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Review: Polymers In Energy Harvesting

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ABSTARCT: *Researchers around the globe, are continuously looking towards the fundamentals for energy conservation and storage. In this paper we shall take a look at the efforts made by various researchers in this field of energy harvesting and it's storage. On searching the literature, it is notice that a lot of work has been done in the field of Piezoelectric materials and studies made in this area. Scientists also found that energy can also be harvested to power small autonomous sensors such as those developed using MEMS (micro electromechanical systems) wherein the power is generated through polymer made capacitors or super-capacitors. Thus in this paper we shall review few scientific works, made with the idea regarding-"how to harvest energy through polymer materials".*

KEY WORDS: *Energy Harvesting, Polymer, Piezoelectric, Renewable energy*

I. INTRODUCTION

The need and demand for energy is ever increasing. There are many sources of energy which are losing (leaking, for example-the human body) energy in a dynamic (continuous) way. This need for energy can be compensated through these leaking energy resources. Apart from these leaking sources, natural sources such as the sunlight and the vapours of water, which can be found in our atmosphere are proved to be a boon for mankind. This paper deals with the aspects of introduction of polymers in the field of energy harvesting. Recycling of the used energy has been discussed by almost all the researchers till now. This can be achieved by working towards the creation of a capacitor out of a suitable polymeric material and the usable energy available for recycling.

We know that any vibration can be transported through a medium which may be converted into the form of an useful energy for other purposes. This basic principle of energy harvesting is used for developing methods of energy harvesting [1]. Different research groups have tried to work in various directions to reach to the final destination of energy regeneration.

In this direction researchers found the human body as an ample source of vibrations and tried to find a way to store the energy generated from these vibrations [2]. The next breakthrough in the field of harvesting energy is via. Hyperbranched polymers [3-6]. Researchers have shown that photons when radiated to the periphery of a polymer (hyperbranched), it is able to pass the very same energy through its branches towards the center of the polymer and thus is able to store it. This way it may work like a capacitor [7-8]. The next advancement has been made in the field of energy generation through water vapour, where steam has been utilized to generate motion which in turn can generate kinetic energy.

1.1. Review Of Literature And Discussion

As discussed in the Introduction, the methods used for energy harvesting using polymers can be discussed under the following categories:

A) Through Piezoelectric Generators [2-7]:

Piezoelectricity is the ability of certain crystals to generate electricity in response to applied mechanical stress. In this method, this property has been used to generate energy. This method is getting more popular because the performance of piezo generators has been boosted and low power consumption semiconductor controllers have emerged. Usually in most of the cases polymers such as Tantalum-Polymer, PVDF (poly vinyledene flouride) etc. have been used to make a thin strip which acts under the action of electromagnetic

vibration. The film/strip is used as energy harvester and energy is being imparted to it via electromagnet which causes oscillations in the strip. These oscillations are subsequently converted into electrical energy. This electricity is obtained in the form of alternating current which is converted to direct current by a rectifier. This energy in form of current is passed through a capacitor and thus we are able to prepare a storage bank for electricity.
There are two types of piezoelectric signals that can be used for technological applications:

1) The direct piezoelectric effect that describes the ability of a given material to transform mechanical strain into electrical signals. The direct piezoelectric effect is more suitable for sensor applications

2) The converse effect of the predecessor which is the ability to convert an applied electrical energy into mechanical energy. This ability of piezoelectric signals is required for actuator applications (actuators are devices which convert applied energy or pressure into motion).

Now, the following discussion will give us an insight into the details of harvesting energy with the help piezoelectricity and how researchers globally follow the trend to create energy harvesting prototypes.

The process of preparing the piezoelectric generator consists of the following steps:

a) Preparation of polymer through which piezoelectricy can be harnessed

The piezoelectric films used for the energy generation are constituted by a polymeric material coated in both sides by a conducting material, which form the electrodes. The polymeric material is based on its electroactive phase (electric sensitive polymer regions). It can be processed in the form of a film by extrusion, injection or from the solution. To obtain the electroactive phase, the phase films must be submitted to mechanical stretching at generally higher temperatures. The main advantages of using polymeric films instead of piezoceramics or single crystals are that polymer films are flexible and can be fabricated in the desired shapes and sizes through simple processing processes. Moreover, electroactive polymers are very cheap in comparison with the ceramic and single crystal counterparts, making them more suitable for mass production systems and devices. A final step of stretching at a temperature around 80^0 C results in oriented films, which further increases the material performance.

(b) Electrode deposition over the polymeric strip to make the strip responsive towards electromagnetic induction [8]

When the material is prepared, electr- deposition is done on both sides by magnetron sputtering or by thermal evaporation. (generally Steel and Aluminum have been used as electrode materials for the present date research purposes)

(c) Positioning of the piezoelectric material near a readily available source of vibrations [12]

Since, piezoelectricity is a dynamic process, hence, a piezoelectricity can be harnessed from sources where energy is draining out steadily. One such source is our body. Be it the heart, hand, legs or any other body part, all are draining energy in some way or the other. The material should be positioned in the places were larger and more variable pressure is exerted during walking.

