Alternative explanation of magnetism without spin

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Magnetic materials are known from ages. Spin of electrons has been used to explain the magnetism and classify the magnetic materials into different classes. In this paper we will provide the alternative explanation of magnetism by using the Brillouin zones, Bragg’s diffraction conditions, band-structure of materials and will explain that the fundamental origin of magnetism is same in all the three cases, namely; in ferromagnet (Fe, Co, Ni, Gd, Dy), magnetism arises due to the passing of electric current in metallic wire, and magnetism in every semiconductor or in perfect insulator after heavily doping by $p$-type dopant, so that the electrochemical potential (Fermi energy) of the material either cut or touch the valance-band maxima. We will explain that why iron have more than one valance electron at the Fermi-level using the Brillouin zones, Bragg’s diffraction condition, and band-structures of iron. We will explain the origin of the exchange magnetic field that present in every magnetic materials. We will also explain that why Fe, Co, Ni, and Gd behaves as a ferromagnet while Cr is anti-ferromagnet. We will develop a general rule which applicable to all crystal structure to classify them into a ferromagnetic, diamagnetic, paramagnetic, ferrimagnetic and anti-ferromagnetic in nature. We will use our developed rule and will explain the giant magneto-resistance (GMR), tunneling magneto-resistance (TMR), spin-transfer-torque random access memory (STT-RAM), and magnetic-cluster femto-second switching devices on equal footing. We will also discuss about the flaw that exist in the current existing models which have been extensively used for the explaining the magnetic devices.

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I. INTRODUCTION

Numerous paper have been written on magnetism using the spin property of electron. No paper has given a satisfactory answer that why only few (Fe, Co, Ni, Gd, Dy) elements in periodic table shows magnetism and others are not; or why non-magnetic elements start showing magnetism after applying high magnetic field in low temperature regimes? Why metallic property is the prerequisite condition for magnetism? Why the origin of magnetism in case of permanent magnets at room temperature like Fe, Co, and Ni, and low temperature magnets like Gd, Dy, and magnetism arises due to the passing of electric current in a straight conducting wire, or in close loop conducting ring, or in a semiconductor/insulators after heavily doping with $p$-type dopant should be the same, or should not be the same? Also, how the magnetic susceptibility arises in the materials? Does the magnetic field and the magnetic susceptibility have the quantum mechanical origin? In literature, these question answers are mainly based on the spin and it thermal fluctuations. In this paper we will use the Brillouin zones, Bragg’s diffraction condition, band-structure of iron (without losing any generality) and will show that the origin of magnetism in all cases arises due to the coupled mode of the vibrations of two connected Brillouin zones. For example, in case of iron, it is the 5th, and the 11th Brillouin zones which are coupled together, and present at the Fermi level, and vibrates with unequal wave-vector $k$. The presence of unequal Bloch wave-vector $k$ are responsible for the non-cancellation of the net phases of the
FIG. 1: The band-structure of iron. Number on the Bands corresponds to the Brillouin zones in which the bands resides. The blue bands correspond to the up-spin, whereas the black bands corresponds to the down-spin. There are two band-gap (first band-gap, second band-gap) appear along the Γ to N direction after single Bragg’s plane diffraction which present at the N point in 1st Brillouin zone and at the edge between the 7th and 8th Brillouin zone.

two coupled Brillouin zones. To elaborate this concept further, we will use the band-structure of bcc iron and will classify the Bloch states into the different Brillouin zones (see in Figure 1).

