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Modern Hybrid Vehicles Powered with Artificial Renewable Sources by Using Smart Methods

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Abstract:
Today we are living in the modern fast moving automobile age, we are in the need to responsible for global warming. In that way hybridvehiclesare playing an important role by producing the lowpollution emission when compared to the internal combustion engines. This is due to the presence of electric motors. But there are some problems acquired in the hybrid vehicles such as storages of batteries, space occupation and so on. To overcome these problems here we introduce some smart methods by using smart materials. Here there arethree smart materials weused; they are piezoelectric powered tyres, hub motor driven mechanism and thermionic materials.

Keywords*: hybrid vehicle, hub motor, piezoelectric powered tyres, thermionic materials*

1. Introduction

A hybrid vehicle is a vehicle that uses two or more distinct power sources to move the vehicle. The term most commonly refers to hybrid electric vehicles (HEVs), which combine an internal combustion engine and one or more electric motors. However other mechanisms to capture and utilize energy are included. The hybrid vehicle typically achieves greater fuel economy and lower emissions than conventional internal combustion engine vehicles (ICEVs), resulting in fewer emissions being generated.

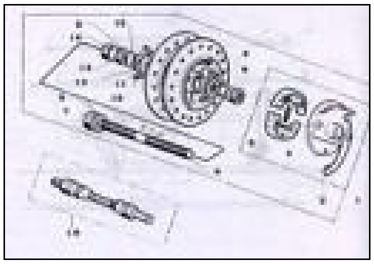
The hybrid vehicle particularly efficient for city traffic where there are frequent stops, coasting and idling periods. In addition noise emissions are reduced, particularly at idling and low operating speeds, in comparison to conventional engine vehicles. For continuous high speed highway use these features are much less useful in reducing emissions.

Hybrid vehicle emissions today are getting close to or even lower than the recommended level set by the EPA (Environmental Protection Agency). The recommended levels they suggest for a typical passenger vehicle should be equated to 5.5 metric tons of carbon dioxide. The three most popular hybrid vehicles, Honda Civic, Honda Insight and Toyota Prius, set the standards even higher by producing 4.1, 3.5, and 3.5 tons showing a major improvement in carbon dioxide emissions. Hybrid vehicles can reduce air emissions of smog-forming pollutants by up to 90% and cut carbon dioxide emissions in half.

1.1. Wheel Hub Motor

The wheel hub motor (also called wheel motor, wheel hub drive, hub motor or in-wheel motor) is an electric motor that is incorporated into the hub of a wheel and drives it directly.

In this modern hybrid vehicles the wheel hub motor is used as both motor as well as generator



1.2. Mechanism

Hub motor electromagnetic fields are supplied to the stationary windings of the motor. The outer part of the motor follows, or tries to follow, those fields, turning the attached wheel. In a brushed motor, energy is transferred by brushes contacting the rotating shaft of the motor. Energy is transferred in a brushless motor electronically, eliminating physical contact between stationary and moving parts. Although brushless motor technology is more expensive, most are more efficient and longer-lasting than brushed motor systems.

Electric motors have their greatest torque at start-up, making them ideal for vehicles as they need the most torque at start-up too. The idea of "revving up" so common with internal combustion engines is unnecessary with electric motors. Their greatest torque occurs as the rotor first begins to turn, which is why electric motors do not require a transmission. A gear-down arrangement may be needed, but unlike in a transmission normally paired with a combustion engine, no shifting is needed for electric motors. Wheel hub motors are increasingly common on electric bikes and electric scooters in some parts of the world, especially Asia.

As wheel motors brake and accelerate a vehicle with a single solid state electric/electronic system many of the above features can be added as software upgrades rather than requiring additional systems/hardware be installed like with ABS etc. This should lead to cheaper active dynamic safety systems for wheel motor equipped road vehicles.

1.3. Weight Savings

Eliminating mechanical transmission including gearboxes, differentials, drive shafts and axles provide a significant weight and manufacturing cost saving, while also decreasing the environmental impact of the product.