(d) **Electronic circuit to obtain a direct current from the alternating current generated by making it pass through a rectifier. Simultaneously joining it to a capacitor as well [13]**

In order to maximize the energy transfer to a charge or to a battery, in the case of energy storage, a rectifying circuit is necessary in order to obtain a single polarity voltage. The whole system is implemented into a shoe and further tests are performed in real walking situations.

(e) Energy storage devices such as a rechargeable battery can be implemented in lieu of a capacitor, so as to improve the energy storage capabilities [8]

A thin-film rechargeable lithium battery can be used to store the energy generated. A layered structure, as presented is being prepared to implement the proposed battery as suggested by the researchers.

(B) Light Energy Harvesting In Dendrimers and Hyperbranch Polymers

It deals with photon capture abilities of highly branched polymers when subjected to light (generally sunlight). Moreover the capability of the polymer to retain the absorbed photon is very important. With the facility to accommodate a proliferation of antenna chromophores, such materials can capture and channel light energy with a high degree of efficiency, each polymer unit potentially delivering the energy of one photon—or more, when optical nonlinearity is involved. Let us focus on the underlining facts behind the accumulation of energy from such polymers. This shall give us an idea about the development done by scientists in the field of light energy harvesting.

(a) Step-wise Energy Transfer [14]

Chromophores are the basic building blocks for energy harvesting through light energy. For the efficient absorption of radiation, the antenna chromophores of light-harvesting dendrimers, commonly the species from which the polymer is constructed, should display strong absorption in a suitable part of the electromagnetic spectrum—generally the visible range of solar radiation that retains significant intensity after passage through the Earth's atmosphere. A device similar to the synthetic material may be designed with the help of photobiological systems which commonly have chromophores for enhanced and effective absorption. Photobiological and dendrimeric systems deploy similar energy harvesting mechanisms in photon absorption and energy transfer to a central trap. The photochemical features which they share include- i) multiple peripheral chromophores that can initially absorb light, producing short-lived electronic excited states; a mechanism for rapid transfer of the resulting excitation towards a trapping site (stepwise resonance energy transfer, RET), ii) a layout that fastens trap-directed absorption, governed by chromophore orientation, and iii) a process for collecting and capturing the energy acquired at the trap. In the construction of light-harvesting dendrimers, each of these photochemical and photophysical principles are put to highly effective use. The repeated branching of the polymer structure, together with the three-dimensional folding that occurs in all but the smallest systems, supports a special proliferation of chromophores on the outermost surface, and the inner, building-block chromophores act with high efficiency as transient hosts for the excitation energy to the core. Moreover, the convergence of the dendrimer branches towards the core also assists the pooling of energy, in the event that more than one photon is initially captured upon the outer surface.

(b) Directed Energy Transfer [9]

As we know that energy transfer through chromophores is a step-wise and continuous process but it has certain drawbacks to it during transfer of resonance energy. Enegy that is being lost to the surroundings does not reach the core region of the hyperbranched polymers and hence the core does not experience maximum energy which was present initially.

Thus rather than transferring energy to the core regions, researchers manipulated the structure of such polymers so that maximum of the polymer structure is exposed to the radiations. This has helped in reducing the energy loss to a large extent and helped in utilising maximum out of the radiant energy source.

In relatively small dendrimers, it is statistically unlikely for two or more excitations to co-exist at the same time in the whole structure. Generally, the timescale for energy delivery from the antenna to the core is shorter than the interval between successive photon capture events—the latter being a time dependent on the irradiance, absorption frequency and σ the net absorption cross-section of the entire dendrimer.

However in larger systems, where trapping also involves a greater number of energy transfer steps, this is no longer necessarily the case. Indeed, if the intensity of ambient sunlight is amplified by focusing down to the diffraction limit, the simultaneous presence of two photon energies can then become significant on the picosecond timescale associated with ultrafast trapping. A good example of supporting experimental evidence is the cis-to-trans isomerisation observed on infrared absorption in large arylether azodendrimers, for which the energetic considerations demand that two (or more) infrared photon energies have to be involved.

(C) Electricity From A Readily Available Source Like Water Vapour [15]:

Researchers have developed a new bio-polymeric film that is able to generate electricity from a readily available source: water vapour. The material changes its shape as it absorbs evaporated water. As the bio-polymer film repeatedly curls and unfurls it drives robotic limbs, which in turn generate enough electricity to power micro- and nanoelectronic devices.

With a sensor powered by a battery, you have to replace it periodically. If you have this device, you can harvest energy from the environment so you don't have to replace it very often.

