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Electricity Generated by Sound Energy Based on the Soundelectric Effect

Dev Raj Joshi
Department of Physics, Tribhuvan University, Kathmandu, Nepal
Email: joshidevraj348@gmail.com

Abstract - An expression is derived for the soundelectric effect for the material. Since the sound wave is the mechanical vibration having oscillation of pressure. There are two pressure acting in the metal surface that reduces the work function much lower such that sound wave can have to full fill the soundelectric effect with the positive kinetic energy of ejected electron. These two are external pressure and pressure created by particle vibration of sound wave both acting inward pressure. We found that inward pressure and outward pressure (due to shielding effect), results two outermost orbits come very closer that reduces the energy gap between two orbits. Due to low work function of material in this way one can eject the electron from sound energy instead of light energy like Einstein photoelectric effect. Thus, it helps to increase the efficiency of converting sound energy to electricity in a large scale by using piezo material (transducer) in highly populated roads or stadium or railway stations etc.

Key words: soundelectric effect, sound wave, pressure, efficiency, piezo, efficiency, eject

1. Introduction

The sound wave is the longitudinal wave in which the direction of vibration of particle is same as that of wave propagation; vibrating continuously by forming compression and rarefaction. Sound velocity is depends on the elastic modulus and density of medium in which wave is propagating. Sound wave propagating in different medium with different velocity with the order solid > liquid > gas. However, it is also depend on the some more external factors such as temperature, pressure, density, moisture (humidity), wind velocity etc. The speed of sound in air at 0^0 C is 331.5 m/s and at normal room temperature (20^0 C) is 343 m/s. Since the air is composed of different gases; some major gases are Nitrogen (78.084% with molar mass 28.013gm), Oxygen (20.946% with molar mass 31.999gm), Argon(0.934% with molar mass 39.948gm), Carbon-dioxide (0.033% with molar mass 44.010gm). Therefore, the molar mass is considered to be the average molar mass with their composition parts that is 28.9647gm.

Soundelectric effect is the process of ejection of electron from the metal surface when the light energy incident on the metal surface. It occurs only when the work function is less than the incident energy. In this process some amount of energy is required to eject the electron (photo electron), that minimum energy is called work function of material and remaining part of energy provides the kinetic energy to the ejected electron. The value of work function is varying with material to material. In general, work function is small in an open lattice metal and large for metal having closely packed. In a known metal, the highest value of work function is approximately 6.35 eV for Platinum (Pt) and lowest value is 2.14 eV for Cesium (Cs). These all are the factor which are responsible for work functions of any atoms and time delay to kick out the electron from surface of material. There are many factor which are responsible for work functions of any atoms and kicking out the electron from surface of material. The factors may be pressure exerted on atom either pulling or pushing of an atom from external environment, electron-electron, electron-proton, electron-neutron, proton-neutron-electron attraction or repulsion inside the atom, consider atom and surrounding environment like effect of free charge particle, atom, neutral charge and other.

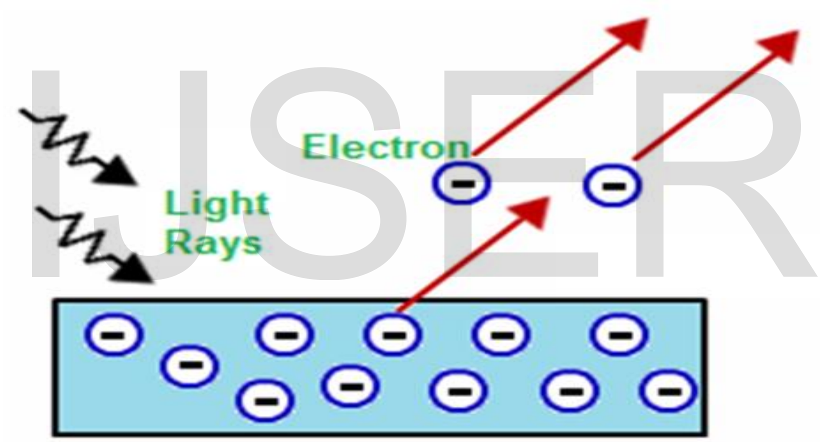

Fig.1 Photoelectric effect in light

In this research work, we are trying to give a theoretical model of soundelectric effect in sound, that decreases the work function of the material especially, photonic material for sound wave frequency range. The utilization of such sound energy is possible only if we constructed materials which can emit the electron from atom, for all ranges of frequencies. This is possible to decrease the work function of the material either by doping of the different material that has shielding effect or by applying the Van der Waals force relation. Base on these principles we can construct photonic materials that have different work function and can be used for sound wave frequency to show soundelectric effect.