1.4. Concept Cars

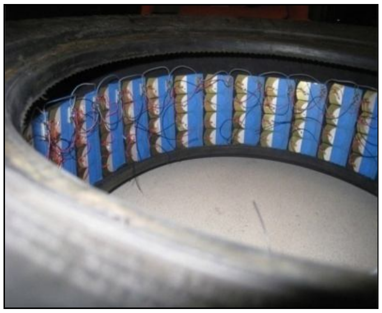
1.5. Uses In Current And Future Vehicles

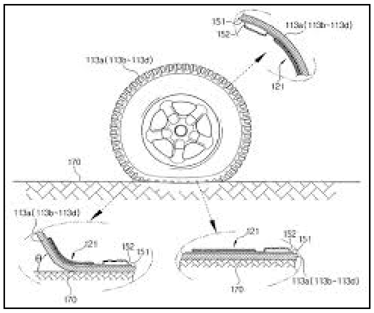
- They are commonly found on electric bicycles.
- Wheel motors are applied in industry, e.g. driving wheels that are part of assembly lines.
- They have not been used very often on cars, despite being invented for this purpose.
- Hub motors can also be found on buses.

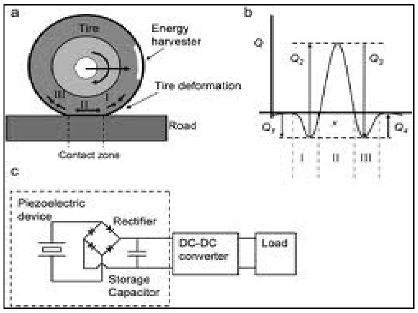
2. Piezoelectric Power Generation in Automobile Tires

Piezoelectric materials including Lead ZirconateTitanate (PZT) and PolyvinylideneFluoride (PVDF) have been used in various forms for energy harvesting using vibrations, repetitive strikes and bending of structures. Different ways of harvesting energy using highly bendable piezoelectric elements, both PVDF and PZT, are explored. Three (3) energy harvesting are explored, with each relying on the deformation of tire's Treadwall and Sidewalls due to vehicle weight acting on it. These methods are compared on the basis of their power production capacity as well as other significant factors for use within the tire.

Energy harvesting within the tire has been of great interest in the recent past for the purpose of powering sensors such as Tire Pressure Monitoring System (TPMS) sensor, Vehicle Speed Sensor (VSS), Strain Monitoring Sensor (SMS) etc. Energy harvesting allows integration of such sensors within the wheel by eliminating the need of relying on a limited permanent power source such as a battery thereby allowing a sufficient increase in usable sensor life. Some interesting ideas have emerged utilizing piezoelectric elements to harvest energy through vibration [1], impact [2] and bending [3-4] of such elements. This paper evaluates three (3) different options for energy harvesting based on the deformation of tire during vehicle motion.







2.1. Deformation Of Tyres

A tire under no load maintains its circular shape as shown in Figure 1 (a). However, under the load of the vehicle a section of the tire Treadwall conforms to the shape of the road i.e. flattens out into an area known as the Contact patch [5]. This section of the Treadwall within the Contact patch is deformed from its regular circular shape. Moreover, the area of the Sidewall just above the contact patch also undergoes deformation i.e. bulges out and the effective Section Height of the tire decreases, Figure 1 (b). As the vehicle moves, new area of the tire continually deforms and relaxes in a cyclic pattern whose frequency is dependent upon the vehicle velocity.

The deformation of the Treadwall and the reduction in the effective Section Height due to the deformation of the Sidewall presents an opportunity for energy harvesting through the use of piezoelectric bender elements that would deform and relax with the tire.

2.2. Energy Harverting Methods

Three methods of energy harvesting are being presented that utilize the previously described tire deformation patterns by bonding PZT and PVDF elements to various parts of the tire's Inner liner.

2.3. PZT Bender Bonded to the Tyres

Very thin and flexible PZT unimorph elements are bonded to the inner liner of the tire opposite to the treads. The brass reinforced elements have a total thickness of 0.23 mm with a 0.1 mm thick circular ceramic plate of 25 mm diameter; Figure 2 (a). A 185/65R14 passenger vehicle tire requires 3.5 mm of end-to-end deformation for a 40 mm element which is beyond the capacity of many PZT benders available in the market. However, the PZT elements used in this paper and previous research [4] can withstand up to 9 mm deflection without physical damage or a permanent shape change; almost thrice as much as the requirement. These elements are only bendable to such a high degree in one direction as shown in Figure.And can undergo much less deformation in the other direction. Bonding of these elements is achieved through the use of very flexible high temperature adhesive which allows the element to deform with the tire while having minimal effects on the deformation pattern of the tire.