II. ORIGIN OF MAGNETISM

We will discuss the iron band-structure first. The reason that we are discussing it because on page-59 in Ashcroft and Mermin solid state physics book in “fundamental mysteries” section it is mentioned that “What determine the number of conduction electrons? We have assumed that all valance electrons become conduction electrons, while the others remain bound to the ions. We have given no thought to the question of why this should be, or how it is to be interpreted in the case of elements, like iron. that display more than one chemical valance”. We will use the Brillouin zones, Bragg’s diffraction condition and band-structure of iron and will explain that why iron display more than one valance electrons. If we see the band-structure of iron (see in Figure 1) along the Γ to H direction, then we see that particle energy varies $E(k) = \frac{\hbar^2 k^2}{2m}$ in 1st Brillouin zone (mark as 1 in iron band-structure, see in figure 1) till the H point reaches. Once the H point reaches and if we further increase wave-vector $k$ along the same direction, then the particle enter into the 5th Brillouin zone (mark as 5 in iron band-structure, see in figure 1). If we keep increasing the $k$ vector along the same direction then we see that particle energy again varies $E(k) = \frac{\hbar^2 k^2}{2m}$ till the next high symmetry point reaches (remain in the 5th Brillouin zone). If we further increases $k$ then we see that particle enter into the 9th Brillouin zone (mark as 9 in Figure 1). We also see that one more particle energy state started around -2 eV. If we plot the total energy $E$ versus $k$ plot of this particle along Γ to H direction, then we see that it varies $E(k) = \frac{\hbar^2 k^2}{2m}$ till H point and particle remain in the 5th Brillouin zone. Once H point reaches and if we further increases $k$, then we see that particle crosses the 5th Brillouin zone and enter into the 11th Brillouin zone. We also see that particle energy $E(k)$ versus $k$, instead of going up in the energy scale from H to Γ, it turns down and moves down as the particle goes towards the next high symmetry point equivalent to the Γ point in the 1st Brillouin zone. We see that particle energy varies like $E(k) = -\frac{\hbar^2 k^2}{2m}$. This is a hole particle energy and thus particle start behaving like a hole in the 11th Brillouin zone. If we further increase $k$ along the same direction and see how the particle behaves, then we see that the particle behaves like a hole till the next high symmetry point, equivalent to the Γ point in the 1st Brillouin zone. Once the particle reaches at the high symmetry point in the 11th Brillouin zone and if we further increases $k$ along the the same direction Γ to H, then we see that the particle never cross the 11th Brillouin zone high symmetry point equivalent to Γ point, and it energy $E(k)$ diagram disappear once it reaches at high symmetry point. This is a very unusual property in band-structure. What we further see that the hole
energy $E(k)$ diagram form a close loop with the 5th Brillouin zone particle energy $E(k)$ diagram at the $\Gamma$ point. This suggest that the 5th and the 11th Brillouin zone particle energy $E(k)$ diagram are coupled to each other and particle move in a close loop once it goes from the 5th Brillouin zone into the 11th Brillouin zone and then from the 11th Brillouin zone into the 5th Brillouin zone. We see that no matter how big we increase the wave-vector $k$ particle never come out from this close loop. We infer that this is the origin of ferromagnetism. We observes that particle behaves like electron in the 5th Brillouin zone and its energy $E$ varies with $k$ as $E(k) = \frac{\hbar^2 k^2}{2m}$, whereas in next connected 11th Brillouin zone particle behaves like a hole, and its energy varies $E(k) = -\frac{\hbar^2 k^2}{2m}$. Both 5th and the 11th Brillouin zones are coupled to each other and never allowing particle to go into a next Brillouin zone (after 11th Brillouin zone). Since second particle energy dispersion relation is present along $\Gamma$ to $H$ direction and particle present at the Fermi-energy level, this particle will also participate in transport. Thus iron have two type pf electron present at the Fermi-energy level. Also due to presence of second particle in 5th Brillouin zone where it behaves like electron and it energy dispersion lead it into the next 11th Brillouin zone where particle behaves like a hole which form a close loop with the 5th Brillouin zone present a uniqueness behavior and leads to the ferromagnetism. What we further observes that this unique behavior is present only in Fe, Co, Ni, Gd, and Dy at the electrochemical potential level (Fermi-level) along the principal directions. In other metals this unique behavior (two Brillouin zones are coupled to each other) are present away from the Fermi energy-level in either directions. What we further observe that in every insulator this unique behavior are also present at the valance-band maxima along the high symmetry point directions. What we observes in iron that electrochemical potential (Fermi-energy level) cut both 5th and the 11th Brillouin zone but particle is about the cross the 5th Brillouin zone and it about to enter into the 11th Brillouin zone (see in Figure[1] at $H$ point at the Fermi-level). We see that the 5th Brillouin zone vibrate with high $k$ wave-vector (means high plane wave-energy), whereas the 11th Brillouin zone vibrate with very small $k$ wave-vector (low plane-wave energy). We see that when the 5th Brillouin zone vibrate with high wave-vector $k$ and it coupled with the 11th Brillouin zone vibrate with low $k$ vector (see Fermi-energy level in Figure[1]), then we have positive magnetic-moments (assume magnetic moments is pointing in the $z$-direction). When the 11th Brillouin zone vibrate with high wave-vector $k$ and it coupled with the 5th Brillouin zone with low wave-vector $k$, then we have negative magnetic-moments (assume magnetic moments is pointing in $-z$-direction). When the 5th Brillouin zone and the 11th Brillouin zone vectors are vibrating with the same magnitude of wave-vector but 180° phase apart, then crystal structure will behave like anti-ferromagnetism. When the 5th Brillouin zone vibrate slightly higher than the 11th Brillouin zone wave-vector $k$, then crystal structure will behave like paramagnetism. When the 11th Brillouin zone vibrate slightly higher wave-vector than the 5th Brillouin zone, then crystal structure will behave like dia-magnetism.

Now we will write a general rule which will decide that whether a crystal structure will be a ferromagnetic, antiferromagnetic, ferrimagnetism, paramagnetic or diamagnetic in nature. In our iron case particle in the 5th Brillouin zone behaves like electron while in next connected Brillouin zone in same direction (11th Brillouin zone), it behaves like hole. Both Brillouin zones are vibrating with different wave-vectors. Ferromagnetism arises due to the imbalance in vibration of wave-vectors $k$ in particle and hole Brillouin zones. This is the origin of exchange magnetic field which present in every magnetic materials. Let break down the two Brillouin zones coupled mode of vibrations into the different cases:
FIG. 2: Schematic diagram of iron band-structure. Point A and B are corresponds to the two stable magnetic state of iron. Point B corresponds to the positive magnetic moments, whereas the point A corresponds to the negative magnetic moments of the iron state. Point E corresponds to the ground state Fermi-energy level of \textit{bcc}-iron when it magnetic moment points along the $+z$ direction. Point F corresponds to the Fermi energy level of \textit{bcc}-iron when it magnetic moment changes direction from $+z$ to $-z$. Point C and point D resides on the 5th and the 11th Brillouin zone respectively. Wave-vector from the $\Gamma$ to C and from the Z to D are equal in magnitude but out of phase by 180°. This situation arises when both 5th and 11th Brillouin zones are vibrating out of phase by 180° with equal magnitude of wave-vector $k$. The Orange point o corresponds to the origin coordinates at which both the 5th and the 11th Brillouin zones vibrates with equal magnitude of wave-vector $k$. The movement of the arrows indicates the particle path which particle will follow once the wave-vector $k$ increases along the $\Gamma$ to Z ($\textit{H}$) direction. The green arrow associated with the second particle energy dispersion relation which form a close loop with 5th and 11th Brillouin zones and cause the origin of exchange magnetic field in magnetic materials. Bands are numbered with the Brillouin zones in which they reside.

