

# Magnetic Field Induced Metal-Insulator Transition in Silicon

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**ABSTRACT:** Metal-insulator transition in doped semiconductors is investigated in the presence of intense magnetic field. Using Thomas Fermi screening function and a screened coulomb potential in the Hamiltonian, a two parameter variational calculation leads to metallization. The correlation effect among the electrons is considered through an effective mass that depends on the spatial separation between impurities.

**KEYWORDS:** Semiconductors; Magnetic field effect; Metal - insulator transition, Si

## I. INTRODUCTION

Metal-insulator transitions are transitions from a metal (material with good electrical conductivity of electric charges) to an insulator (material where conductivity of charges is quickly suppressed). These transitions can be achieved by tuning various ambient parameters such as pressure or, in case of a semiconductor; doping. The classical band structure of solid state physics predicts the Fermi level to lie in a band gap for insulators and in the conduction band for metals, which means metallic behavior is seen for compounds with partially filled bands. However, some compounds have been found which show insulating behavior even for partially filled bands. This is due to the electron-electron correlation. Anderson localization is a general wave phenomenon that applies to the transport of electromagnetic waves, acoustic waves, quantum waves, spin waves, etc. This phenomenon is to be distinguished from weak localization, where the transition from metallic to insulating behavior is not due to disorder, but to a strong mutual Coulomb repulsion of electrons.

MIT observed in doped semiconductors are referred as Mott transition. For a hydrogenic donor it has been observed that ionization energy increases with the strength of the magnetic field. Hence, it is interesting that, if MIT is possible in a magnetic field.[1-3]

## II. THEORY

### Donor binding energy

The Hamiltonian for an isolated donor immersed in a dielectric constant  $\epsilon_0$  and an electron effective mass  $m^*$  is given by [4-6]

$$H_o = -\frac{\hbar^2 \nabla^2}{2m^*} - \frac{e^2}{\epsilon_0 r} e^{-\lambda r}$$

We have considered Thomas Fermi screening function with a screening parameter

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$$\lambda = \left( \frac{4\pi e^2 \eta}{\epsilon_0} \right)^{\frac{1}{2}},$$

where 
$$\eta = \frac{3}{2} \left( \frac{N}{E_F} \right)$$

is the density of states for electrons.

In the presence of magnetic field the above Hamiltonian becomes

$$H_1 = \frac{1}{2m^*} \left( \vec{P} + \frac{e}{c} \vec{A} \right)^2 - \frac{e^2}{\epsilon_0 r} e^{-\lambda r}$$

And for convenience, we choose

$$l = (h/2m^*c)^{1/2} \text{ as the unit of length.}$$

To study MIT, presence of all impurities situated in the neighborhood of a particular donor has to be considered. Assuming a Poisson like distribution of impurities, the leading term in the potential energy is of the form

$$V(r) = (e^2/\epsilon_0 r) e^{-\lambda r}$$

Within the Thomas-Fermi theory. So the Hamiltonian pertinent to this problem is  $H_1$ . To find the ionization energies perturbation method is used.[7-9]

Treating the perturbation as

$$H = H_1 - H_2 = - \frac{e^2}{\epsilon_0 r} (e^{-\lambda r} - 1)$$

And taking  $\psi$  as the zeroth order eigen function, the first order perturbation theory leads to

$$\Delta E^{(1)} = \frac{4(\gamma/2)^{-1/2}}{R} \left( \frac{1}{4} - \frac{1}{(2 + \lambda R)^2} \right)$$

where  $R = \left( (3/4) a^2 b \right)^{1/3}$ .

The ionization energy is given by  $E_{ion}^{(1)} = E_{ion}^{(0)} + \Delta E^{(1)}$ .

