Solar Textiles


Samidha Mayee
S.Y.B.Tech.
Fibres and Textiles Processing Technology Department


Anshu Shrivastava
S.Y.B.Tech.
Fibres and Textiles Processing Technology Department

Abstract

There is increasing concern about the huge dependence on fossil fuels as a source of energy. The renewable resources are unevenly distributed. Moreover the coal and oil resources has led to environmental problems. The only long-term solution lies in the storage of solar energy either as chemical energy (mimicking photosynthesis) or as electrical energy. The conventional solar cells use glass as substrates which are rigid, fixed. This review is devoted to incorporation of solar cells in textile which serve as flexible, light weight and mobile substrates.

We have also elaborated working of SOLAR-α fabrics that absorb visible solar radiation and convert it into heat in the form of infra-red radiation which is released in the clothing.

Keywords: Solar-textiles, photovoltaic-cell,Solar-α.

Introduction

True energy crises is building and cannot be avoided as long as we rely on fossil fuel sources or on indeed any finite terrestrial source. Although coal and oil resources are immense, their extraction and use damage environment. There are concerns too about nuclear fission as a source of energy, and controlled fusion has yet to be proven feasible . Consequently, there is growing interest in harnessing energy by other means that do not rely on the consumption of reserves nor involve dangers like in nuclear fission.Moreover the renewable resources are unevenly distributed across the globe.

The only long term solution lies in the utilization of solar energy The source of direct energy which arguably arouses the greatest potential is the sun itself. There are numerous attempts to utilize solar energy for storage of chemical energy (mimicking natural photosynthesis) and for the storage of electrical energy in batteries. Greatest success has been achieved in the direct conversion of solar energy into electrical energy with the aid of photovoltaic devices , "SOLAR CELLS"[1]. Apart from using an endless source of energy ,the application of photovoltaic devices offer a number of other advantages: the technology is clean and noiseless, maintanence costs are very small and the technology is attractive for remote areas which are difficult to supply by conventional means from grid.

Typically solar cells are either encased between glass plates which are rigid and heavy, or covered by glass. We have devoted this review to the incorporation of solar cells to textile fabrics. Here textiles are the substrates which unlike glass or ceramic are flexible and rollable. Solar cells used in these textiles are semiconductor photovoltaic cells.These leads to the development of power dresses that can provide the power to charge our mobile phones, MP3 players or even serve as an urgent power source during earthquakes or any such disaster.

Solar Cell

A photovoltaic cell converts optical energy directly into electrical energy. It is a solid state device in which photons release valence electrons from the constituent atoms. In a semiconductor, valence electrons are freed into the solid to travel to the contacts, when light below a wavelength specific to that of the solid is absorbed. This threshold wavelength must be selected to provide an optimum match to the spectrum of light source, too short a wavelength will allow radiation to pass through unabsorbed , too long a wavelength will extract only part of the energy of the shorter wavelength photons. The typical solar spectrum requires a threshold absorption wavelength of 800nm, in the near infra-red to provide the maximum electrical conversion, but this still loses some 40% of the solar radiation. Further losses occur due to incomplete absorption or reflection of even this higher energy radiation. The current that is developed is delivered by a solar cell depends directly on the number of photons that are absorbed.

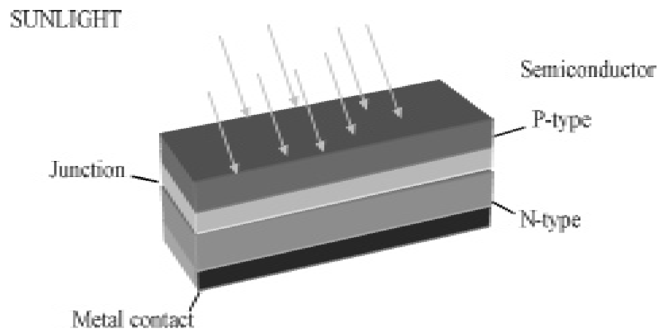

Figure-1.1 : Photovoltaic – Cell

The underlying principles of current and voltage generation in solar cells can be understood from analysis of the effect of illumination on the simplified pn homojunction structure[2]. Light incident on the p-type face absorbs photons of energy greater than the band gap energy. As light is absorbed electron hole pairs are created in the three regions: the p-type front face, the depletion region around the junction, and the n-type base. An ohmic back contact is essentially metallic in optical properties and will absorb long wavelength photons which have not created electron hole pairs in the semiconductor.(Fig-1.1)

The electrons in the face and holes in the base diffuse toward the depletion region ,and in that region are swept by the junction field across the junction and are collected as majority carriers on the other side. This results in an excess of electrons in the base and of holes in the face. Under open circuit conditions, i.e, with no external electrical path around the junction, the face is charged positively and the base is charged negatively. If a conductor is connected round the cell a current will flow.