The circular element bonded to the tire atop a tire circular tire repair patch. The rectifier attached on top of the element can also be seen with wires extending out to the rim. These elements generate a voltage peak with each revolution with maximum voltage rising as high as 45.5V, Figure 3 (a). In order to calculate the maximum power generated by each deformation various resistive loads were connected in parallel to the PZT element and the output voltage was measured. The graph of power output from PZT bender at different load resistances is also presented in Figure 3 (b) . A maximum of 4.6 mW of power can be extracted from the element bonded to the tire at a load resistance of 46 kΩ and a rotational wheel speed of 80 revolutions per minute (RPM), roughly equal to 9 km/h.

2.4. PVDF Bended Bonded to the Tyres

PVDF elements are composed of a thin PVDF sheet with electrodes on either side. Aftermarket ready-to-use PVDF elements were acquired from Measurement Specialties Inc. in the form of 216 x 280 mm sheets [7]. These sheets and subsequently the elements developed from it are 110 µm in thickness with silver ink electrodes on either side. These elements without any additional reinforcements can only be used in high frequency vibration mode. To be able to utilize the low frequency (less than 20 Hz) deformations pattern of the tire for power generation the PVDF elements have to be bonded to a reinforcement layer e.g. a plastic or brass sheet. There have been several previous publications that describe the need for such a reinforcement and thus will be omitted in this paper.

A 100 µm thick 40 x 40 mm square element, Figure 4 (a), bonded to a 0.3 mm plastic sheet is used for this research to provide reinforcement and preserve the flexibility of the PVDF element. This element was bonded to the tire using the same adhesive as described in the previous section, Figure 4 (b). Figure 5 (a) shows the peak voltage generated by the element at a rotational wheel speed of 80 RPM. A peak voltage of 62.3 V and an average voltage of 1.0 V is generated at no load.

2.5. Power Output GRAPH of PZT bender bonded to tire

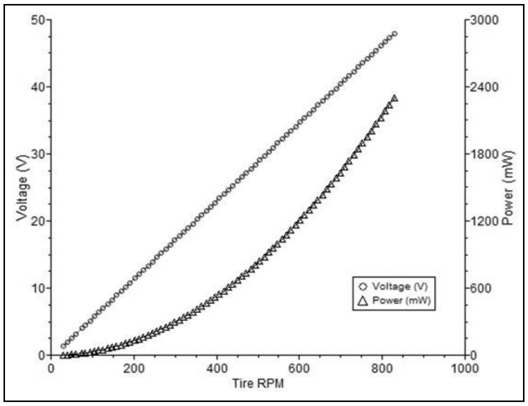


Figure 2.Voltage and power across a 1000Ωload at various rotations per minute

The power output delivered by the PVDF bender to different loads As A peak output of 0.85 mW is produced by the element at a high load resistance of 380 kΩ, very less when compared to their PZT counterpart. However, PVDF elements being a lot more flexible present themselves as a more suitable candidate for high deformation applications such as a tire based power generation. Furthermore, unlike the PZT elements PVDF elements can handle deformation in either direction without suffering physical damage. Lastly, PVDF elements have minimal impact on the deformation pattern of the tire due to their inherent flexibility.