2. Literature Review

Perovskite oxides containing transition metals are promising materials in a wide range of electronic and electrochemical applications. The work function trends of a series of perovskite (ABO_3 formula) materials using density functional theory (DFT), and show that the work functions of (001) terminated AO^- and BO_2^- oriented surfaces can be described using concepts of electronic band filling, bond hybridization, and surface dipoles. The calculated range of AO (BO_2) work functions are 1.60 - 3.57 eV (2.99 - 6.87 eV). Furthermore, $SrVO_3$ as a stable, low work function, highly conductive material. Undoped (Ba-doped) $SrVO_3$ has an intrinsically low AO^- terminated work function of 1.86 eV (1.07 eV). These properties make $SrVO_3$ a promising candidate material for a new electron emission cathode for application in high power microwave devices, and as a potential electron emissive material for thermionic energy conversion technologies [1].

The efficiency of organic light-emitting devices is significantly influenced by the performance of the electron injecting contact. Lowering the energetic barrier between the metal contact and the lowest unoccupied molecular orbital of the adjacent organic electron transport layer should facilitate the injection of negative charge carriers, and, thus, improve the electro-luminescence yield by increasing the electron density in the emitting zone. Therefore, it is widely believed that lowering the work function of the cathode metal will improve the quantum efficiency of the devices and, concomitantly, reduce the operating voltage. The report on measurements of devices with tris (8- hydroxyquinolinolato) aluminum-(III) as electron transport and emissive layer. The latter layer is contacted with a variety of chemically very different cathode metals (including some lanthanides), which cover a range from 2:63 eV up to 4:70 eV on the work function axis. It demonstrated the existence of an efficiency maximum at a work function of about 3:7 eV. These results are of practical importance with respect to the choice of pure cathode metals for organic electroluminescent display applications [2].

The work function of the materials is depending on the roughness of the surface. Surface of silver has important effects on its performance in natural environments. Surface roughness and work function of the silver samples were measured using confocal laser scanning microscopy and scanning Kelvin probe respectively. Based on the theories of flat parallel-plate capacitor and the surface roughness, a numerical model of the relationship of work function (WF) and surface roughness (SR) was deduced. The numerical model revealed that WFs of the surfaces of the silver samples decreased linearly with *S*a. Comparison between the experiments and the model about roughness and work function showed the model was in agreement with the experiments. The theoretical results of numerical model were obtained by computational approaches and based on Maple® codes. The numerical model deduced from the software might be used to detect the value of SR or WF after one of them was decided, and could be used to calculate the depth of the groove on the polished surface of the silver samples as well [3].

The work function can be lowered to nearly 1 eV by combining electrostatic gating with surface engineering techniques for the graphene system. Due to its two-dimensionality and low surface density of states, electrostatic gating can effectively control the graphene work function by changing its Fermi level. It demonstrates for the first time that an ultralow work function graphene is achieved by combining electrostatic gating with a Cs/O surface coating. A simple device is built from large-area monolayer graphene grown by chemical vapor deposition, transferred onto 20 nm HfO_2 on Si, enabling high electric fields capacitive charge accumulation in the graphene. Firstly it observed over 0.7 eV work function change due to electrostatic gating as measured by scanning Kelvin probe force microscopy and confirmed by conductivity measurements. The deposition of Cs/O further reduced the work function, as measured by photoemission in an ultrahigh vacuum environment, which reaches nearly 1 eV, the lowest reported to date for a conductive, nondiamond material. This combination approach demonstrated here provides a route toward ultralow work function electrodes for energy conversion and electron emission applications [4].