The power developed by a solar cell depends on the product of current and voltage. To operate any load will require a certain voltage and current and this is tailored by adding cells in series and or parallel. At least one of the electrical contact must be semitransparent to allow light through, without interfering with the electrical current. Thus optimizing of a solar cell involves optics, material science and electronics.

Technological Specifications

Optimum performance of a solar cell or array requires the electrical load and the current vs voltage characteristics of the solar cell to be matched. When the cell area is very large there is ample provision for selecting an appropriate combination of current and voltage. One potential advantage of the low cost flexible array is the ability to tailor the interconnections between the individual cells at the manufacturing stage and perhaps with some contact designs to enable this to be done by the user. The voltage of the solar cell depends on the cell construction. There are ways to increase this voltage by stacking cells on top of each other, upto three in total.

This added complexity reduces production yield and requires careful optimization of each cell .Since the same current must flow through each cell in the stack, each cell must generate exactly the same current .Therefore an increasing thickness is required for each cell into the stack if it is to produce current from a successively weaker flux of light. This is more readily achieved by making the topmost cells absorb the shortest wavelength light and successive cells the longer wavelengths. In amorphous silicon this adjustment is achieved by alloying other elements into the semiconductor. The addition of carbon makes the cells more transparent to long wavelengths and the addition of germanium increases the long wavelength absorption.

Fiber Selection

The successful integration of solar cells into textiles has to take into account the type of fiber used and the method of textile fabrication. The selection of type of fiber is strongly influenced by its ability to withstand prolonged irradiation to ultraviolet (UV) light. Fiber selection is also governed by the temperatures required to lay down the thin films compromising the solar cell (Ref-18,19).It has been shown that nanocrystaline silicon thin films can be successfully deposited at temperatures as low as 200°C.

Commercial polyolefins melt below 200°C.Cotton, wool, silk and acrylic fibers start to decompose below this temperature. Polyamide fibers are likely to be too sensitive to UV radiation.Thus the two factors of UV resistance and maximum temperature restrict the choice of commodity fibers.

Polyetylene Terepthlate (PET) fibers, however, are viable substrates. They melt at 260-270°C and exhibit good stability to UV light[3]. They are commercially attractive too because of their existing widespread use.Thus fabrics composed of large variety of PET grades are currently available. PET fibers posses good mechanical properties and are resistant to most forms of chemical attack. They are less resistant to alkalis but a solar cell would not normally find use in an alkaline environment. Fabrics thus constructed from PET fibers should therefore be suitable as substrates for solar cells, whilst also possessing flexibility and conformability to any desired shape.

Fabrics composed of glass fibers produced from E-glass(electrical) formulations could also be used [20]. Advantage of using these is their transparency, as with glass plate in conventional solar cells. Moreover the price of E-glass is similar to that of PET [21]. E-glass fibers however are more prone to flexural rupture.

Fibers like polybenzimidazole (PBI), polyimide (PI),and polyetheretherketone (PEEK) also are suitable textile substrates for solar cells. However these fibers are expensive. There are clear commercial attractions therefore in adopting PET as substrates.

Fabric Construction

The type of fabric construction is also important to the performance of the solar cell. The construction affects the physical and mechanical properties of a fabric and also its effectiveness as an electrical conductor. Where conduction in textile fabrics is required, woven fabrics are considered to be the best .They posses good dimensional stability and can be constructed to give desired flexibilities and conformations. Moreover the yarn paths in woven structures are well ordered which allows the design of complex woven fabric-based electrical circuits.

Knitted structures do not retain their shapes so well and the rupture of yarn may cause laddering. This problem is heightened in apparel usage. Nonwovens generally do not possess the strength and dimensional stability of woven fabrics. The construction of electrical circuits in them is limited as their yarn paths are highly unoriented. Embroidery however offers an opportunity for circuit design.

Textiles as Substrates

Despite the many attractions of solar cells as vehicles for providing energy the way in which they are constructed provides problems in their application.Typically solar cells are encased between glass plates, which are rigid and heavy or the cells are covered by glass. Glass plates are fragile and thus care must be taken with their storage and transport.The rigid nature of solar cells require their attachment to flat surfaces and since they are used outdoors they need to be protected from atmospheric pollution and adverse weather.

The use of textile substrates on the other hand allow the construction of lighter, flexible cells. Textiles are materials with huge range of applications and markets and can be produced by a number of fabrication processes, which offer enormous versatility for tailoring fabric shape and properties.