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**Table 1.**

Characteristic parameters of a few semiconductors

Semiconductor	m* (a.u)	ε <sub>0</sub>	No of conduction band minima
CdTe	0.091	10.23	1
Si	0.3	11.7	6

**Table 2**

Critical concentration of donor in a magnetic field[10]

γ	Si
0	6x10 <sup>17</sup>
0.5	5x10 <sup>18</sup>
1.0	1x10 <sup>19</sup>
5.0	5x10 <sup>20</sup>

### III.RESULTS AND DISCUSSION

Table 2 gives a critical concentration of donor in a various magnetic fields. These results are based on the Thomas Fermi theory. The results are interesting in the sense that MIT is obtainable in every magnetic field. However the critical concentration at which MIT occurs increases with magnetic field. The observed MIT in doped semiconductors is due to formation of impurity band split by electron- electron correlation effects. Though an exact theory based on the Hubbard model for such a problem eludes, some approximation schemes assuming a simple cubic or Fcc coordination, etc, have been worked out. The effect of electron-electron interaction on MIT appears to be more significant in intense magnetic fields.

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## REFERENCES

1. N.F.Mott, Metal Insulator Transition, Taylor and Francis, Philadelphia, PA1974
2. Shanthi B., Revathy C., Devi A.J.M., Parameshwari P.J., Stephen T., "Serum 25(OH)D and type 2 diabetes mellitus", Journal of Clinical and Diagnostic Research, ISSN : 0973 - 709X, 6(5) (2012) pp.774-776.
3. Madhubala V., Subhashree A.R., Shanthi B., "Serum carbohydrate deficient transferrin as a sensitive marker in diagnosing alcohol abuse: A case - Control study", Journal of Clinical and Diagnostic Research, ISSN : 0973 - 709X, 7(2) (2013) pp.197-200.
4. M.N.Alexander, D.F.Hocomb, Rev.Mod.Phys.40 (1968) 815
5. Nagarajan C., Madheswaran M., "Stability analysis of series parallel resonant converter with fuzzy logic controller using state space techniques", Electric Power Components and Systems, ISSN : 1532-5008, 39(8) (2011) pp.780-793.
6. Bhat V., "A close-up on obturators using magnets: Part I - Magnets in dentistry", Journal of Indian Prosthodontist Society, ISSN : 0972-4052 , 5(3) (2005) pp.114-118.
7. P.W.Anderson, Phys.Rev. 109 (1958) 1492
8. P.A.Lee, T.V.Ramakrishnan, Rev.Mod.Phys, 57 (1985) 815
9. G.Jeyam, K.Navaneethakrishnan, J.Appl.Phys. 89 (2001) 6198.
10. Dr.V.Krishnasamy, S.Rosy Christy, SUBSTITUTED AROMATIC ANILS - A KINETIC STUDY USING PYRIDINIUM CHLOROCHROMATE ( PCC ), International Journal of Biotech Trends and Technology (IJBT), ISSN: 2319-8753, pp 495-499 , Vol. 2, Issue 2, February 2013
11. DR.V.Krishnasamy, S.Rosy Christy, KINETICS OF OXIDATION OF AROMATIC ANIL BY PYRIDINIUM DICHROMATE – STUDY OF THE EFFECTS OXIDANTS AND SUBSTRATE, International Journal of Biotech Trends and Technology (IJBT), ISSN: 2319-8753, pp 298-302, Vol. 2, Issue 1, January 2013
12. Mrs.Shanthi & Dr.A.Mukunthan, Nucleation kinetics of L-Alanine acetate, International Journal of Innovative Research in Science, Engineering and Technology, ISSN: 2319-8753, pp 2650-2653, Vol. 2, Issue 7, July 2013
13. Mrs.V.G.Vijaya, DESIGN AND FABRICATION OF SEQUENCING CIRCUIT WITH SINGLE DOUBLE ACTING CYLINDER, International Journal of Computer Trends and Technology(IJCTT), ISSN: 2319-8753, pp 6315-6322, Vol. 2, Issue 11, November 2013
14. Bharthvajan R, A STUDY ON THE EFFECTIVENESS OF SALES INCENTIVES IN IMPROVING SALES PERFORMANCE, International Journal of Computer & Organization Trends (JCOT), ISSN: 2319-8753, pp 10931-10933, Vol. 3, Issue 4, April 2014