A. Ferromagnetism:

For strong ferromagnetism the magnitude of the wave-vector $k$ in electron and hole Brillouin zones should follows the condition,

$$k_{el} \gg k_{hole}, \quad (1)$$

or,

$$k_{el} < k_{hole}. \quad (2)$$

Equation (1) corresponds to the situation when magnetic moments point towards $+z$-direction (see $E$, and $B$ points in Figure 2), whereas equation (2) corresponds to the situation when magnetic moments point towards $-z$-direction (see $A$, and $F$ points in Figure 2) in real space. This situation arises in Fe, Co, Ni, Gd, Dy. Ferromagnetism in iron arises when 5th and 11th Brillouin zones vibrates likes at $E$, $B$, $F$, and $A$ point (see in Figure 6). $E$ point vibration corresponds to the ground state normal iron (without external magnetic field) and magnetic points in the $+z$-direction. $B$ point vibrations corresponds to the saturated magnetic moments of iron and it point along the $+z$-direction. Point $F$ and point $A$ modes of vibration are just opposite to the point $E$ and point $B$ modes of vibration respectively (see in Figure 6). At point $A$ and point $F$ modes of vibrations are corresponds to the magnetic moment of iron which points along the $-z$-direction.

B. Anti-ferromagnetism:

For antiferromagnetism, both electron and hole Brillouin zones are vibrating with same magnitude of wave-vector $k$. However, their Bloch wave-function are out of the phase by (180°) degree (see in Figure 7).

$$k_{el} = k_{hole}. \quad (3)$$

This situation arises when electron (5th Brillouin zone in case of Fe) Brillouin zone and hole (11th Brillouin zone in
FIG. 3: Schematic diagram of vibrations of 5th and 11th Brillouin zones in k space at E-point (see in Figure 2). 5th Brillouin zone vibrates with wave-vector Γ to E, whereas the 11th Brillouin zone vibrates with wave-vector Z to E. Since 5th Brillouin zone wave-vector is higher in magnitude than the 11th Brillouin zone, therefore there is effectively net positive mode of vibration present in the iron, and this corresponds to the net positive magnetic moments of iron in ground states.

FIG. 4: Schematic diagram of vibrations of 5th and 11th Brillouin zones in k space at B-point (see in Figure 2). 5th Brillouin zone vibrates with wave-vector Γ to B, whereas the 11th Brillouin zone does not vibrates. Since 5th Brillouin zone wave-vector is highest in magnitude than the 11th Brillouin zone, therefore there is highest net positive mode of vibration present in the iron, and this corresponds to the highest positive magnetic moments of iron (also called saturated magnetic moment of iron) in ground states.

FIG. 5: Schematic diagram of vibrations of 5th and 11th Brillouin zones in k space at F-point (see in Figure 2). 5th Brillouin zone vibrates with wave-vector Γ to F, whereas the 11th Brillouin zone vibrates with wave-vector Z to F. Since 11th Brillouin zone wave-vector is higher in magnitude than the 5th Brillouin zone, therefore there is effectively net negative mode of vibration present in the iron, and this corresponds to the net negative magnetic moment of iron in ground states.

FIG. 6: Schematic diagram of vibrations of 5th and 11th Brillouin zones in k space at A-point (see in Figure 2). 5th Brillouin zone does not vibrates, whereas the 11th Brillouin zone vibrates with highest wave-vector Z to A. Since 11th Brillouin zone wave-vector is highest in magnitude than the 5th Brillouin zone, therefore there is highest negative mode of vibration present in the iron and this corresponds to the highest negative magnetic moment (also called negative saturated magnetic moment of iron) in ground states.
C. Ferrimagnetism

Ferrimagnetism arises when the two coupled Brillouin zones are vibrating with slightly different magnitude of wave-vector \( k \), so that their Bloch waves are out of phase with slightly less or slightly higher than the \( 180^\circ \) degree, and thus their is net small magnetization which is responsible for the ferrimagnetism. This situation arises in Al, Mn, Co, Ni and Zn.

D. Diamagnetism:

For Diamagnetism case, both electron and hole Brillouin zones are vibrating with same magnitude of wave-vector \( k \), however with \( \pi \) degree phase difference in their Bloch waves. When external magnetic field is applied, which distort the vibration in both the Brillouin zones by changing the wave-vector \( k \), and increases the hole Brillouin zone wave-vector \( k \) a bit larger in magnitude than the electron Brillouin zone wave-vector (external magnetic field will decrease the electron Brillouin zone Bloch wave-vector \( k \)). An imbalance in the magnitude of the wave-vector \( k \) between electron and hole Brillouin zones with condition that \( k_{\text{hole}} > k_{\text{el}} \), force the crystal structure to behave as diamagnetsism with negative susceptibility. This situation arises when point \( C \) (see in figure) moves towards the left (follow the green arrow in Figure 2) after applying the magnetic field. So for diamagnetism, condition is

\[
k_{\text{hole}} > k_{\text{el}},
\]

so that hole (11th Brillouin zone in case of Fe) Brillouin zone start vibrating a little higher than the electron (5th Brillouin zone in case of Fe) Brillouin zone after applying the external magnetic field.

E. Paramagnetism:

The condition for paramagnetic is just opposite to the condition for diamagnetic. If after applying the external magnetic field the electron Brillouin zone Bloch wave vector magnitude increases and hole Brillouin zone Bloch wave vector decreases then paramagnetism arises and crystal structure behave like paramagnetism with positive susceptibility. The condition for paramagnetism is

\[
k_{\text{el}} > k_{\text{hole}}.
\]

This situation arises when point \( C \) moves towards the right (see in Figure 2) after applying the external magnetic field.
III. ANALYSIS OF THE MAGNETIC DEVICES

In this section we will discuss about giant magnetoresistance (GMR), tunneling magnetoresistance (TMR), spin-transfer torque random-access-memory (STT-RAM), ultra-fast switching of magnetic clusters using the Brillouin zones, Bragg’s diffraction condition and band-structures. We use iron band-structure without losing any generality.

