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COMPARATIVE STUDY OF POLYMER AND SEMICONDUCTOR FOR FRACTIONAL QUANTUM HALL EFFECT

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Over the last few years conductive polymers and semiconductor have become the most important material for the fabrication of electronic and optoelectronic devices. The discoveries of Quantum Hall Effect have resulted in the quest for the new electronic devices based on low dimensions semiconductor structures such as two one and even zero dimension system. In these structures, quantum mechanical effects will become essential, once a typical length scale of 100 *nm or less is reached. We have analyzed and realized that certain conductive polymers can also exhibit the fractional quantum hall effect and compare to semiconductor they are more reliable cost effective and potential candidate for the future quantum hall effect based devices.*

Keywords: *SEMICONDUCTOR, GRAPHENE, QUANTUM HALL EFFECT, CONDUCTIVE POLYMER, HALL RESISTANCE.*

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1. INTRODUCTION

In 1980 Von Klitzing et al. found that the fine structure constant can be determined quit accurately from such experiments. This was the discovery of the integer Quantum Hall Effect the hall resistance under suitable conditions is given only by fundamental constants h and the elementary charge *e*. On the other hand, the discovery of the Fractional Quantum Hall Effect brought along the development of the theory of strongly correlated electron systems. Fractional quantum hall effect is researched on metal and semiconductor till now, so we have to study Fractional Quantum Hall on polymer in use of different application. One fundamental property which normally distinguishes polymers from metals is electrical conductivity. Hall Effect can be observed in certain polymers as well as semiconductors. During the last decades, the researches, through the simple modification of ordinary organic conjugated polymers, have succeeded in preparing polymers with high electrical conductivity, called electrically conducting polymers or synthetic metals, these materials which combine the electrical properties of the metals with the advantages of polymers such as lighter weight, greater workability, resistance to corrosion and chemical attack and the lower cost have become extremely attractive [1].

Graphene is the recently discovered two-dimensional allotropic form of carbon. Its structure consists of a carbon honeycomb lattice made out of hexagons can be thought of benzene rings from which the hydrogen atoms were extracted. It is the building block for many forms of carbon allotropes e.g. three dimensional (diamond, graphite), one dimensional (nanotubes) and

zero dimensional (fullerenes). Graphite is obtained by the stacking of Graphene layers. It is found that in Graphene electrons travel much faster than electrons in other semiconductors. Hence, Graphene can be used in place of silicon for making ultra-fast and stable transistors based on quantum physics. Further, it is found that Graphene has a minimum electrical conductivity of the order of the quantum unit even when the concentration of charge carriers is zero. This is peculiar property of Graphene because in all other system, the conductivity is zero if no charge carriers are present. Graphene also shows very interesting behavior in the presence of a magnetic field. Graphene shows an anomalous quantum hall effect with the sequence shifted by half with respect to the standard sequence. It is usually observed at very low temperatures, typically below – 243 °C. In this paper we compare the properties of conducting polymer and semiconductor in terms of Fractional Quantum Hall Effect [2].

2. ANALYSIS

To understand the Fractional Quantum Hall effect we first need to understand the motion of electrons in a magnetic field. We summarize what is known about single electron states in a magnetic field, which provides the foundation for the theoretical understanding. The Hamiltonian in quantum mechanics is

$$H = \frac{1}{2me}[P - eA(r)]^2 + gB, \tag{1}$$

P is the canonical momentum operator, which satisfies the canonical commutation relation.

The choice of the vector potential is not unique for a given magnetic field. This is called a freedom in the gauge. Now the Hamiltonian does not depend on the magnetic field directly but on the vector potential. Let H be an eigen function corresponding to an Eigen value E of a Hamiltonian,

$$H = \frac{1}{e}(P - eA)^2 + H \tag{2}$$

The invariance of the observables with respect to the freedom in the choice of the vector potential is called gauge invariance.

Where fermions operator on lattice site i. the first term represent hopping or kinetic energy of the electrons and the hopping phases are determined by the uniform magnetic field. The second term represents a random onsite potential [3].

We measure resistivity' (diagonal and Hall resistivity) in a strong magnetic field, we obtain results which are quite different from those we obtain in a weak magnetic field. The basic fact about the Quantum Hall Effect is that the diagonal electric conductivity of two dimensional electron systems in a strong magnetic field is vanishingly small $\sigma_{xx} \to 0$, while the non-diagonal conductivity is quantized in multiples of

$$(\frac{e^2}{h}) \tag{3}$$

In recent experiments, the integral Quantum Hall Effect is observed in grapheme. But in this case it is found [1]

$$\sigma_{xy} = \pm 4(n + 1/2)\, e^2/h\,. \tag{4}$$

That is why it is characterized as half-integer quantum hall effect. This anomalous QHE is the direct evidence for Dirac fermions in Graphene. The Fractional Quantum Hall Effect in Graphene has also been studied. Further it is found that the FQHE at room temperature can be observed in Graphene.