Chemical and electronic properties of anatase (001), anatase (101), polycrystalline anatase, rutile (110) and rutile (001) with different surface treatments were studied using XPS and UPS. The Fermi energy and work function depend drastically on surface conditions, which are characterized by different oxygen vacancy concentrations and surface adsorbates. Polycrystalline anatase thin films, (001)- and (101)-oriented anatase TiO_2 single crystals and (001)- and (110)-oriented rutile TiO_2 single crystals with various surface treatments were studied by photoelectron spectroscopy to obtain their surface potentials. Regardless of orientations and polymorph, a huge variation of the Fermi level and work function was achieved by varying the surface condition. The most strongly oxidized surfaces are obtained after oxygen plasma treatment with a Fermi level 2.6 eV above the valence band maximum and ionization potentials of up to 9.5 eV (work function 7.9 eV). All other treated anatase surfaces exhibit an ionization potential independent of surface condition of 7.960.15 eV. The Fermi level positions and the work functions vary by up to 1 eV. The ionization potential of rutile is 0.56 eV lower than that of anatase in good agreement with recent band alignment studies. The effect of light were carried out on Au, Pt and Cu surfaces immersed in water, in order to study the changes of work function arising from the interaction between the metallic surfaces and water. The results show an action of liquid water about three times larger than that of low-temperature ice. Theoretical calculations, present in literature, have predicted values much lower than those they measured. The substantial changes in work function measured here appear to arise from the complex structure of water in the vicinity of the metal surface [5, 6].

A Universal Method to Produce Low–Work Function Electrodes for Organic Electronics is Organic and printed electronics technologies. It requires conductors with a work function that is sufficiently low to facilitate the transport of electrons in and out of various optoelectronic devices. It show that surface modifiers based on polymers containing simple aliphatic amine groups substantially reduce the work function of conductors including metals, transparent conductive metal oxides, conducting polymers, and graphene. The reduction arises from physisorption of the neutral polymer, which turns the modified conductors into efficient electron-selective electrodes in organic optoelectronic devices. These polymer surface modifiers are processed in air from solution, providing an appealing alternative to chemically reactive low–work function metals. Their use can pave the way to simplified manufacturing of low-cost and large-area organic electronic technologies [7].

The work function of transparent conducting ZnO thin films is decrease by the implementation of Phosphorus ion. To confirm the possibility of engineering the work function of ZnO thin films, it has implanted phosphorus ions into ZnO thin films deposited by radio-frequency magnetron sputtering. The fabricated films show n-type characteristics. It is shown that the electrical and optical properties of those thin films vary depending sensitively on the ion dose and rapid thermal annealing time. Compared to as-deposited ZnO films, the work-function of phosphorus ion-implanted ZnO thin films is observed to be lower and decreases with increasing ion doses. It is likely that the zinc or oxygen vacancies are firstly filled with the implanted phosphorus ions. With further increased ions, free electrons are generated as Zn^{2+} sites are replaced by those ions or interstitial phosphorus ions increase at the lattice sites, the fermi level by which approaches the conduction band and thus the work function decreases. Those films exhibit the optical transmittance higher than 85% within the visible wavelength range (up to 800 nm) [8].

A new approach on the photoelectric effect is that when photons hit a material surface they exert a pressure on it. It shows that this pressure has a negative component (opposite to the direction of propagation of the photons) due to the existence of the negative linear momentum transported by the photons. In the photoelectric effect, the electrons are ejected by the action of this negative component of the momentum transported by the light photons. It is still shown that, also the gravitational interaction results from the action of this negative component of the momentum transported by specific photons [9].

The first observation of the laser-assisted photoelectric effect from a solid surface by illuminating a Pt(111) sample simultaneously with ultra short 1.6 eV and 42 eV pulses. There observe side bands in the extreme ultraviolet photo-emission spectrum. The magnitude of these side bands as a function of time delay between the laser and extreme ultraviolet pulses represents a cross-correlation measurement of the extreme ultraviolet pulse. This effect promises to be useful to extend extreme ultraviolet pulse duration measurements to higher photon energies, as well as opening up femto second to atto second time-scale electron dynamics in solid and surface-adsorbate systems [10].

The theoretical expressions of photoelectric emission from a metal surface are taking account of the dependence, established by Bardeen, of the effective surface barrier on the momentum of the impinging electron, due to exchange and correlation forces in the interior. This generalization reduces by a significant factor the magnitude of the theoretical expression for the absolute photoelectric yield. The shapes of the energy and spectral distributions of emitted photo-electrons are essentially unchanged, so that certain well-known disagreements between theoretical and observed distributions near the threshold remain unexplained. The influence of the transmission coefficient of the surface potential barrier on the photoelectric properties of a metal is determining directly the variation with energy of the transmission coefficient, leading to information concerning the shape of the barrier [11].

To decrease the work function of the given material or compound or element by applying the external pressure and doping of the material that has screening or shielding effects, such a way that to decrease the bandwidth between conduct band and valance band. Because according to definition of work function, the amount of energy that required the remove the electron from valance band of an atom and it is also called ionization energy. These all energies depend upon the band width that is greater the band width greater energy required to remove the electron from the surface and vice versa. This model can increase the efficiency of material used in solar cell that is cell work for all range of frequencies and by construction material bases on this we can increase the efficiency of solar cell or any type of material working solar cell principle [12].