A. GMR

A GMR device consists of ferromagnet|non-ferromagnet-metal|ferromagnet layers. We will take Fe|Cr|Fe structure as a test case in our analysis. Both Fe and Cr have bcc crystal structure and their lattice parameters are same (2.89 Å). So, entire Brillouin zones of Cr is exactly the same as the entire Brillouin zones of Fe. The Bloch state available at Fermi level in both Fe and Cr are resides in the 9th and the 5th Brillouin zones. When the magnetic moments of both Fe electrodes are parallel to each other, then the electron from the left electrodes which stay in the 9th and the 5th Brillouin zones goes into the 9th and the 5th Brillouin zones of Cr and then the 9th and the 5th Brillouin zones of Fe in the right electrodes. Because Cr has same lattice parameter as Fe, it Brillouin zones are exactly the same as the Fe. So, when the electron from the 9th and the 5th Brillouin zones from the left electrodes goes into the 9th and the 5th Brillouin zones of Fe and then the 9th and the 5th Brillouin zones of Cr again, it faces a minimum resistance. When the right side electrode magnetic moment changes then the electron from the left electrodes which reside into the 9th and the 5th Brillouin zones goes into the 9th and the 5th Brillouin zones of Cr and then the 5th and the 11th Brillouin zones of the right side of Fe electrodes. Since the electron going from the 9th and the 5th Brillouin zones into the 5th and the 11th Brillouin zones, maximum resistance arises. The origin of this resistance is purely based on the different geometrical structure of Brillouin zones. In Fe, 9th and the 5th Brillouin zones, and 5th and the 11th Brillouin zones are geometrically very different and thus offer maximum resistance. In principle the difference of resistance between parallel configuration (when both Fe electrodes magnetic moments are parallel to each other) and resistance between anti-parallel configuration (when both Fe magnetic moments are anti-parallel to each other) must be constant. Because, resistance purely arises when the electron goes from the 9th and the 5th Brillouin zones from the left electrodes into the 5th and the 11th Brillouin zones in the right Fe electrodes. The electron from the 5th Brillouin zone from the left Fe (having large wave-vector k) goes into the 5th Brillouin zone of Cr (have smaller wave-vector k at the Fermi level in Cr) some resistance will arises due to the Cr layer as well. If we take minimum Cr layer thickness and thick Fe electrodes, then the difference in resistance between parallel and anti-parallel configuration of the magnetic moments should be a constant.

B. TMR

A TMR device consist of ferromagnet|insulator|ferromagnet. We will take Fe|MgO|Fe structure as a test case in our discussion. When the both Fe electrodes are parallel to each other then the electron from the 9th and 5th Brillouin zones in the left Fe electrodes goes into the 9th and the 5th Brillouin zones of Cr and then the 9th and the 5th Brillouin zones of Fe again, it faces a minimum resistance. When the right side Fe electrodes magnetic moments changes into anti-parallel, then the electron from the 9th and the 5th Brillouin zones in the left Fe electrodes goes into the 9th and the 5th Brillouin zones into the right electrodes respectively. When the right side Fe electrodes magnetic moments changes into anti-parallel, then the electron from the 9th and the 5th Brillouin zones from the left electrodes goes into the 5th and the 11th Brillouin zones into the right electrodes respectively. Since the 9th and the 5th Brillouin zones vibrations need to be accommodated into the 5th and the 11th Brillouin zones vibration, resistance must be arises, and this resistance must be
constant, because the origin of resistance is purely based on the accommodation of the electrons from different Brillouin zones. In other words, resistance in this device has quantum-mechanical origin. We see the hysteresis curve in figure 10 and concluded that the hysteresis curve is nothing but the same iron 5th and the 11th Brillouin zones are inter-coupled to each other and vibrate. So, it should be equal to the magnetization energy of iron if fairly thick iron film chosen in experiment which can produce the bulk property of iron. In Fe|MgO|Fe junction, resistance between parallel and anti-parallel configuration of magnetic moments increases on logarithmic scale with the thickness of the MgO layers is the clear signature of the tunneling (see in Figure 8). Whereas, a periodic oscillation in tunneling magneto-resistance as a function of the MgO layer thickness is a clear signature of coherent tunneling which purely arises due to the quantum mechanical effect (see in Figure 9).

C. STT-RAM

A typical STT-RAM device consists of FM|INS|FM structure, where FM stands for ferromagnet and INS stands for insulator. We will take Fe|MgO|Fe device as a test case in our discussion. In STT-RAM devices we change the ferromagnet electrode magnetic moments by passing the electric currents. In this process electric energy associated with current has been used to convert into magnetic energy associated with the ferromagnetic electrode. When magnetic moments of both ferromagnet electrodes are in parallel then the electron from the left electrode which reside in the 9th Brillouin zone and the 5th Brillouin zone goes into the 9th and the 5th Brillouin zone in the right electrodes, after tunneling across the MgO insulator. When the right side ferromagnet magnetic moments rotated and make it anti-parallel to the left electrode magnetic moments, then the electrons from the left electrode which reside in the 9th and the 5th Brillouin zones goes into the 5th and the 11th Brillouin zones respectively in the right side of ferromagnet. Since the electrons from the 9th Brillouin zone need to accommodate into the 5th Brillouin zone and the electrons from the 5th Brillouin zone need to accommodate into the 11th Brillouin zone, resistance arises due to geometrical constrain of ferromagnet Brillouin zones, and
the difference in resistance between a parallel and anti-parallel configuration of the magnetic moments of the two ferromagnetic electrodes is purely independent with the switching frequencies (see in Figure 11).