The superconductivity can be induced in Graphene and the FQHE in it on the basis of suoersymmetric quantum mechanics has been studied. When a piece of a metal or semiconductor carrying a current is placed in a transverse magnetic field, an electric a field is produced inside the material in a direction normal to both the current and the magnetic field. This phenomenon is known as the Hall Effect. Hall performed his experiments at room temperature with moderate magnetic fields of less than 1 tesla .It is found that the Hall conductance varies linearly with $\rho e/B$, where ρ is the electron density and B is the magnetic field. This is the classical Hall Effect. But it is found that at low temperatures of only a few Kelvin and high magnetic field (up to 30 T), the hall conductance did not vary linearly with $\rho e/B$ instead, it varied in a stepwise fashion.

In polymer the FQHE plateau transition is of great interact because it links Anderson localization and the FQHE, two of the fundamental phenomena of condensed matter physics. Non-interacting electrons moving in two dimensions in a random potential from energy states which do not extend to infinity but are exponentially localized in finite regions of the plane. The situation changes drastically in a magnetic field: there are then extended states at discrete critical energies E separated by the cyclotron energy. These extended states are remnants of the Landau bands at zero disorder. At other energies the electron Eigen states are localized and the localization length near a critical energy scales according to

$$\xi\,(E) = \xi_0\,(\frac{E_C}{E - E_C})\,\nu \tag{5}$$

Splitting of energy level in semiconductor and polymer is discussed in this section and effect of splitting in FQHE. We have drawn the nuclear Zeeman energy splitting for the simplest $I = S$ case. The nuclear spin up state is energetically more favorable to populate than the spin down [4, 5] Mz, decreases as the Larmor frequency is reached state. The number of nuclei populating the levels $|+1/2\,i$ and $|-1/2\,i$, that is $N+$ and $N-$ respectively, is determined by the Boltzmann's factor:

$$\frac{N_-}{N_+} = \exp\frac{-\Delta N}{k_B T} = \exp\frac{-\gamma N \hbar B_z}{k_B T} \tag{6}$$

In which k_B is the Boltzmann's constant and T the temperature. At high temperatures ($k_B T >> \Delta N$) the ratio N_-/N_+ is approximately unity so both levels are nearly equally populated. Low temperatures and high magnetic fields, on the other hand, the thermal nuclear polarization

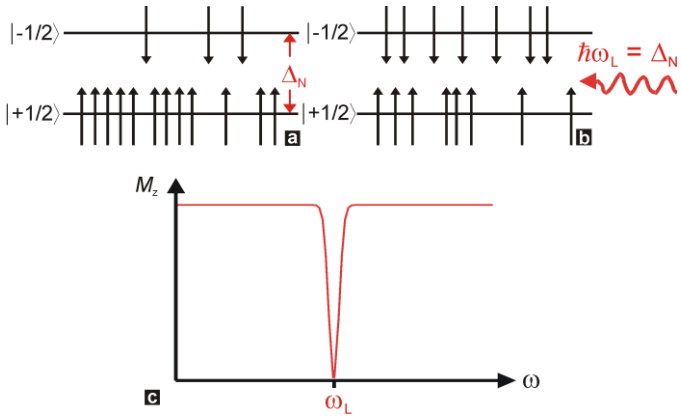

Fig. 1 *– Schematic diagram for the energy splitting _N of a nucleus with spin I = 1/2 in the presence of a magnetic field Bz (a). Applying an RF signal tuned to the Larmor resonance frequency L induces transitions between the levels (b). In a continuous wave (CW) experiment, the magnetization in z direction (c)*

becomes considerable (15 % at $T = 20$ mK and $B = 10$ T). If we consider the whole Ensemble of spins, the excess of spin up nuclei will amount to a net magnetization M_0 pointing in the same direction as the external magnetic field B_z.

Now turn to apply these results to the Dirac fermions in the surface states of topological insulator. The Dirac fermions are mass less and Dirac point is protected by the time reversal symmetry and is robust against impurities or defects. Since the Dirac fermions carriers real spin with a texture structure in the momentum space, a Zeeman splitting will be induced when a system is subjected to a perpendicular magnetic field $g_{\text{eff}}\mu$ which is equivalent to the effective mass term $m_{\text{eff}} = g_{\text{eff}}\mu$. If the gap is smaller than the Zeeman splitting the hall conductance is while if it is larger than Zeeman splitting the quantum hall conductance is $2(n^{+1/2})$. The Hamiltonian for interacting electrons in a partially filled valence band Landau level can thus be mapped exactly to the Hamiltonian for interacting electrons in the lowest level of a two dimension. Electron with an effective interaction specified.