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3. Methodology

Theoretical Calculation

In this paper we are trying to give theoretical model of soundelectric effect by sound energy in different work function materials. To give the theoretical relation here we follow the Bohr's relation of energy for hydrogen atom and pressure area relation.

If we increase the pressure on an atom surface externally, the distance between two outer most orbits come closure. This shows that the amount of energy required to excite electron from second outer most orbit to first outer most orbit needed very less. Since, in normal condition(without applying pressure) the distance between the second and first outer most orbit is quite greater then applied pressure condition and hence the energy required to excite the electron from second to first outer most orbit needed more.

Mathematical Derivation

Let the kinetic energy of incident sound wave on the surface of material is $\frac{1}{2}m \cdot Vin^2$, where m is mass of air molecules and V_{in} is velocity of sound wave. The minimum amount of energy required to remove or eject the electron from metal surface called work function of material. If V_{eje} be the velocity of ejected electron from metal surface of work function W_0, then its kinetic energy gain is $\frac{1}{2}m \cdot Veje^2$.

For the soundelectric effect (from Einstein photoelectric effect concept),

Incident energy = Work function + KE of ejected electron

i.e. $$\frac{1}{2}m \cdot V_{in}^2 = W_o + \frac{1}{2}m \cdot V_{eje}^2 \quad (1)$$

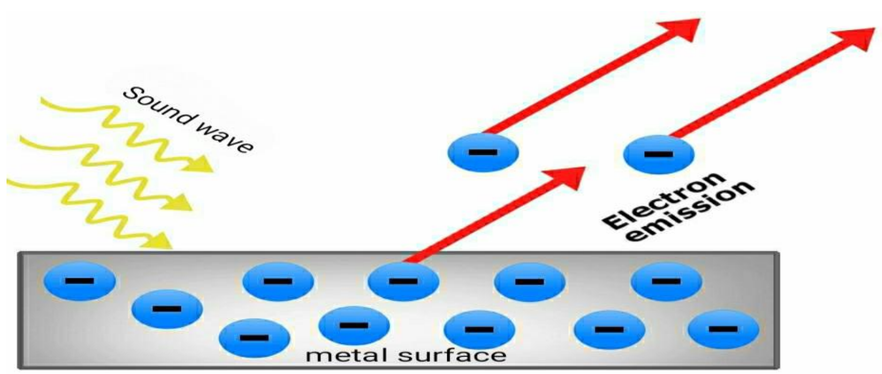

Fig.2 Soundelectric effect in sound wave

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Let us consider for atom the energy of valance band or energy of ground state electron is E_n and conductance band or excited state electron is E_{n+1}. Valence and conduction bands are the energy bands that are closest to the fermi level. The valence band is the highest occupied band and conduction band is the lowest unoccupied band closest to the fermi level. Then the work function of the material is given by,