D. Magnetic-cluster

When we shine ultra-fast femto-second laser pulse on magnetic cluster then it magnetic moments direction get changes from up to down or vice-versa. We will use Fe cluster in our discussion and we will treat it like a bulk Fe so that we can explain it using band-structure of Fe. As we have discussed before, that in Fe, there are two Bloch states are available at the Fermi energy-level. One resides in the 9th Brillouin zone and other reside in the 5th Brillouin zone. We have also discussed that in the 5th Brillouin zone particle behaves like an electron, whereas in the next Brillouin zone it behaves like a hole. We have discussed that the energy dispersion of the electron which reside in the 5th Brillouin zone and energy dispersion of hole which reside in the 11th Brillouin zone are coupled to each other. Coupling of the 5th Brillouin zone and the 11th Brillouin zone cause ferromagnetism. This coupling is the origin of the exchange filed which present in ferromagnets. In the band-structure of Fe, it is clear that in the 5th Brillouin zone Bloch waves have very high wave-vector $k$, whereas in the 11th Brillouin zone Bloch wave have lower wave vector $k$. This imbalance in wave-vector which controls the coupling strength between the 5th and the 11th Brillouin zone vibration causes ferromagnetism. We call it positive magnetic moments. When the 11th Brillouin zone vibrate with higher wave-vector $k$ than the 5th Brillouin zone then overall vibration generate a net magnetic moments and we call it a negative magnetic moment. If wee see the vibration closely then we can say that femto-second laser pulse energy has been used to change the mode of vibration in 5th and 11th Brillouin zones. This energy is equal to the minimum energy require to swap the mode of vibration of the 5th and the 11th Brillouin zones. What we can
conclude from our discussion is that in magnetic-cluster also, $5^{th}$ and the $11^{th}$ Brillouin zones of Fe cluster participate in magnetic moments switching by absorbing the laser pulse energy and then redistribute it into the $5^{th}$ and the $11^{th}$ Brillouin zones mode of vibration in such a way that the $5^{th}$ Brillouin zone start vibrating like the $11^{th}$ Brillouin zone, whereas the $11^{th}$ Brillouin zone start vibrating like the $5^{th}$ Brillouin zone.

E. Magnetism in every insulator

The valance-bands of any insulator have the same loop closing (particle energy varies like an electron in one Brillouin zone (e.g. $5^{th}$ Brillouin zone in iron) and it varies like hole in next connected Brillouin zone (e.g. $11^{th}$ Brillouin zone in iron)) feature which present in the ferromagnet like Fe, Co, Ni, Gd, and Dy. The only difference between Fe, Co, Ni, Gd, Dy, and any semiconductor is that, in ferromagnets this closing loop is present at the Fermi-energy level, while it is present around maxima of valance-bands in every insulator. In diamagnetic metals like Cu and Zn, this close loop present just below the Fermi level. What we are predicting is that if any insulator doped heavily with hole type elements so that Fermi-energy move from the middle of the band-gap to the valance-band maxima of insulator and either it touch or cut the valance band, then ferromagnetism will arises in the insulator. The origin of the magnetism is same as it is in the case of ferromagnetism. It arises due to the coupling of two connected Brillouin zones (for example $5^{th}$ and the $11^{th}$ in Fe) into each other in such a way that the particle total energy $E(k)$ varies as an electron in one Brillouin zone, whereas it varies as a hole in other Brillouin zone. In this way both the electron and hole total energy $E(k)$ forms a close loop. Forming a close loop is the origin of ferromagnetism (or exchange field in ferromagnet). We have seen the same type of close loop present at the valance-band maxima in every insulator including ferro-electric materials along the principal directions. What we are also concluding that the origin of ferro-electricity is also due to the presence of this close loop which appear as a hysteresis curve during experiments. What we are further concluding is that the coupling of two connected Brillouin zones, vibration of two coupled Brillouin zones with different magnitude of wave-vectors $k$ which are out of phase are the cause of the origin of ferromagnetism(exchangefield), and ferroelectricity in any material. There will be many materials in nature whose constituents have no net spin elements but it will show ferromagnetism. We have explained magnetism by using the Brillouin zones, Bragg’s diffraction conditions and band-structure (of iron without losing any genrality) which come after density functional theory calculation. What we found that the ferromagnetism arises due to the coupled mode of vibration of the two connected Brillouin zones, in one, the particle energy varies like an electron, whereas in other Brillouin zone it is vary like a hole, and both form a close loop. The different mode of vibration of the electron Brillouin zone and the hole Brillouin zone are the cause of ferromagnetsim, anti-ferromagnetism, paramagnetism, diamagnetism and ferramagnetism. What we are concluding is that the spin is not the reason of ferromagnetism. We have explained every magnetism phenomenon using only Brillouin zones, Bragg’s diffraction condition and band-structure of materials. These three are very fundamental in nature and nature follows them absolutely. We have never used spin and explained the root cause of the origin of exchange magnetic field which present in every ferromagnetic material. Our claim is that the experiment which conducted by Otto Stern and Walther Gerlach in 1922 using Ag atom beams in external magnetic field in which Ag atoms get separated because of Bragg’s plane diffraction situated in the middle of the apparatus. Magnetic field distort the space and help in the separation of the Ag atoms. The presence of the Bragg’s plane (Bragg’s plane are made of from vacuum) along the symmetry line in apparatus will never allow all the atom
to go in one place. The Bragg’s plane will diffract the both side of atom at two different positions. Our further claim is that Pauli exclusion principle is correct. Two particle can not take same position not because of their spin, but because of the diffraction due to the Bragg’s plane which present between any two particle. Bragg’s plane are made from emptiness (vacuum). Emptiness present everywhere. It is infinitely elastic, and it is perfectly connected (in mathematical sense). In our next paper we will use Max Plank black-body idea, Brillouin zones constructions rule, Bragg’s diffraction conditions and will prove that the origin of stationary orbits in an atom, origin of the stationary orbit in our solar system, origin of mass, origin of all type of forces including four fundamental forces in nature, namely: gravitational, electric, magnetic and nuclear force have the quantum mechanical origin. Our further claim is that resolution in degenerate energy levels in atom after applying magnetic field (Zeeman splitting) is not because of the spin but because of distortion of connected space by the magnetic field and due to the Lorentz force, the degenerate energy states get separated. For example if one see the figure at $H$ point which has 5 degenerate energy states. If one apply the magnetic field in the system then it will distort the space and due to the Lorentz force, each energy state will move along their respective energy lines like $H$ to $\Gamma$, $H$ to $N$, and $H$ to $P$. We further claim that the hydrogen is a reactive because it has net angular momentum pointing along one principal direction (let say $z$-direction), while helium is non-reactive because the net angular momentum in helium is zero. If one calculate the angular momentum of any system, then one must calculate the total angular momentum of the system including the electron, proton and neutrons angular momentum together. Because proton and neutron are also revolving in a stationary orbit around the singular point (we will discuss it in great details in our next paper).

