2004, when the common wisdom was flaunted by the experimental discovery of Graphene and other free-standing 2D atomic crystals [11].

2.4 Discovery of Graphene

Graphene has always existed; the crucial thing was to be able to spot it. Similarly, other naturally occurring forms of carbon have appeared before scientists when they viewed them in the right way: first nano-tubes and then hollow balls of carbon, fullerenes. Trapped inside graphite, Graphene was waiting to be released. No-one really thought that it was possible. The pessimistic assumption was put to rest in 2004. **A. K. GEIM**, in collaboration with then postdoctoral associate **K. S. NOVOSELOV** and his co-workers at the University of Manchester in England, was studying a variety of approaches to make even thinner samples of graphite. At that time, most laboratories began such attempts with soot, but Geim and his colleagues serendipitously started with bits of debris left over after splitting graphite by brute force. They simply stuck a flake of graphite debris onto plastic adhesive tape, folded the sticky side of the tape over the flake and then pulled the tape apart, cleaving the flake in two. As the experimenters repeated the process, the resulting fragments grew thinner. Once the investigators had many thin fragments, they meticulously examined the pieces- and were astonished to find that some were only one atom thick. Even more unexpectedly, the newly identified bits of Graphene turned out to have high crystal quality and to be chemically stable even at room temperature. The experimental discovery of Graphene led to a deluge of international research interest. Not only it is the thinnest of all possible materials, it is also extremely strong and stiff. Moreover, in its pure form it conducts electrons faster at room temperature than any other substance. Engineers at laboratories worldwide are currently scrutinizing the stuff to determine whether it can be fabricated into products such as super tough composites, smart displays, ultrafast transistors and quantum- dot computers. Since its discovery in 2004, Graphene has been viewed as a promising new electronic material because it offers superior electron mobility, mechanical strength and thermal conductivity. These characteristics are crucial as electronic devices become smaller and smaller, presenting engineers with a fundamental problem of keeping the devices cool enough to operate efficiently.

Graphene Fabrication:-

The most common method of Graphene fabrication is exfoliation which finds its roots with a technique that has been around for centuries writing with a graphite pencil. By writing with a pencil you create many Graphene sheets spread over your paper. Unfortunately this method is uncontrolled and you are typically left with many sheets of varying thicknesses.

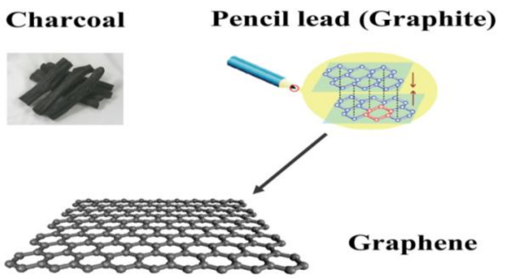

Fig.3.1 Extraction of Graphene using Exfoliation of graphite pencil lead

.3.2 Epitaxial Growth

3.2.1 Epitaxial growth on silicon carbide

Yet another method of obtaining Graphene is to heat silicon carbide to high temperatures (>1100°C) to reduce it to grapheme [13]. This process produces a sample size that is dependent upon the size of the SiC substrate used. The face of the silicon carbide used for Graphene creation, the silicon-terminated or carbon-terminated highly influences the thickness, mobility and carrier density of the graphene.

3.2.2 Chemical vapor deposition (CVD) Recently, two groups one led by MIT's Jing Kong, the other by Byung Hee Hong of SKKU University in South Korea used chemical vapor deposition of methane to grow Graphene on thin nickel films [14]. The Graphene was then either patterned lithographically or transferred onto silicon or plastic. The SKKU team has now adapted that approach to a scalable industrial manufacturing process that uses copper rather than Si. In roll-to-roll production, as outlined in the Fig. 3.4, Graphene-laden Cu was pressed against a polymer support, bathed in an etchant that removed the Cu, and then dry-transferred to another flexible polymer. To increase the film's conductivity, multiple layers of Graphene were stacked together and chemically doped in a bath similar to that used for etching. The technique which currently seems to have the greatest potential for mass production is the direct growth of Graphene.

CONCLUSION:-

Graphene films and composites have ideal electronic and optical properties for photonics and optoelectronics. Graphene is an attractive replacement for ITO and other transparent conductors. In many cases (touch screens or OLEDs, for example), this increases fabrication flexibility, in addition to having economic advantages. Present liquid-crystal-based devices face high fabrication costs associated with the requirement for large transparent electrodes. The move to a graphene-based technology could make them more viable. New forms of graphene-based transparent electrodes on flexible substrates for solar cells can add value and a level of operational flexibility that is not possible with current transparent conductors and rigid glass substrates. Recent progress in growth and dispersion processing of graphene have definitely made this material 'come of age', thus encouraging industrial applications. Deterministic placement of graphene layers on arbitrary substrates, and the creation of multilayers by the individual assembly of monolayers at given angles, are now possible. Future efforts in the field of nonlinear optical devices will focus on demonstrators at different wavelengths to make full use of graphene's ultrawide broadband capability. This could include high-speed, transparent and flexible photosensitive systems, which could be further functionalized to enable chemical sensing. Ultrafast and tunable lasers have become a reality, with an ever-growing number of groups entering this field. The combination of graphene photonics with plasmonics could lead to a wide range of advanced devices.

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