$$E_{n+1} - E_n = W_0 \qquad (2)$$

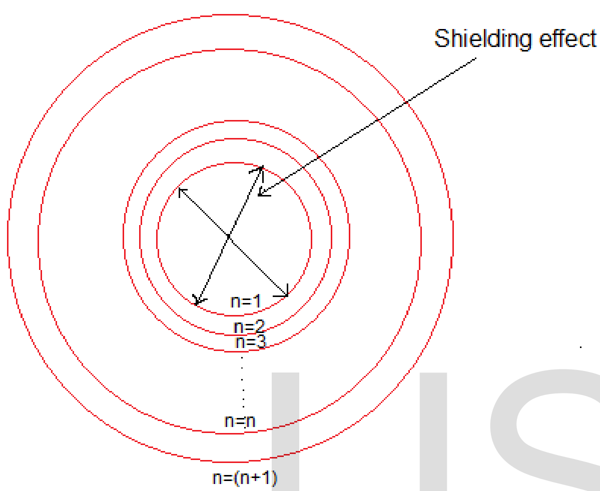
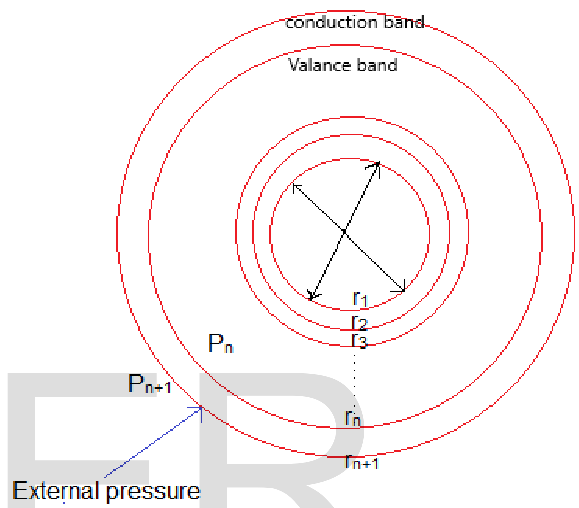
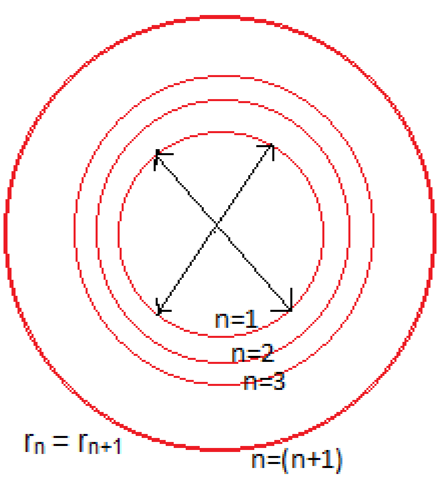


Fig.3(a) Energy Level for an atom without applying the external pressure.



(b) Energy Level for an atom by applying the external pressure.



(c) Energy Level for an atom by applying the external pressure. ($r_n = r_{n+1}$ for ideal condition)

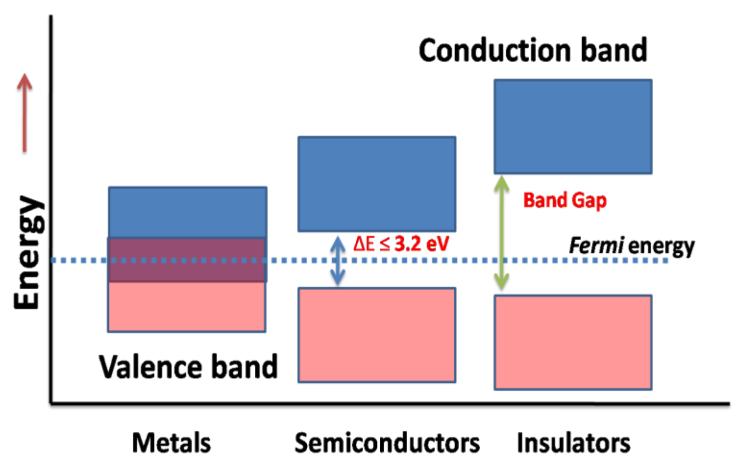


Fig.4 Energy band in the materials

Since the atom is not solid that is within atom there is the space so we can compress the atom. The atom is compressed by applying external pressure and pressure due to molecule vibration of sound wave. During the compression an atom compressed equally from all sides, and hence outer shell come to closure to the second last orbit or ground state orbit while the ground state orbit is less effect due to apply of the pressure from outer side of atom.

Let P_n and P_{n+1} are the pressure applying on energy level of an atom which is at a distance of r_n and r_{n+1} from nucleus, with constant force F then from energy different (work function) and pressure relation is:

$$P_{n+1} - P_n = \frac{F}{4\pi}\left[\frac{(E_{n+1}-E_n)(r_{n+1}+r_n)}{0.529ZR_H(r_{r+1}.r_n)}\right] \quad [12] \qquad (3)$$

From (2) and (3)

$$E_{n+1} - E_n = W_o = \frac{(P_{n+1}-P_n)4\pi\times0.529ZR_H(r_{n+1}\times r_n)}{F(r_{n+1}+r_n)} \qquad (4)$$

Here, Z is the atomic number of material and R_H is Rydberg's constant. It's value is 1.09677×10^7 m^{-1} or 2.178×10^{-18}Jor 13.61 eV.

For constant force F, the pressure area relation is,

$$\left.\begin{aligned} P_n &= \frac{-F}{A_n} \\ P_{n+1} &= \frac{-F}{A_{n+1}} \end{aligned}\right\} \qquad (5)$$

Here negative sign in (5) implies that force is acting from outside in outer most orbit. Since the external pressure on surface of an atom of $(n + 1)^{th}$ orbit is greater than pressure exerted on n^{th} orbit for constant force.

