ELECTRET: A DEVICE FOR MICROELECTRONIC APPLICATIONS

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Abstract: Polymers acquire persistent polarization due to the alignment of dipoles and migration of charge carries over macroscopic distances. Information on the charge storage and transport phenomena in polymer electrets is of great interest for several industrial applications. The present paper is an attempt to elucidate the classification, types, mechanisms, charging methods applications and uses of Electrets.

Index Terms – Polymers persistent polarization Electret.

1. INTRODUCTION:

During the last three decades, development in the field of electrets has continuosly extended the fascinating world of micromechanics. Several devices based on electrets, such as various types of transducers, were introduced. In addition to proper electrical characteristics, or more precisely the charge storage and transport properties one has to care about the mechanical properties of the materials used in a micromechanical device [1]. Solid electrically insulating or dielectric, material that has acquired a long-lasting electrostatic polarization Electrets are produced by heating certain dielectric materials to a high temperature and then letting them cool while immersed in a strong electric field [2]. The word electret was then coined in 1892 by Oliver Heaviside [3] .He defined Electret as "an electrified dielectric having opposite charges on two faces" analogous to magnet [1]. Magnetic – bodies possessing long-lasting magnetization had established their place in science and industry a long time ago and are now familiar to practically everyone. But not many people know that there are also bodies possessing long-lasting electrization, called electret [4]. The name comes from electrostatic and magnet; drawing analogy to the formation of a magnet by alignment of magnetic domains in a piece of iron. Electrets are commonly made by first melting a suitable dielectric material such as a plastic or wax that contains polar molecules, and then allowing it to re-solidify in a powerful electrostatic field. The polar molecules of the dielectric align themselves to the direction of the electrostatic field, producing a permanent electrostatic "bias" [5].If a substance whose molecules possess permanent dipole moments is melted and placed in a strong stationary electric field, the molecules become partially aligned in the direction of the field. If the melt is cooled until it solidifies and the electric field is switched off, the molecules cannot easily rotate in the solidified substance and retain their orientation for a long time.[6] An electret so prepared may remain in a state of polarization for quite a long time, ranging from several days to many years. The first such electret was prepared from wax by the Japanese physicist M. Eguchi in 1922 [7].

Electret (formed of elektr- from "electricity" and -et from "magnet") is a dielectric material that has a "quasi-permanent" electric charge or dipole polarization. An electret generates internal and external electric fields, and is the electrostatic equivalent of a permanent magnet. Materials with electret properties were, however, already studied since the early 18th century. One particular example is the electrophorus, a device consisting of a slab with electret properties and a separate metal plate. The term "quasi permanent '' means that the time constant characteristics of the decay of charge is much longer than the time periods over which the studies are performed with the Electrets [3].

2. CLASSIFICATION OF ELECTRET:

Electrets may be classified as real-charge electrets and dipolar-charge electrets. Real-charge electrets are dielectrics with charges of one polarity at or near one side of the dielectric and charges of the opposite polarity at or near the other side, while dipolar-charge electrets are dielectrics with aligned dipolar charges. Some dielectrics are capable of storing both real and dipolar charges. An example of a charge arrangement of an electret metallized on one surface is shown in Figure 1. Cellular space charge electrets with internal bipolar charges at the voids provide a new class of electret materials, that mimic ferroelectrics, hence they are known as ferroelectrets [8].

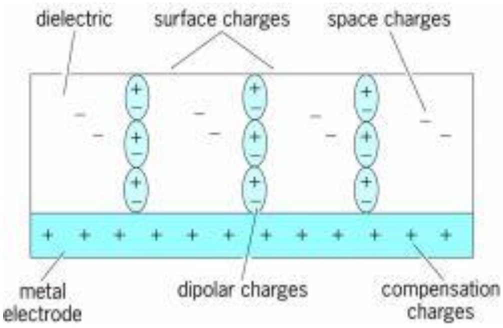

Figure 1: Schematic cross section of an electret disk metallized on one side.