The origin of this mappings lies in the fact that

$$\varphi_{n,m}^{(k)} = \frac{b^{+m}}{\sqrt{m!}}\varphi_{n,m}^{(k)} = 0 \qquad (7)$$

Just as in conduction band. The FQHE for a partially filled Landau level in a two dimensional hole gas is equivalent to the FQHE for a two dimensional electron gas except that the coulomb interaction is replaced by an effective interaction. The effective interaction depends on the valence band mixing [6]. Non-interacting electrons moving on a lattice with a uniform magnetic field and random onsite potential, described by the Hamiltonian [7].

3. EFFECT OF DOPING

Doping in a semiconductor and polymer is important to increase the conductivity of material which helps in Fractional Quantum Hall Effect. Polymer is a insulator which do not conduct the electricity, doping in polymer increase the free carriers and conductivity of polymers, how the doping increase the conductivity explain in this section. Pure semiconductors do not conduct electricity at low temperatures. There are no free electrons that can move about the crystal. All of them have been consumed by the bonds that hold the solid together. To conduct electricity, semiconductors require the addition of a small number of impurities, known as doping. Doping entails somewhat of a physical "catch 22": without doping there are no free electrons, but doping introduces impurities, which strongly scatter the newly introduced free carriers (2). The motion of a hole in an applied electric field. Initially the band is filled except for the single vacant state F at the top of the band. An electric field is now applied in the + x direction. The motion of the electrons in the band is governed by the used equation

$$\frac{h}{2\pi}\frac{dk_x}{dt} = -\varepsilon_S \tag{8}$$

Each electron changes its value at the same time. The group velocity is

$$\nu_g = h^{-1} \tag{9}$$

The velocity of the hole increases in the direction of the electric field [8]. High doping densities cause the band gap to shrink of the electrons bound the impurity atoms start t instance, at doping density of 1, the aver overlap forces the energies to form an energy band rather than a discreet level.

If the impurity levels are shallow, this impurity band reduces the energy band of the host material by

$$\Delta E_g(N) = -\frac{3q^2}{16\pi\varepsilon_S}\sqrt{\frac{q^2}{\varepsilon_S KT}} \tag{10}$$

Where N is the doping density, q is the electronic charge, ε_S is the dielectric constant of the k is Boltzmann's constant and T is temperature.

In polymer When U/W is small and a delocalized band picture is appropriate then addition or removal of electrons just changes the occupancy of the relevant energy band. When U/W is large and the electrons localized, then the extra electron or hole may lead to a local distortion at the site where it is trapped a state of affairs described as a small polaron [1] u is the electron − electron repulsion parameter and the bandwidth W (proportional to β) are the obvious pair [9, 10].

Localization of holes also occur when polyacetylene is doped [1].The band model leads to the expectation that the underlying skeleton remains basically unchanged for small doping levels and that the electron density remains fairly uniformly distributed over the atoms of the solid. In fact the solid state analog of a carbocation or carbon ion is generated. In carbon ion around which the single and double band alternation is now out of phase. The carbon ion site is frequently called a domain wall, since it separates these two parts of the chain

(domain) with bond alternation patterns that are mirror image of each other. The term soliton is also used to describe this state of affairs. The conductivity is limited by inter chain contacts in this polymer rather than the intrinsic properties of an individual chain [4, 5, 11].

High doping densities cause the band gap to shrink of the electrons bound the impurity atoms start instance, at certain doping density, the aver overlap forces the energies to form an energy band rather than a discreet level [12].

In the above discussion polymer can be used in FQHE in place of semiconductor, through the simple modification of ordinary organic conjugated polymers, have succeeded in preparing polymers with high electrical conductivity, called electrically conducting polymers or synthetic metals, these materials which combine the electrical properties of the metals with the advantages of polymers such as lighter weight, greater workability, resistance to corrosion and chemical attack and the lower cost have become extremely attractive.

4. CONCLUSION

We have found and analyzed in the literature that the certain materials are exhibits the the strong fractional hall effect that leads to fabricate very small size devices based on Hall Effect. Our theoretical predictions that polymers show the replacement capability of the semiconductor devices in the future this will verify experimentally in future. We think this fascinating result is due to the highly unusual nature of charge carriers in grapheme. These facts lead to enrichment in the phenomenology of FQHE in grapheme (polymer). The study of FQHE in grapheme is a very challenging field both theoretically and experimentally in condensed matter Physics as well as quantum field theory.

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