Different types of woven, knitted and nonwoven constructions can be achieved and technical uses are beginning to be found for crocheted and embroidered constructions.[12,13,14]

Several examples have recently appeared of solar cells in plastic films. Examples are 'Power Plastic' [24]. Iowa technologies have led the development of a roll-to-roll manufacturing method for integrating solar modules on plastic.[26]

Textiles can be wound and rewound. A retractable woven canopy is developed which stores energy.[17]

Conductive Layers for Polyvoltaics

Solar cells require two contacts with an active semiconductor between them. At least one of the contacts must be transparent to solar radiation over the waveband which the semiconductor absorbs. Amorphous silicon cells, like most thin film cells have a more insulating top semiconductor layer and so require the whole surface to be contacted. This is achieved without blocking the layer of incoming light by a layer of transparent conducting oxide (TCO) such as ZnO or Indium tin oxide (ITO), often with other elements added to enhance the conductivity without reducing the transparency. In addition a fine gridded contact is often superimposed to further the current collection efficiency.

The "superstrate configuration" in which the cell is build in such a manner that the light enters through the substrate can also be used. But the textile substrates are not sufficiently transparent that this construction may be used, although the substrate can be translucent. Hence the textile material is likely to be coated with a conducting layer that may be opaque.Alternatively the textile may itself form part of the active structure enabling the conduction of photocurrent.

We require a continuous conducting layer to be placed over the whole textile surface before adding the semiconductor. Unless the textile can be made from conducting fibers, an additional material is needed. The choice of material is determined by electrical conductance, compatibility with the substrate and with the semiconductor. A lower electrical conductance material is used as thick layers.

A conducting polymer layer on the textile or incorporated within its structure, superimposed by a thin more conducting layer can be used to retain the flexibility of the substrate with high conductivity. So even if the layer breaks the gaps will be bridged by the underlying organic layer. This allows the semiconductor to be in contact with its preferred metal.

Applications

- Solar Textiles can be rolled and transported to remote areas and then unrolled at the location to serve as a source of electricity.
- They can be used to get power supply quickly to disaster areas hit by earthquakes.
- These can be used to design solar tensile tents which while providing shade and shelter also capture sunlight and convert it to electricity.
- These when used as apparel textiles can charge up our mobiles, MP3 players etc.[6]
- Similarly curtains made of solar textiles utilize solar energy by converting it to electrical energy.

Solar-α Fabrics[7,5]

A futuristic fiber material Solar-α has been developed which absorbs and preserves the optical energy of the sun. Solar-α fabrics absorb the solar visible radiation efficiently and convert it into heat in the form of infra-red radiation which is released in the clothing.

Working of Solar-α Fabrics

Zirconium carbide powder is enclosed within the core of the synthetic fibers (polyamide or polyester). Zirconium carbide compounds have excellent characteristics in absorbing and storing heat.It radiates Ca.60mW far infra-red of wavelengths 8-14 μm at a body temperature of 36°C. It absorbs the visible rays and reflects the light of long wavelength, which makes upto 95% of sunlight and converts it into stored heat energy. (Fig-1.2)

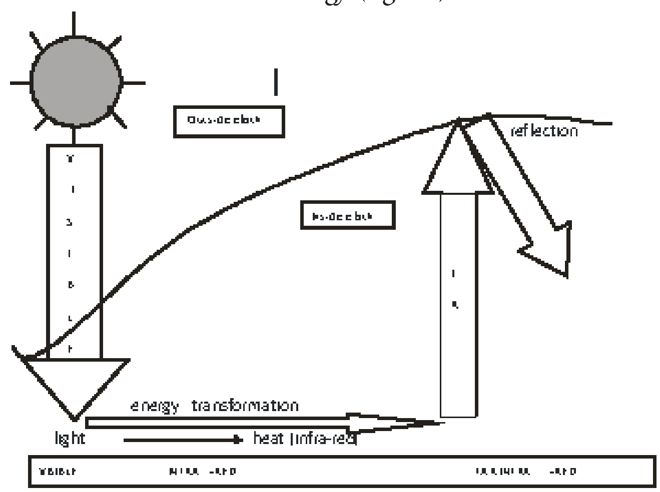

Figure-1.2 [7] : Solar-α

Solar-α has been employed for a downhill skiing suit. In addition to its smooth surface and aerodynamic form, this suit is aimed to increase the insulating efficiency by solar-α in order to warm the muscle and bring out its best power.

Conclusion

The conversion of solar energy into electrical energy by the incorporation of photovoltaic cell on textile substrate (flexible) is possible. This has led to globalization of power rather than distribution from a concentrated source. It has curtailed the use of heavy, rigid and fixed conventional solar cell by the development of light, flexible and mobile solar cells.

Finally the word "textile" still often suggests the application in clothing and the user expects the same performance of solar textiles with respect to washing, folding, abrasion etc, as with normal textiles.

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