IV. MAGNETISM DUE TO THE CURRENT CARRYING WIRE

Current carrying wire generates magnetic field. The origin of the magnetic field in this case as well due to the quantum mechanical effects. The space associated with the wire are connected with the outer-space world (where wire does not present physically). This wire space and outer space are coupled and vibrates in the same manner as the iron 5th, and the 11th Brillouin zones vibrates. Thus in this case as well the coupled mode of vibrations of two connected space (wire material space and out side space) generates magnetism. In permanent magnets case, two coupled Brillouin zones vibrates themselves, whereas in current carrying wire case a external agency such as an electrochemical battery which creates potential difference between two points in space will vibrates the space indirectly. Electrochemical battery will allow the carrier to flow from the positive electrodes towards the negative electrodes. Carrier moves in space which is infinitely large, has perfectly connected domain (mathematical sense) and have infinite elastic property. Movement of the carrier in wire space produce close mode of vibration with outer space and thus magnetic filed is generated. The coupled mode of vibration is also the cause of non-zero curl in magnetic field. Whereas, the electric field generated after linear open mode of the vibration of the space between the two points. Linear mode of vibrations produce zero curl. The similar vibrations occurs in the close loop wire case as well. In close loop wire case the wire materials space and outer space which are perfectly connected are vibrating in a similar fashion as bcc iron 5th and the 11th Brillouin zones vibrates. One need the external agency to pass the current in a close loop and thus in close loop wire magnetic field will only sustain till the external agency present. Once the external agency removed, the close mode of the connected space vibrations will disappear. What we can conclude with our discussion is that the origin of magnetism arises
due to the close mode of vibration of the space. In permanent magnets case this close loop of vibrations present and persistent all the time, whereas in current carrying wire case external agency needed which can vibrates the space in close mode. In case of heavily p-type doped semiconductor or an insulators magnetism arises due to the movement of chemical potential (Fermi energy) level from the middle of the band-gap towards the valance-band maxima where it either cut or touch the valance-band maxima. At valance-band maxima the two Brillouin zones are coupled and vibrates as in the case of bcc iron and thus generates magnetism.

V. FLAWS IN THE CURRENT EXISTING MODELS WHICH EXPLAIN MAGNETISM

There are two model available in the literature which explain the working principle of giant magneto-resistance (GMR), tunneling magneto-resistance (TMR), and spin-transfer-torque random access memory (STT-RAM) devices. First model is based on the symmetry filtering of the Bloch states by the insulator which sandwiches between the two ferromagnet. Second model is based on the two-spin channel model developed by N.F.Mott in 1936.