The Process of energy generation consists of the following steps:

(a) **Harvesting energy**

The new film is made from an interlocking network of two different polymers. One of the polymers - polypyrrole, forms a hard but flexible matrix that provides structural support. The other polymer - polyol-borate, is a soft gel that swells when it absorbs water.

The film harvests energy in the water gradient between dry and water-rich environments. When the 20-micrometer-thick film lies on a surface that contains even a small amount of moisture, the bottom layer absorbs evaporated water, forcing the film to curl away from the surface. Once the bottom of the film is exposed to air, it quickly releases the moisture, somersaults forward, and starts to curl up again. As this cycle is repeated, the continuous motion converts the chemical energy of the water gradient into mechanical energy.

Such films could act as actuators (a type of motor) or generators. As an actuator, the material can be surprisingly powerful: The researchers demonstrated that a 25-milligram film can lift a load of glass slides 380 times its own weight, or transport a load of silver wires 10 times its own weight, by working as a potent water-powered "mini tractor." Using only water as an energy source, this film could replace the electricity-powered actuators now used to control small robotic limbs.

(b) **Generating electricity**

The mechanical energy generated by the material can also be converted into electricity by coupling the polymer film with a piezoelectric material, which converts mechanical stress to an electric charge. This system can generate an average power of 5.6 nanowatts, which can be stored in capacitors to power ultra-low-power microelectronic devices, such as temperature and humidity sensors.

If used to generate electricity on a larger scale, the film could harvest energy from the environment — for example, while placed above a lake or river. Or, it could be attached to clothing, where the mere evaporation of sweat could fuel devices such as physiological monitoring sensors. "You could be running or exercising and generating power," as researchers say .

On a smaller scale, the film could power microelectricalmechanical systems (MEMS), including environmental sensors, or even smaller devices, such as nanoelectronics. The researchers are now working to improve the efficiency of the conversion of mechanical energy to electrical energy, which could allow smaller films to power larger devices.

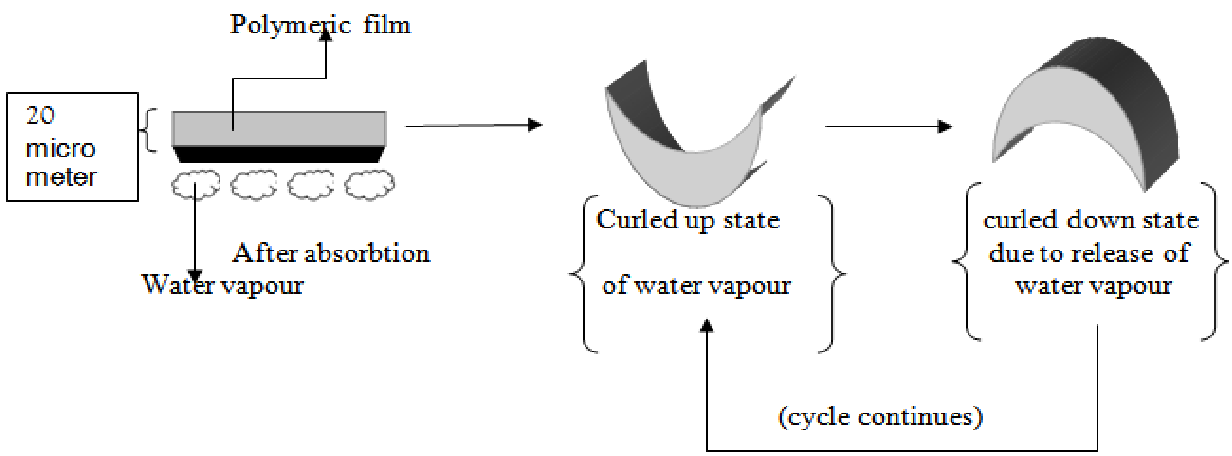

Figure 1: General process of curling and uncurling of polymer film under the action of water vapour.

II. CONCLUSIONS

On going through the above discussion, it may be concluded that the major source for energy recreation is via vibrations. Since polymeric strips have been discussed, therefore their higher capacitance and internal resistance are of utmost importance, while keeping in mind the main objective i.e. energy harvesting. Moreover the generation and storage are important. Therefore an entire circuit needs to be drawn so that the energy which has been harvested can be used to run other general appliances. Thus accomplishing both the harvesting and storage part, researchers have achieved a way to counter the energy demand for the further applications**.**

The most basic property of Aryl based polymeric compounds is successive Resonance. This proved to be a very useful property for absorbing energy from the radiated light and then pass the very same energy towards the core area of the polymer, where it could be stored for a longer period of time.

In the third process of energy generation, a direct motion has been created so that this motion in turn shall be able to run other appliances. A continuous folding and unfolding of polymers on absorption and release of water vapour has been the new field of research for the scientists.

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