2.6. PVDF Ribbon Attached to the Tyres Bead

This novel method of energy harvesting does not use the deformation of the tire, as described earlier, directly as it does not involve the bonding of piezoelectric element on the deformable part of the tire. Instead it relies on the deformation of a plastic ribbon bonded to the rigid bead section of the tire due to the changing tire Section height – the height of the Sidewall of the tire [5]. As stated earlier, the Sidewall deforms and reduces in the overall height just above the contact patch due to the weight of the vehicle, Figure 1 . As the wheel rotates the Sidewall and consequently the ribbon relaxes and deforms; effective Section height increases and decreases in a cyclic pattern. The attachment of three (3) PVDF element (blue) ribbon (red) on to the tire (black) is depicted in the graphic illustration in Figure 6 below. The ribbon is only bonded to the rigid Bead of the tire at points A and B while the remainder of the ribbon rests freely on the Inner liner of the tire as shown. The space between the ribbon and Inner liner of the tire Sidewall is also evident. As the Sidewall deforms under the weight of the vehicle; the Section width of the tire increases while the Section height decreases, the ribbon also deforms and moves closer to the Sidewall while getting squished vertically. The PVDF elements are placed at the location of maximum ribbon deformation and thus produce power with each revolution of the wheel by deforming with the ribbon.

2.7. Advantages of Mounted PVDF Elements in this Manner Include

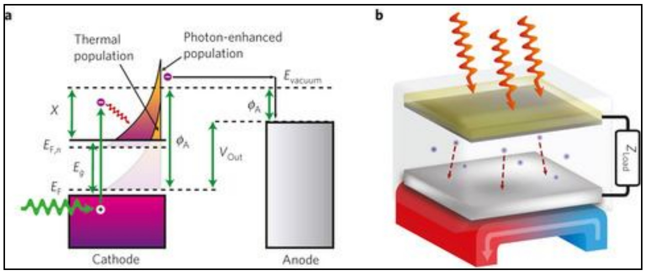
- Damage prevention – since the PVDF elements or the ribbon in not bonded to the treadwall or sidewalls, chances of damage due to tire puncture or other penetrable foreign objects is greatly minimized
- Minimized effect on the deformation of the tire – The ribbon is bonded to the rigid bead section of the tire bearing steel wires that do not undergo deformation. Since no deformable areas of the tire are affected, the overall deformation characteristics of the tire remain unchanged and the safety rating of the tire unaffected.
- Damage free removal of the Ribbon – Bonding PVDF and PZT directly onto the tire poses difficulty of their removal at the end of tire's service life. This is because the elements may be subjected to higher deformation than they can undergo during the removal process rendering them unusable. In case of a ribbon the bonding point is located conveniently away from the elements allowing easier removal without damaging the actual elements.
- Possibility of mounting sensors on the rim – When the energy harvesting piezoelectric elements are mounted onto the tire, the subsequently powered sensor whether Tire Pressure Monitoring Systems (TPMS) Sensor, Vehicle Speed Sensor (VSS), or Tire Health Monitoring Sensor (THMS) have to be mounted on to the tire as well. However, in case of the PVDF ribbon mounted in close proximity to the Tire-Rim interface the sensor could possibly be mounted on to them rim itself which is the ideal location within the wheel assembly.

The three (3) methods of energy harvesting presented above have different power outputs for different load resistances. However, the elements used it all of the three (3) cases are of different size and thus not directly comparable. In order to better quantify the power production capability of each method they should be compared on the per unit area basis as shown in Table 1 below.

3.Thermionic Emission

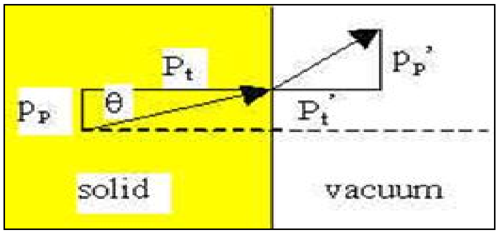
Thermionic emission is the energy emitted by the thermionic materials which are made up of semiconductors. It generate the electricity by converting heat energy in to electrical power.

In these modern hybrid vehicles the thermionic emission is done by coating the thermionic materials on the engines casting (casing) frames.

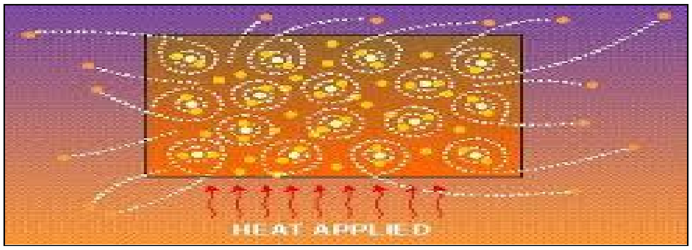


Inside the solid, there is a small tail in the energy distribution of electrons that extends to energies above the Fermi level. The energy distribution inside the solid is N(E)P(E) where N(E) is the density of states (dn/dE) and P(E) is the Fermi-Dirac distribution. At high E, the energy distribution is dominated by the strongly varying tail of P(E),
This tail is determined by fluctuations or unusual collisions between electrons.

