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SERVICES FOR SCIENCE AND EDUCATION

Constant Total Energy for A Given Mass and At A Given Temperature Is the Source of The Universal Mass-Energy Equivalence Relation in Semiconductor and Insulator Materials Having A Bandgap

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ABSTRACT

In this research article it is shown that the motion of an electron or hole in semiconductor and insulator materials having a bandgap is similar to the falling object on the surface of the earth at constant acceleration due to gravity g of 9.8 meters/sec^2. The constant total energy for a given mass and at a given temperature is the source of the universal mass-energy equivalence relation in materials having a bandgap. This relation is given as dE/E = dm/m. In materials, dE is the differential potential energy from the intrinsic Fermi energy level E_i to the conduction band of the materials, and E is the semiconductor bandgap as the total potential energy of the electrons. These energies are also the total mechanical energies of the electrons at the cathode of the materials where the velocity of the electron in the material is zero at zero electric field, and so it possesses only potential energy as the total mechanical energy. The dm is the differential mass as the longitudinal electron effective mass and m is the free electron mass.

Keywords: Bandgaps, Energy, Materials, Mass-Energy equivalence.

SHORT COMMUNICATION

In Classical mechanics at the school level, it is taught that the change in potential energy is equal to a change in kinetic energy for an object of mass m dropped from a height h at constant acceleration due to gravity g of 9.8 meters/sec^2, ignoring the friction on the falling object due to air. The potential energy of the object at height h is given as mgh. Since the velocity before dropping the object is zero, therefor the kinetic energy of the object at height h is zero. The total mechanical energy which is the sum of the kinetic and potential energy is therefore equal to mgh at height h. When the object is dropped, it reaches the ground with a final velocity v in meters/sec. The kinetic energy of the object is now $0.5mv^2$ and the potential energy is zero after reaching the ground. So, the total mechanical energy is $0.5mv^2$. The total mechanical energy is constant due to conservation of energy and so mgh equals $0.5mv^2$. In other words, the potential energy of the object changes from mgh at height h to zero at the ground and the kinetic energy of the object changes from zero at height h before being dropped, to $0.5mv^2$ when dropped and at the time of reaching the ground. The change in potential energy equals the change in kinetic energy.

The final velocity of the object when reaching the ground can analogous to the saturated drift velocity of electron in a material at high field at a given temperature. This saturated drift

velocity is constant. At zero electric field at the cathode across a semiconductor or insulator, the kinetic energy of the electron is zero and the potential energy of the electron is the energy from the metal to the conduction band of the material. So, the total mechanical energy of the electron at the cathode is the same as the total potential energy because the kinetic energy of the electron at the cathode is zero. After applying the field, for example a 10 to 20KV across a Si semiconductor, the saturated and constant drift velocity is reached at the anode where the potential energy is zero. The total energy being constant, the change in potential energy of the electron at the cathode equals the change in kinetic energy of the electron of $0.5mv^2$ at the anode having a constant drift velocity v meters/sec. Thus, the motion of the electron in a semiconductor or insulator material is similar to the falling object from height h at constant acceleration due to gravity. For both, constant velocity and constant acceleration due to gravity, the total energy is constant due to conservation of energy and gives the same universal mass-energy equivalence relation dE/E =dm/m when the total energy is differentiated once giving a first-order differential equation as above [1-4]. This universal mass-energy equivalence relation is discussed in more detail in the author's earlier studies [1-4]. In materials, the total potential energy of the electron E, as the semiconductor bandgap, is the total mechanical energy of the electron at the cathode where the field is zero with respect to the anode at voltage V, and thus the kinetic energy of the electron is zero.

The difference in the motion of an electron in a material and an object falling under acceleration due to gravity g is that the electron in materials move under the electrostatic force and acquire a constant drift velocity or saturation velocity at a high enough electric field at a given temperature, whereas the object falling on earth move under the gravitational force and acquire a final velocity when it reaches the earth. For a given electron mass at a given temperature, the constant drift velocity gives a constant total energy of electrons in materials. If there is increase in energy, say, in thermal energy caused by heating the material, then there is increase in electron mass as shown earlier giving the relation dE/E=dm/m [1]. Similarly, for the falling object under gravity, the total mechanical energy E is mgh with g and h being invariable, and thus keeping the energy constant. Now a change in mass would cause a change in energy giving again the relation dE/E=dm/m [4]. The same will be true for the falling object having total mechanical energy as $0.5mv^2$ when reaching the earth's surface. So, for both constant velocity motion of the electron particle as it reaches the saturated drift velocity at high electric fields, and constant acceleration motion of the falling object, the universal mass-energy equivalence relation is manifested as dE/E=dm/m. This was first proposed by the famous scientist Albert Einstein by the equation of the total relativistic energy equation of a relativistic moving mass m as $E = mc^2$, where c is the speed of light. This equation is the final form of his mass-energy equivalence that he showed as a conclusion of his special theory of relativity. If this equation is differentiated once, it gives the same universal mass-energy equivalence relation dE/E=dm/m [1]. A recent article by the author describes how the discovery of the universal mass-energy equivalence relation given as dE/E=dm/m was made in materials having a bandgap [5-7].

CONCLUSION

The universal mass-energy equivalence relation is valid for different forms of energy such as potential, kinetic, nuclear, chemical, thermal, electrical, mechanical etc. In this paper it is shown conclusively, the analogous behavior of a falling object under gravity to the motion of electrons

in materials having a bandgap such as semiconductors and insulators. Biological materials like proteins and amino acids also fall in this category.

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