A. Flaw in the first model

(1) Symmetry filtering model says that the insulator favors one type of symmetry of the Bloch state over the others during tunneling. Insulator perform this job by overlapping of the tunneling electron Bloch-wave function with either the valance-band Bloch states or with the conduction-band Bloch states. This means that electron either hop via the valance-bands or via the conduction bands. During the hopping process (either via the valance-bands or through the conduction-bands) electron energy changes, which is not allowed in any coherent or elastic tunneling process. In a tunneling process an electron energy and phase of the electron wave-function must remain conserved, and it should not change during a tunneling process. This rule has been violated in symmetry filtering model. For example, Butler wrote “One obvious difference between the simple barrier model and MgO (or any other insulator) is that the insulator has valance-bands as well as a conduction-band. Electrons can also tunnel through the barrier via the valance-bands; this would be describe as ‘hole’ tunneling because it would describe a process in which a valance electron makes an upward transition from the top of the valance-band to the Fermi energy of the right electrode simultaneously with the transition of an electron at the Fermi energy of the left electrode making a downward transition that fills the hole”. Now question arises that who provides the difference of energy between valance-band maxima of insulator and the Fermi energy of the right electrode, so that electron can make transition from valance-band maxima to the Fermi energy of the right electrode and make a space for the left electron which will make a transition from the Fermi energy of the left electrode to the valance-band maxima of the insulator? During this transition process at the left electrodes as well the electron energy has been changed, which again violate the essence of a tunneling process. He further wrote, “In particular, for MgO, the valance-band with $\Delta_1$ symmetry continues through the gap region as an evanescent state for which $k_z$ is imaginary and re-emerges at the top of the gap as the conduction-band”. Again the electron energy has been continuously changed during this transition process from the valance-band maxima to the conduction-band minima in the insulator, which is not allowed in a tunneling process. The movement of an electron from the Fermi-energy of the left lead towards the right lead via valance-band maxima or via conduction-band minima at the $\Gamma$ point or any other point in the Brillouin zone is no longer called tunneling. This process should be called a hopping process in which the electron energy as well as the phase of the wave-function have been changed. In a hopping process, the phase of the wave-function will no longer
remain conserve. In-fact the phase information of the wave-function is completely wipe-out during a hopping process. (2) The procedure use to calculate the symmetry filtering by the insulator is also wrong. During the symmetry filtering classification, the left lead, insulator, and the right lead made with the same material as the insulator. The Fermi energy of the insulator lies in the middle of the band-gap. The only Bloch state which available to move from the left lead towards the right lead is the Bloch state available at the valance-band maxima in left lead. If one apply the voltage at the left lead (which made of insulator) the Fermi energy will not move or shift in the band-gap. In-fact, valance-band, Fermi energy level, and conduction-band move together (shift rigidly) so that the difference between the Fermi energy level and valance-band maxima or between the conduction-band minima will remain the same as before. (Fermi energy level which will always present in the middle of the band-gap (due to diffraction after single Bragg’s plane which open the band-gap) can only be changed by doping the insulator with either $p$-type or $n$-type dopant (as in the case of Si semiconductor), or it can be changed by changing the crystal structure of insulator). So, when the left lead Fermi energy move up or down (still remains in the band-gap of insulator) from it initial position, and allow the Bloch state to go in the right direction, then it is always the valance-band maxima Bloch state which travel in the right direction via valance-band or via the conduction-band of insulator. So, there should not be any surprising that insulator filter the same symmetry of the Bloch states from which the valance-band maxima or conduction-band minima are made-of. (3) The coupling matrix between the left-lead, right lead and the insulator during calculation come after tight binding approximation, which is same as the microscopic quantum transport. (4) Lippmann-Schwinger and Dyson’s equations have been used for Green’s function calculation in time domain which will give the phase of the Bloch waves after multiples scattering from the scattering potential $V$. Lippmann-Schwinger and Dyson’s equations are based on a recursive method which means the infinite times of scattering in the phase of the Bloch waves by the scattering potential $V$, and thus the phase information of the Bloch-waves has been completely lost. So after infinite times of scattering the system will behave like a pure ohmic transport system in which the drop of external-potential will be continuous across the device with single value slope (as one can see it in any ohmic transport system) which start at the left lead and end at the right lead. Now this transport even no longer remain as a quatum transport, because in quantum transport potential drop can only appear at the interface between two solids, and potential is completely flat without any slope in the solid (see for example at page 56). Flatness in the potential in the middle of the solids allows one to use the Landuer-Büttikker formalism for quantum transport (see for example book at page 56). In Landuer-Büttikker formalism, externally applied voltage can only appear at the interface between the materials and there is no potential drop across the materials, and thus a ballistic coherent transport (also called transport via channel) is possible inside the materials (see for example page 56). Supriyo Dutta in his book electronic transport in mesoscopic systems at chapter 2, page-51 has discussed about the ballistic conductor and it resistance. He wrote Where does this resistance come from? After all, a ballistic conductor (that is, a conductor with no scattering) should have zero resistance. This resistance arises from the interface between the conductor and the contact pads which are very dissimilar materials. For this reason we will refer to this resistance ($G_c^{-1}$) as the contact resistance. The current is carried in the contacts by infinitely many transverse modes, but inside the conductor by only a few modes. This requires a redistribution of the current among the current-carrying modes at the interface leading to the interface resistance. Could we get rid of this contact resistance simply by making the contacts identical to the conductors? Yes, but then the
measurement we are talking about would not make sense. The contacts have to be 'infinitely' more conducting than the conductor in order to justify our assumption that the applied voltage drops entirely across the conductor. In the same book, on page 53, he wrote “The contact resistance of a single-moded conductor is $\sim 12.9 K \Omega$, which is certainly not negligible! This is the resistance one would measure if a single-moded ballistic conductor were sandwiched between two conductive contacts”. On page 56, in the same book he further wrote “Now if we sketch the average quasi-Fermi level we find that it drops equally at the two interfaces but is flat across the conductor as shown in Fig. 2.1.1.c. Since a voltage drop is associated with resistance we conclude that there are two equal resistances at the two interfaces but none inside the conductor”. In the same page he further wrote “No matter how we choose to define the ‘voltage’ there is no drop across the conductor. All the drop is at the interfaces”. So, the symmetry filtering model does not even doing the quantum transport because this model uses Lippmann-Schwinger and Dyson’s equations in which the voltage drop appears in the entire scattering region of the devices and thus we conclude that this model is doing the ohmic transport.

(5) Lippmann-Schwinger and Dyson’s equations can only be used if the total energy of the particle is greater than or equal to the scattering potential energy. This equation must not be used if total energy is less than the scattering potential energy. Tunneling process only happens when the total energy is less than the potential energy and thus using Lippmann-Schwinger and Dyson’s equations will violate the essence of quantum tunneling rule, consequently a tunneling process will end up as a ohmic transport. In other words, Lippmann-Schwinger and Dyson’s equations can never be able to capture the tunneling process, because in a tunneling process only two scattering happens from tunneling potential. One, when the particle enter into tunneling process, and second when it come out from the tunneling process. No scattering happens during the tunneling process because of the flatness in the top edge in a square potential for example. Flatness of the edge in a square potential is the necessary and the sufficient condition for a coherent tunneling. If edge is not flat (have slope) then there is no guarantee that the current in a experimental observation is due to the tunneling current only. It could be then a Richardson thermionic current. Also, symmetry filtering model predict a very large TMR in many materials, but the TMR in any experiment is always a small value (less than 200%). Also the experimental hysteresis curve is always equal to the hysteresis of the ferromagnet (if sufficiently thick ferromagnetic layer has been used in experiment).