3. TYPES OF ELECTRET:

Electret exhibits a quasi permanent electrical charge after the polarization treatment is terminated. As they are source of an electric field, they are particularly useful in instruments and devices where one requires a stable electrostatic field. Depending on the method of inducing polarization and the materials used for preparation electrets, in general can be distinguishes as, Thermo-electret, Electro-electret, Ceramic-electret, Photo-electret, Thermo -photo-Electret, Magneto-Electret, Radio Electret, Bio-electret, Autophoto Electret, Mechano-Electret, Psuedo-Electret and Cathodo-Electret. The term 'Thermo-electret' is obtained by polarizing a dielectric by simultaneous application of heat and electric field [8,9, 10]. An electret prepared at room temperature by applying high electric field is called an 'electro-electret' [11-15]. Material for electrified ceramics may be fabricated by pressing or extruding and slip casting. Thereafter, they usually are fired at high temperature. After firing process, the fabricated ceramics are cooled and are then polarized with theapplication of high voltage, thus 'ceramic electrets' are formed [16-20].A dielectric can also be charged by simultaneous application of an electric field and UV or visible light radiation of energy sufficient enough to release carrier (either band to band transition or excitations put of deeper traps). An electret so form is called 'photoelectret' and remains polarized for longer time when kept in dark. Photo-electrets were first prepared by Nadzhakov [21,22] in 1938 and later in detail, studied by Fridkin and Zheludev [123] and Kallmann [24,25]. A photoconducting dielectric polarized at high temperature by light radiation of high energy under an applied electric field results into a 'thermophoto-electret'. This was first prepared by Padgent [26]. A magneto-electret is obtained by cooling the softened or melted dielectric in a magnetic field. Bhatnagar [27] is credited for his remarkable contributions in the field of 'magneto-electrets'. An electret prepared under the simultaneous application of high energy radiations, such as x-rays, β-rays, γ-rays and monoenergetic electron beams, etc. and electric field is called a 'Radio-electret' [28-30].Electrets prepared from biological materials and biopolymers are called 'Bio-electrets' [14]. An electrets prepared by charging a dielectric by a mechanical effect, i.e. deformation or friction is called 'Mechano-electret' [31]. These are prepared by polarizing a dielectric under the action of an ionizing irradiation such as γ- rays without the application of an electric field known as Pseudo-electrets [32].A electrets is obtain by charging a dielectric under the simultaneous action of electric field and a beam of electrons known as Cathodo-electret [33,34].

4. MECHANISM OF CHARGING:

Charging or polarization of a dielectric for preparing an electrets entail simultaneous occurrence of the following phenomena; namely "microscopic displacement of charges", "dipole orientation", "macroscopic space charge polarization", "barrier polarization", and "external polarization". When an electric field is applied to the dielectric, it produces a small movement of charges within the atoms and molecules of a dielectric, displacing the negative electron cloud relative to the positive nucleus generating a small dipole moment. This type of polarization is called microscopic or electronic polarization or deformation. Many dielectrics including polymers have a permanent dipole moment. This dipole moment may be a deliberate part of the structure (carboxylic group, chlorinated hydrocarbons, etc.) or may be accidental or unavoidable impurities (carbonyl group in polyethylene). Under normal temperatures, the dipoles are randomly arranged and the resultant dipole moment is zero. An external electric field when applied tends to orient these elementary dipoles along its own direction producing an electric moment of the whole body. This is called dipolar polarization and occurs in the entire volume.

All dielectrics contain a small number of free charges, i.e. ions or electrons or both. These free charges are randomly distributed and there is not net dipole moment when one arranges all the charges. In such materials, the applied electric field causes displacement of the cautions near the cathode and of the anions near the anode. If a space charge of opposite sign develop in front of an electrode, the potential distribution deviates from the linear nature; in that case the potential drop near the electrodes is larger than in the center. This effect is known as macroscopic space charge potential.

In a heterogeneous dielectric, often there exist some microscopic domains or grains separated by highly resistive interfaces. In such dielectrics the free charge carriers can move relatively free only within the grains.This result in piling up of free charges along the barrier causing in barrier polarization.

A dielectric can also be charged by direct injection of charge carriers when a large electric field of the order of 10^5 V/cm is applied between the electrodes in intimate contact with it. Alternatively charges may be sprayed or deposited upon the dielectric if a high voltage electrode is in contact with the dielectric and a corona discharge occurs either in the neighbouring air space at the edges of the arrangement or in the thin air space between the electrode and dielectric. The deposition or injection of charge on either surface produces an external polarization.

5. METHODS OF CHARGING:

There are various methods for charging or polarizing of dielectrics, viz., “thermal method”, “corona methods”, “liquid contact method”, “electron beam method”, and “photoelectric method”.An electrical field is applied on a polymeric dielectric at a high temperature and thereafter it is cooled down while the field is still applied. Eguchi [7, 35] used this method for polarizing a dielectric for preparing the thermoelectret known as ‘Thermal method’. The sample polymer is charged by injection of electron of proper energy into it. When the range of electron striking the dielectric is less than the thickness of the polymer sample, the electrons are trapped inside and sample gets charged. If the range of the electrons is greater than the polymer sample thickness, charging occurs mainly due to the secondary emission of back scattering is known as ‘Electron beam method’. When inorganic photoconductors are irradiated with ultraviolet or visible light under an applied field, a permanent polarization is achieved due to the generation of charge carriers in the sample. These carriers are than displaced by the applied field eventually trapped at the dielectric electrode interface or in the volume resulting in a two separate charge clouds of opposite sign or a single charge cloud is known as ‘Photoelectric method’[36,37].A stable electret may be produced by the following methods: the heating of a dielectric to a temperature below or equal to its melting point followed by cooling in a strong electric field; the illumination of a dielectric in a strong electric field; the radioactive irradiation of a dielectric; placing a dielectric in a strong electric or magnetic field; the mechanical deformation of a polymer; friction; or placing a dielectric in the field of a corona discharge. Electrets produced by illuminating a dielectric in a strong electric field are called photoelectrets. All electrets have a stable surface charge of ~ 10^{-8} coulomb/cm^2 [38, 39]