Using (5) in (4) we get,

$$W_o = 4\pi\times0.529\times ZR_H \frac{(r_{n+1}\times r_n)}{(r_{n+1}+r_n)}\left[\frac{1}{A_n} - \frac{1}{A_{n+1}}\right] \qquad (6)$$

If A_n and A_{n+1} are the area of n^{th} and $(n+1)^{th}$ orbits having radius r_n and r_{n+1} respectively then

$$\left.\begin{aligned} A_n &= 4\pi r_n^2 \\ A_{n+1} &= 4\pi r_{n+1}^2 \end{aligned}\right\} \qquad (7)$$

or, $$W_o = 4\pi \times 0.529 \times ZR_H \frac{(r_{n+1} \times r_n)}{(r_{n+1} + r_n)} \frac{1}{4\pi} \left[\frac{1}{r_n^2} - \frac{1}{r_{n+1}^2} \right]$$

or, $$W_o = 0.529 \times ZR_H \frac{(r_{n+1} \times r_n)}{(r_{n+1} + r_n)} \left[\frac{r_{n+1}^2 - r_n^2}{r_{n+1}^2 \times r_n^2} \right]$$

or, $$W_o = 0.529 \times ZR_H \frac{(r_{n+1} \times r_n)}{\cancel{(r_{n+1} + r_n)}} \frac{(r_{n+1} - r_n)\cancel{(r_{n+1} + r_n)}}{r_{n+1}^2 \times r_n^2}$$

or, $$Wo = \frac{(r_{n+1} - r_n)}{r_{n+1} \times r_n} 0.529 \times ZR_H$$

Since we are supposing the external force and force due to atom vibration in sound wave to the atom exert the pressure inward and shielding effect puss outside from the nucleus of an atom, such that the outermost orbit come closer and closer with inner outermost orbit i.e. (n+1)th orbit can be assumed to overlap with nth orbit (in ideal condition). Therefore we can neglect (r_{n+1}) in above relation.

$$W_o = \frac{-\cancel{r_n}}{r_n \times \cancel{r_n}} 0.529 \times ZR_H \qquad (\because r_{n+1} \sim r_n)$$

or, $$W_o = \frac{-0.529 \times ZR_H}{r_n} \qquad (8)$$

According to Bohr's, radius of orbit is given by

$$r_n = \frac{n^2 h^2}{4\pi^2 Zme^2} = 0.529 \times \frac{n^2}{Z} \qquad (9)$$

This is the distance from the center of nucleus to the orbit of an electron revolving around the nucleus.

Using equation (9) in equation (8)

$$W_0 = \frac{-0.5\cancel{29} \times ZR_H}{0.5\cancel{29} \times \frac{n^2}{Z}}$$

$$W_O = \frac{-Z^2}{n^2} R_H \qquad (10)$$

Since, it is consider that a free particle has zero potential energy. Any particle that is gravitationally or electrically bound (in our case it is bounded by external pressure and pressure due to particle vibration of sound wave push inside and shielding effect push outside) has negative potential energy, i.e. it requires positive work to be added, in order to free it. Therefore negative work function tells that how much work needs to be added to the bound electron, by the sound wave it absorbs.

Now, using relation (10) in (1)

$$\frac{1}{2}m \cdot V_{in}^2 = \frac{-Z^2}{n^2}R_H + \text{KE}$$

$$\text{or, KE} = \frac{1}{2}m \cdot V_{in}^2 + \frac{Z^2}{n^2}R_H \qquad (11)$$

Since, relation (10) represents the work function of the material is negative that depends on only the atomic number and orbit number of an atom. This negative value of work function results the positive kinetic energy of the ejected electron by sound energy from the soundelectric equation similar to Einstein Photoelectric effect that represented by relation (11).

4. Result and Conclusion

Hence, from the above relation (11), kinetic energy of the ejected electron is found to be positive and satisfy the soundelectric effect due to sound wave by applying external pressure and pressure due to sound wave. Because sound is mechanical wave in the form of oscillation of pressure.

The ejection of electron be easier in the case of light compared to that of sound because the wavelength of light waves is very small compared to that of sound and hence number of electron is also less in the case of sound wave. However, this helps to increase the efficiency of converting sound energy to electricity in a large scale by using piezo material (transducer) in highly populated roads or stadium or railway stations etc. Hence such material can also solve the problem of energy where solar radiation is absent.

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