B. Flaw in the second model

(1) The two spin channel model is based on the N.F. Mott proposition. In solid state physics volume 56, page 120, E.Y. Tsymbal and D.G. Pettifor wrote “GMR can be qualitatively understood using the Mott model, which was introduced as early as 1936 to explain the sudden increase in resistivity of ferromagnetic metals as they are heated above Curie temperature. There are two main points proposed by Mott. First, the electrical conductivity in metals can be described in terms of two largely independent conducting channels, corresponding to the up-spin and down-spin electrons, which are distinguished according to the projection of their spins along the quantization axis. The probability of spin-flip scattering processes in metals is normally small as compared to the probability of the scattering process in which the spin is conserved. This means that the up-spin and down-spin electrons do not mix over long distance and, therefore, the electrical conduction occurs in parallel for the two spin channels. Second, in ferromagnetic metals the scattering rates of the up-spin and down-spin electrons are quite different, whatever the nature of the scattering centers is. According to Mott, the electric current is primarily carried by the electrons from the valance sp bands due to their low
effective mass and high mobility. The d-bands play an important role in providing final states for the scattering of the sp electrons. In ferromagnets the d-bands are exchange split, so that the density of states is not the same for the up-spin and down-spin electrons at the Fermi energy. The probability of scattering into these states is proportional to their density, so that the scattering rates are spin-dependent, i.e. are different for the two conduction channels. Although, as we will following, this picture is too simplified in a view of the strong hybridization between the sp and d states, it form a useful basis for a qualitative understanding of the spin-dependent conduction in transition metals”.  

This model is based on the heuristic approach, whereas our analysis is based on the Brillouin zones, Bragg’s diffraction condition and the band-structure of 3d metals. Our analysis is purely based on the quantum-mechanical effects. In our previous discussion on iron we have discussed that why iron or any 3-d transition metals shows more than one valance electrons at the Fermi level. We found that in iron or any other 3d transition metals, one type of electron resides in the 9th Brillouin zone while other type of electron resides in the 5th Brillouin zone. If we take gradient of the total energy E(k) with respect to k along the Γ to H direction, then we see that the 9th Brillouin zone electron have higher gradient than the 5th Brillouin zone electrons. If we multiply the energy gradient with $\frac{1}{\hbar}$, then we will get the group velocity of the electron with which it travel in the 9th and the 5th Brillouin zones along the Γ to H direction. We can clearly see that the 9th Brillouin zone electron travel much faster than the 5th Brillouin zone electrons. If we multiply the energy gradient with $\frac{1}{\hbar}$, then we will get the group velocity of the electron with which it travel in the 9th and the 5th Brillouin zones along the Γ to H direction. We can clearly see that the 9th Brillouin zone electron travel much faster than the 5th Brillouin zone electron (see in Figure[1]). (2) In two spin channel model, the reason that why up spin electron face different rate of scattering than the down spin electrons is purely unknown. This model is purely based on the ad – hoc picture and have no solid quantum mechanical foundation. (3) Using Boltzman equation, Albert Fert et al.[11] derived a spin current conversion rates. They concluded that the difference in a chemical potential between spin up and spin down electrons which varies spatially are the driving force for the current conversion[11]. Further, the chemical potential differences between the both spins (up and down) channels follows the diffusion equation[11]. The magnitude of a chemical potential difference is determined by the ease with which the current conversion process can take place[11]. First, the Boltzman equation are the semi-classical equation. Second, the electrochemical potential in any semi-conducting material always lies in the middle of the band-gap and it is not vary spatially until the material is very heavily doped with either the p-type or n-type dopant, and concentrations of dopant vary spatially. Because the Bragg’s diffraction is the root cause for the electrochemical potential to lies in the middle of the band-gap which throw away the two energy states symmetrically about the single Bragg’s plane after very strong diffraction. Thus saying that the chemical potential varies spatially[11] in any pure or nearly pure material is very surprising. The other model like E.C.Stoner, and few others, are based on semi-classical approach in which the various microscopic quantum mechanical effect have not been included. However, once the quantum mechanical effects are known, then the natural process can be modeled using the semi-classical equation on a macroscopic level.

VI. CONCLUSION

In this paper we have tried to address the long lasting mysterious problem in condense matter physics that why iron has more than one valance electron using Brillouin zones, Bragg’s diffraction condition, and iron bands structures which come after density functional theory calculation. We have also discussed the classification of bands in a different Brillouin zones in iron case, although the same rule can be applied in any other material without losing any generality. We have explained the origin of magnetism or exchange magnetic field using the Brillouin zones, Bragg’s diffraction condition, and
band-structure of iron. We found that the 5th and the 11th Brillouin zones in iron are coupled (closed) and vibrates together with 180° phase difference are the cause of ferromagnetism and presence of the exchange magnetic field. We have seen the similar closed curve in every insulator band-structure which present at the valence-band maxima in principal directions. We predict that the every insulator will show magnetism if it dope sufficiently heavily with p-type elements, so that the Fermi energy level move towards the valence bands maxima. Once the Fermi-energy level either touch or cut the valence-band maxima of the material, then material will show magnetism. Whether the material behaves like a paramagnetic, diamagnetic or a ferromagnetic will depends upon the level of doping and Fermi-energy level after doping. We have seen a similar close loop in ferroelectric materials which present at the valance-bands in band-structure as well, and thus we are expecting that the same close curve is also the cause of ferro-electricity in ferroelectric materials. We have explained the working principle of GMR, TMR, STT-RAM, and magnetic cluster devices using Brillouin zones, Bragg’s diffraction condition and band-structure of iron. We have addressed the flaw that exist in a current existing models which explains the working principle of these devices.

We hope that this paper will stimulate the scientific community to start looking the physical observations using the full Brillouin zones (not only the 1st Brillouin zone), Bragg’s diffraction conditions, complete band-structures, classifying the Bloch states into the different Brillouin zones, anisotropic traveling velocity and anisotropic effective mass which arises due to the geometrical spatial constrained in the higher Brillouin zones, spatially distributed of Brillouin zones around the Γ point, all-together during the analysis of the electronic and the magnetic properties of any material.

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