6. APPLICATIONS O F ELECTRET:

Electret has found commercial and technical interest. Permanent electrification effects in dielectrics have been utilized in electret microphones and in copy machines [40].in 1962 microphones with thin flexible polymer electrets were introduced [41]. Application of charge storage phenomena of great practical importance is in field of electrophotography [42]. The breakthrough in this field came a few years later when investigations of photoconductive image formation [43] led to the development of xerographic reproduction methods [44]. Electret device includes gas filters, motors, relay switches, optical display system, and radiation dosimeters. Important commercial applications of real-charge electrets are in electro-acoustic and electromechanical transducers, and in electret dosimeter. Gas filters use corona- charged electrets fibers to capture sub micron particles by electrostatic attraction. [45]. Experimental electret motors employ stators or rotors of charged dielectric [46].The relay type switches utilize the external field of electrets to open or close contacts [47]. The decay of a previously stored charge or the generation of radiation induced conductivity is employed to measure radiation doses in dosimeters [48].Some applications are based on the piezoelectric or pyroelectric effects in polarized polymer material .Electro acoustic transducers utilizing piezoelectric films [49, 50].Operating in transverse or longitudinal modes [51, 52].They are also used in some types of air filters, for electrostatic collection of dust particles, in electret ion chambers for measuring ionizing radiation or radon and in vibration energy harvesting . Also of interest are biological applications based on the blood compatibility of charged polymers or on their favorable influence on wound or fracture healing. Commercial applications of dipolar electrets are in piezoelectric transducers and in pyroelectric detectors like Dielectric materials and Electrical insulation [6]. An electret microphone is a type of electrostatic induction-based microphone, which eliminates the need for a polarizing power supply by using a permanently charged material. An electret is a stable dielectric material with a permanently embedded static electric charge (which, due to the high resistance and chemical stability of the material, will not decay for hundreds of years).

Clark and Ramsay [53] consider force-driven piezoelectric generators for medical applications. The input energy for the generator is intended to be in the form of fluctuating pressure in a blood vessel. The authors study a square sheet of piezoelectric material held in a rigid frame, with pressure applied normal to the sheet surface. They find that the generated power increases as the sheet thickness is decreased but, for the given operating frequency of 1 Hz, and 1 cm^2 sheet of piezoelectric material can only generate around 1W. They suggest that the supply could be used to power load electronics at a low duty cycle. The possibility of harvesting energy from bending of the knee has been realized by Donelan et al. [54]. Their device extends over substantial portions of the upper and lower leg, so that large torques can be produced, and output powers up to 7W for normal walking motion are obtained. The metabolic cost is reduced by the generative braking action of the device, i.e., the transduction is actually assisting the leg motion on the decelerating portion of the stride. The examples of inertial generators using electromagnetic transducers are to be found in the patent literature. The first description of an electrically operated self-winding watch, and indeed of a small inertial energy harvester, is a patent filed in 1989 by Hayakawa of Seiko Epson Corporation .This describes the ideas behind the Seiko Kinetic watch, which is now a commercial product [55, 56].

Snyder [57] describes the use of a piezoelectric generator embedded in the wheel of a car to power a tire pressure sensor. The generator would be powered from wheel vibration during driving, and abnormal tire pressure could be reported to the driver using a low-power radio link. Tire pressure monitors have been required on every new car in the United States since September 2007, and consequently this application area is receiving much interest [58].Segal and Bransky [59].Describe a novel application for a piezoelectric inertial generator. This is the first such device reported in the research literature. The authors suggest using a piezoelectric disk to power the guidance system of a projectile; although batteries are well suited to the short operational life in this application, energy harvesting would avoid the problem of battery discharge during long storage time [60]. Numerous generators for human power generation have been explored, such as piezo-based devices that produce power from pressure and vibration, electrostatic vibration generators, thermal convertors, magnetic induction based generators and RF-based electrical generators [61].The physical principles behind electret design have been known for a long time and used in developing sensors, such as microphones, as well as MEMS-based harvesters that convert ambient vibration into electrical power [62]. Recently the electret principle was utilized to convert human finger tapping into power to actuate an array of flashing LEDs.An important first step in exploring this power harvesting approach at the macro scale. The reported devices, however, required complex and expensive micro fabricated structures, i.e., silver coated Nano wires deposited on a plastic substrate. The energy harvester presented in this current paper differs from in structure and function and uses common materials that do not require micro fabrication. While only a single mode of operation was investigated in [63].

7. USES OF ELECTRET:

Electrets are used as sources of a stationary electric field in such devices as electret microphones, electret headphones, vibration pickups, and signal generators. They are also used to produce an electric field in, for example, electrometers and electrostatic voltmeters. Electrets may also be employed, for example, as sensing elements in dosimetric instruments and electrostatic storage devices, as piezoelectric transducers, and as focusing devices for a beam of charged particles, as well as in barometers, hygrometers, and gas filters. Photo electrets are used in electro photography. Polymers can be or other materials can be effectively used in controlling and detecting pollutants in the form of particulate matter and gases. Electrets certainly provide a quicker and cheaper way of collection of pollutant particulate matter for environmental studies. It is also useful in filtration. Electret have to be a source of fresh and potentially useful fertile field of research in material science for physicist, chemists or material scientists interested in Solid State Electronics.

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