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# Change in Energy of Quasi Particles in Materials

**Ravi Kumar Chanana**
Self-Employed Independent Researcher, Gr. Noida-201310, India

## ABSTRACT

**This short communication reviews the change in energy of quasi particles in materials by providing the mathematical equations of differential calculus for the change in energy. These equations find applications in the Electron Physics related area of the Condensed Matter Physics. Photodiodes and Phototransistors are also proposed based on the finding of the intrinsic Fermi energy levels in semiconductors.**

**Keywords:** Quasi Particles, MOS device, Thermal Silicon Dioxide, Materials, Phototransistors.

## SHORT COMMUNICATION

Einstein's special theory of relativity resulted in the equation for intrinsic energy of a particle as: $E_0 = m_0 c^2$. Here, $m_0$ is the rest mass of the particle and $c$ is the speed of light. The relativistic energy $E$ of the particle is obtained by multiplying the above equation by the Lorentz factor $\gamma$, where $\gamma = 1/\left(\sqrt{1-v^2/c^2}\right)$. Thus,

$$E = \gamma m_0 c^2 \quad (1).$$

The full derivation of the relativistic energy gives:

$$E^2 = p^2 c^2 + m_0{}^2 c^4 \quad (2).$$

Here, a massless particle as a wave will give $E = pc$ and a particle with mass $m_0$ will give $E = E_0 = m_0 c^2$ as the intrinsic energy of the particle. A differentiation and rearrangement of the two equations of $E$ gives:

$$\frac{dE}{E} = -\frac{d\lambda}{\lambda} \quad (3),$$

and

$$\frac{dE}{E} = \frac{dm}{m} \quad (4).$$

Here in equation (4), m is the mass of the moving particle at constant velocity $v$ having energy $E = mc^2$ with $(v/c)$<<1. This changes the energy $E_0$ of the particle and its rest mass $m_0$ to become differentiable. Also, for equation (3), $p = h/\lambda$ with $p$ as the momentum of the particle, $h$ is the Planck's constant and $\lambda$ is the wavelength of the wave. It can be observed from equations (3) and (4) that, the percentage change in energy $dE/E$ of the quasi particles in materials can be obtained either by using the wavelengths of the photons before and after scattering, as in the Raman effect or, by using the electron effective mass in the material as $dm/m$. In thermal silicon dioxide, the relative electron effective mass is 0.42 as dm/m [1]. Two new pieces of scientific knowledge in the area of Electron Physics has come about based on the above Mathematics of differential calculus. One, the intrinsic Fermi energy level in materials having a bandgap is determined using equation (4) above. dE is the intrinsic Fermi energy from the conduction band of the materials which equals the longitudinal electron effective mass as dm/m multiplied by the bandgap of the material. For example, the longitudinal electron effective mass of one conduction valley in Si (100) semiconductor is 0.49 as dm/m. This multiplied by the Si bandgap of 1.12 eV gives the intrinsic Fermi energy level below the conduction band as $E_i$ = 0.5488 eV. Considering a third decimal place value of 3 or 4 in the Si bandgap value of 1.12 eV makes the $E_i$=0.550eV [2]. The intrinsic Fermi energy level can be found for all parabolic semiconductors and insulators. The implication of this finding is that all the properties of a MOS device can be calculated without the need for fabrication of the device. Fabrication may be needed to find the interface trap density at the oxide/semiconductor interface to estimate electron mobility in the MOS transistor device [3-5]. Two, it has been shown that quasi particles lose energy in the materials while traversing through them. In particular, it has been shown in thermal silicon dioxide, 42 % of average electron energy of about 5.5 eV at the bottom of the oxide conduction band is lost while tunneling through the oxide at high fields across the MOS device to overcome the Si-$SiO_2$ conduction band barrier of 3.2 eV. This loss leads to the explanation of the anode hole injection over the anode-oxide hole barrier of 4.6 eV [1]. It is to be noted that 0.42 is the relative electron effective mass in the thermal $SiO_2$ which equals the percentage change in lost energy from equation (4). A third technological outcome is the proposal of two photodiodes that can be designed from the intrinsic semiconductors and possible hetero junction bipolar phototransistors can result by adding a reverse-biased second n-Si junction [6].

## CONCLUSION

New scientific knowledge about Mathematics of differential calculus in relation to Electron Physics and design of Phototransistor devices is reviewed and highlighted in this brief communication.

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