3.1. Electrons Escaped From The Solids
Not all electrons that have energy above the vacuum level can escape. They also need to be moving in the right direction. As we have seen, the surface barrier is corrugated, but not within the range of the electron wavelength l. Recall that l(Å) = (150 eV/Ek)1/2. Since the kinetic energy Ek decreases when going across the surface, the wavelength increases. Close to the energy of the vacuum level, the wavelength is very large outside the solid, and of the order of l(Å)=(150/11)1/2 ~ 3.7 Å inside (neglecting band structure effects), where I = 11 eV is a typical value for the inner potential. One can then consider the surface barrier to be approximately planar.
In a planar barrier, the lattice cannot take up momentum (except in the Bragg condition where a reciprocal lattice vector is exchanged). The momentum of the electron parallel to the surface is conserved: pp = pp'. The planar barrier acts on the momentum transversal to the surface, pt, the energy outside is reduced by the barrier, E' = E – I = (1/2m)(pp2 + pt'2). The transverse momentum inside is pt = p cos(q)



Thus the electron is refracted by the surface. Only electrons which have sufficient transverse momentum can escape to vacuum:
This means that when q < qmax the electrons suffer total internal reflection.
In thermionic emission, electrons have energies barely above the vacuum level (internally, E very close to I). This means cos(qmax) » (1-E'/I)½, or qmax»2E'/I, very small. That means that not only the electrons must be in the tail of the energy distribution to be emitted, but they also must be traveling nearly perpendicular to the surface. In this case, one also needs to consider a quantum mechanical effect: an electron that is above the barrier might be reflected because of the uncertainty in the momentum caused by the width d of the barrier (Dp = ®/d). The reflection coefficient, r, decreases with energy above the vacuum level and for gradual barriers.



3.2. Thermionic Current
If an anode (metal electrode) with a positive potential with respect to the electron emitter (cathode) is placed nearby, it will collect the emitted electron current. The current density at the cathode is:
J = A (1-r) T2 exp(-f/kT)
where A = 4pmk2e/h3 = 120 Amperes/cm2 K-2 is a fundamental constant, r is the reflection coefficient of the electrons mentioned above, T is the temperature and f the work function of the surface. This is called the Richardson-Dushman equation.
The equation is dominated by the exponential factor which is a very small number, since a typical work function is much larger than thermal energies. Large thermionic currents require high T. For a surface with f=4.5 eV at room temperature, exp(-f/kT) ~

10-78, and 1.5x10-8 at 3000 K. Increasing T does not ensure observable electron emission since materials evaporate, melt or decompose when heated. Only refractory materials like W are useful as thermionic sources of electrons. Most low work function materials are very volatile, an exception is LaB6 with f = 2.5 eV, which is used in the electron emitting filaments of electron microscopes. Other materials are thoria-coated iridium, used in ionization vacuum gage tubes.

If the anode voltage is small, electrons will travel slowly in vacuum. Therefore, their density, n = J/(eV) will be large (v is the electron velocity and e its charge.) This density, called the "space charge", induces an electrostatic potential by Poisson's law that is negative in front of the cathode and, therefore, presents a barrier. In other words, an electron that exits the solid with see a cloud of electrons in front of the surface which may return it to the cathode. The space charge is responsible for J increasing initially as Va3/2 (law of Child-Langmuir) and saturating at large VA to the value predicted by the Richardson-Dushman equation. This describes well the behavior of vacuum diodes.

3.3. Schoktty Effect

A closer look at a the current-voltage characteristic of a real diode show that it doesn't really saturate, it has a small slope that depends on the electric field at the cathode (hence it depends on geometry, for a given Va.) The reason is that the electric field curves the surface potential (as seen when discussing field emission). The electric field in a normal diode is not large enough for "cold" field-emission, the barrier is too broad. However, the barrier is decreased slightly, allowing more electrons to come out. The decrease of the barrier is proportional to the square root of the field F. The modified equation is:

$J = A (1-r) T2 \exp [-(f-F1/2)/kT]$

where a is a constant. The lowering of the barrier due to the electric field is called the Schottky effect.

The equation can be used to determine the work function of the surface. One measures J(T) as a function of Vanode at different temperatures T. One then extrapolates the "saturation" region to Vanode = 0 to get rid of the Schottky effect, the extrapolated currents are Jo(T). One then does a plot of lnJo(T)/T vs. 1/kT, which should be a straight line, and obtains f from the slope. If the temperature range is wide, one finds a deviation from the straight line. This is because the work function changes slightly with temperature because the solid expands, and because of changes in surface composition and structure.

Thermionic emission is the heat-induced flow of charge carriers from a surface or over a potential-energy barrier. This occurs because the thermal energy given to the carrier overcomes the binding potential, also known as work function of the metal. The charge carriers can be electrons or ions, and in older literature are sometimes referred to as "thermions". After emission, a charge will initially be left behind in the emitting region that is equal in magnitude and opposite in sign to the total charge emitted. But if the emitter is connected to a battery, then this charge left behind will be neutralized by charge supplied by the battery, as the emitted charge carriers move away from the emitter, and finally the emitter will be in the same state as it was before emission. The thermionic emission of electrons is also known as *thermal electron emission.*

The classical example of thermionic emission is the emission of electrons from a hot cathode into a vacuum (also known as the Edison effect) in a vacuum tube. The hot cathode can be a metal filament, a coated metal filament, or a separate structure of metal or carbides or borides of transition metals. Vacuum emission from metals tends to become significant only for temperatures over 1000 K. The science dealing with this phenomenon has been known as thermionic, but this name seems to be gradually falling into disuse.

The term "thermionic emission" is now also used to refer to any thermally-excited charge emission process, even when the charge is emitted from one solid-state region into another. This process is crucially important in the operation of a variety of electronic devices and can be used forelectricity generation (e.g., thermionic converters and electrodynamic tethers) or cooling. The magnitude of the charge flow increases dramatically with increasing temperature. Because the electron was not identified as a separate physical particle until the 1897 work of J. J. Thomson, the word "electron" was not used when discussing experiments that took place before this date.

The phenomenon was initially reported in 1873 by Frederick Guthrie in Britain.[1] While doing work on charged objects, Guthrie discovered that a red-hot iron sphere with a negative charge would lose its charge (by somehow discharging it into air). He also found that this did not happen if the sphere had a positive charge.[2] Other early contributors included Johann Wilhelm Hittorf (1869–1883),[3] Eugen Goldstein (1885),[4] and Julius Elster and Hans Friedrich Geitel (1882–1889).[5]

The effect was rediscovered by Thomas Edison on February 13, 1880, while trying to discover the reason for breakage of lamp filaments and uneven blackening (darkest near one terminal of the filament) of the bulbs in his incandescent lamps.

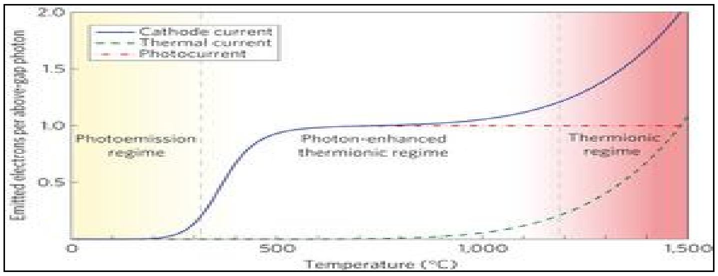
Edison built several experiment bulbs, some with an extra wire, a metal plate, or foil inside the bulb which was electrically separate from the filament, and thus could serve as an electrode. He connected a galvanometer, a device used to measure current, to the output of the extra metal electrode. When the foil was charged negatively relative to the filament, no charge flowed between the filament and the foil. We now know that this was because the filament was emitting electrons, and thus were not attracted to the negatively charged foil. In addition, charge did not flow from the foil to the filament because the foil was not heated enough to emit charge (later called thermionic emission).

However, when the foil was given a more positive charge than the filament, negative charge (in the form of electrons) could flow from the filament through the vacuum to the foil. This one-way current was called the *Edison effect* (although the term is occasionally used to refer to thermionic emission itself). He found that the current emitted by the hot filament increased rapidly with increasing voltage, and filed a patent application for a voltage-regulating device using the effect on November 15, 1883 (U.S. patent 307,031,[6] the first US patent for an electronic device). He found that sufficient current would pass through the device to operate a telegraph sounder. This was exhibited at theInternational Electrical Exposition in Philadelphia in September 1884. William Preece, a British scientist took back with him several of the Edison Effect bulbs, and presented a paper on them in 1885, where he referred to thermionic emission as the "Edison Effect."[7][8] The British physicist John Ambrose Fleming, working for the British "Wireless Telegraphy" Company, discovered that the Edison Effect could be used to detect radio waves. Fleming went on to develop the two-element vacuum tube known as the diode, which he patented on November 16, 1904.[9]

The thermionic diode can also be configured as a device that converts a heat difference to electric power directly without moving parts (a thermionic converter, a type of heat engine).

Following J. J. Thomson's identification of the electron, the British physicist Owen Willans Richardson began work on the topic that he later called "thermionic emission". He received a Nobel Prize in Physics in 1928 "for his work on the thermionic phenomenon and especially for the discovery of the law named after him".

3.4. Graphical Representation Of Power Generation With Coresponding Temparature



3.5. Richardson's Law

In any solid metal, there are one or two electrons per atom that are free to move from atom to atom. This is sometimes collectively referred to as a "sea of electrons". Their velocities follow a statistical distribution, rather than being uniform, and occasionally an electron will have enough velocity to exit the metal without being pulled back in. The minimum amount of energy needed for an electron to leave a surface is called the work function. The work function is characteristic of the material and for most metals is on the order of several electronvolts. Thermionic currents can be increased by decreasing the work function. This often-desired goal can be achieved by applying various oxide coatings to the wire.

However, a modern theoretical treatment by Modinos assumes that the band-structure of the emitting material must also be taken into account. This would introduce a second correction factor $\lambda_B$into λ_R, giving $A_G = \lambda_B(1 - r_{av})A_0$. Experimental values for the "generalized" coefficient A_G are generally of the order of magnitude of A_0, but do differ significantly as between different emitting materials, and can differ as between different crystallographic faces of the same material. At least qualitatively, these experimental differences can be explained as due to differences in the value of λ_R.

Considerable confusion exists in the literature of this area because: (1) many sources do not distinguish between A_G and A_0, but just use the symbol A (and sometimes the name "Richardson constant") indiscriminately; (2) equations with and without the correction factor here denoted by λ_R are both given the same name; and (3) a variety of names exist for these equations, including "Richardson equation", "Dushman's equation", "Richardson–Dushman equation" and "Richardson–Laue–Dushman equation". In the literature, the elementary equation is sometimes given in circumstances where the generalized equation would be more appropriate, and this in itself can cause confusion. To avoid misunderstandings, the meaning of any "A-like" symbol should always be explicitly defined in terms of the more fundamental quantities involved.

Because of the exponential function, the current increases rapidly with temperature when kT is less than W. (For essentially every material, melting occurs well before $kT = W$.

3.6. Some Of The Thermo Emission Materials Are

- Gallium nitride
- Caesium
- Silicon
- Gallium arsenide
- Tungsten.

4. Conclusion

Though hybrid cars consume less fuel than conventional cars, there is still an issue regarding the environmental damage of the hybrid car battery. Today most hybrid car batteries are one of two types: 1) nickel metal hydride, or 2) lithium ion; both are regarded as more environmentally friendly than lead-based batteries which constitute the bulk of petrol car starter batteries today. There are many types of batteries. Some are far more toxic than others. Lithium ion is the least toxic of the two mentioned above.

Use of lithium-ion batteries reduces the overall weight of the vehicle and also achieves improved fuel economy of 30% better than petro-powered vehicles with a consequent reduction in CO_2 emissions helping to prevent global warming.

In addition, if we implement the above smart methods in the modern hybrid cars/vehicles then some of the major problems commonly acquired in the hybrid cars/vehicles must be nullified.

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