2581-4575

International Journal For Recent Developments in Science & Technology

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NANOWIRES FOR SPACE-BASED SOLAR CELLS

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ABSTRACT

Space applications require electronic devices which are reliable, efficient, and mechanically stable and with low power consumption. Space-based solar power is an excellent source of energy of satellites and space missions. This paper gives the information about the efficiency of the silver nanowires, its optical, electrical properties and conductivity. The silver nanowires have its usage in the photovoltaic devices and solar cells. Using silver nanowires in the solar cells increases its efficiency due to its immense light absorbing capacity and widthness. The structural property of the silver nanowire plays an important role in the absorption of solar energy. Thus by using nanowires, we can increase the electricity production and thus decrease the current crises in our country. This paper is a survey of nanowires in the field of solar energy generation.

Keywords: Nanowires, Solar cell, Silver nanowires, Optical, Synthesis

1. INTRODUCTION

Solar energy is an abundant source of energy which is more eco-friendly compared other non-renewable energy sources. Space applications demand a lot of power for the orbiting satellites. Normally, we use bulk materials in solar cells, but during recent years scientists have created nanoscale wires which are more efficient than bulk materials. It has been proved that the particles property changes with decrease in surface area. Compared to the bulk particles the nano particles are more conductive and have high efficiency. Even in bulk materials, III-V compound solar cells were found to be very efficient compared to silicon solar cells.

Nanowires are one-dimensional, anisotropic structures, small in diameter, and large in surface-to-volume ratio. Thus, their physical properties are different than those of structures of different scale and dimensionality [1]. While the study of nanowires is particularly challenging, scientists have made immense progress in both developing synthetic methodologies for the fabrication of nanowires, and developing instrumentation of their characterization. In recent years, 1D nano-structures have been actively researched as candidates for future transparent electrode materials principally nanowires, nanotubes, and nanorods [2]. Space applications demand efficient systems which require low power to operate and can withstand extreme ambient conditions. Recently, space-based solar cells are given more importance as it is a renewable energy source. When discussing nanowires for space applications, several factors should be taken into account such as mechanical strength, high temperature tolerance and optical efficiency in extreme environmental conditions. Efficiency of nanowires in space energy conversion applications has been found to be excellent. Nanowire-based devices are well suited for space applications because the nanowire cross-sectional dimensions and mass are on the molecular scale, which enables low power operation while providing high sensitivity to external signals. At the same time, the much larger scale of the nanowire length provides a practical means for coupling between the macroscopic and nano-worlds.

In this paper, synthesis of silver nanowires has been explained. Section III, IV describes the properties of silver nanowires. Section V deals with comparative studies of few nanowires with good conductivity and optical transmission properties.

2. NANOWIRES

Nanowires are nanostructures which are confined in two dimensions and unconfined in one direction. The electrical conductivity is modified in nanowires where the conduction is based on that of bulk materials and tunneling mechanism [3]. The properties of nanowires can be altered non-linearly with small diameter ranges. It has the advantage of having unique density of electronic states leading to excellent electronic and thermal properties. Nanowires of Si, Ge, GaN and InAs present high electron mobility in view of a quasi-ballistic transport of electrons in the axial direction [4]

Silver nanowire (Ag NW) is another promising alternative, and it has been reported to have the potential to surpass and replace ITO [5, 6]. Silver nanowires have been attracting more attention because of their intriguing electrical, thermal, and optical properties [7]. Silver has the highest electrical conductivity (6.3 × 107 S/m) among all the metals, by virtue of which Ag NWs are considered as very promising candidates in flexible electronics. Lee et al. [8] have pioneered this material and shown that the cast Ag NW thin film used as transparent electrode showed equal merit or better than that as compared with sputter-coated Indium Titanium Oxide (ITO) in solar cells.

The interesting properties of nanowires hold promises for quite a few fields such as electronics, medicine, weaponry, materials, etc. In this work, the optical properties of nanowires have been emphasized to develop efficient solar cells for space applications. Nanowires were also found to have important applications in electrochemical devices such as lithium ion batteries and biosensors.

3. SYNTHESIS

3.1 Large Scale Synthesis Of Silver Nano Wire Via Solvothermal Method

Solvothermal method is simple method for the synthesis of silver nano structure. This method is carried out by reducing silver nitrate (AgNO3) with Ethylene Glycol (EG) and using Poly Vinyl Pyrrolidone (PVP) as absorption agents with different concentration of Ferric chloride (FeCl3). In this case, uniform silver nanowire is grown preferentially. Finally this procedure require only simple reagent and equipments and does not need shielding

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atmosphere, making it cost effective and potentially competitive for large scale production uniform silver nanowires [9].

3.2 One Dimensional Silver Nanowires Synthesised by Polyol Process

Silver nanowires with uniform diameters are synthesized in the presence of silver seed with Cetyl Trimethyl Ammonium Bromide (CTAB) served as soft template. Xia et al in 2002 first proposed polyvinylpyrrolidone (PVP) assisted polyol process to generate silver nanowires by reducing silver nitrate within the presence of PVP which has become the most popular method now-a-days. The key to the formation of the wire like nanostructures is the introduction of exotic seeds (platinum nano particles, gold nano particles) to reaction mixture [10].

3.3 Salt Mediated Polyol Method

Based on the PVP-assisted polyol method, Xia and co-workers also developed a salt-mediated polyol process to prepare silver nanowires [11, 12]. Usually salt-mediated synthesis strategy is a simple and effective method which is useful for the mass synthesis of silver nanowires [12] nanowires. Figure 1 shows the proposed mechanism of oxidative etching and growth of MTPs.

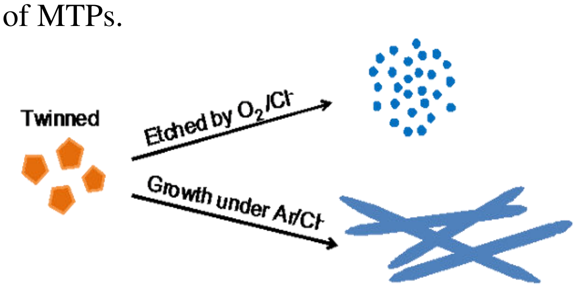

Fig. 1. Oxidative etching and growth of MTPs

3.4 Seedless and Surfactant less Wet Chemical Syntheses

Murphy and co-workers reported the work to make crystalline silver wires in water in the absence of surfactant polymer to direct nano particle growth [13] and without externally added seed crystallites. It is the simple method to prepare nanowires of silver in the high yield, with relatively few spherical nano particle byproducts. Most importantly, it does not require a surfactant or seeds .This method makes it possible to prepare metallic nano structures with as a clean surface in water. The figure shows schematic illustration of the experimental mechanism to generate spherical, rod and wire like nanoparticles.

4. STRUCTURAL PROPERTY OF SILVER NANOWIRES

Nanowires, like any other nanostructure, have physical dimension of the order approximately the wavelength of light. Following such an argument, optical microscopy cannot be engaged to physically exemplify the nanowires. Electron microscopy is used to measure the diameter and length of nanowires.

Silver nanowires films with varied thicknesses from different samples are illustrated in Figure 2. For each of these samples, an array of films with different thicknesses by repeating the coatings and varying the NW concentrations in suspension has been prepared. Figure 2a, 2b, 2c and 2d, 2e, 2f shows successive SEM images with increasing film thickness (decreasing transmittance) for two different Ag nanowires. It can be seen from these SEM images that the one with relatively high

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transmittance has sparse NW networks. The bare and insulated PET substrates were charged and showed bright convex morphology. As the thickness was increased, the networks become dense, and the substrates appear less frequently

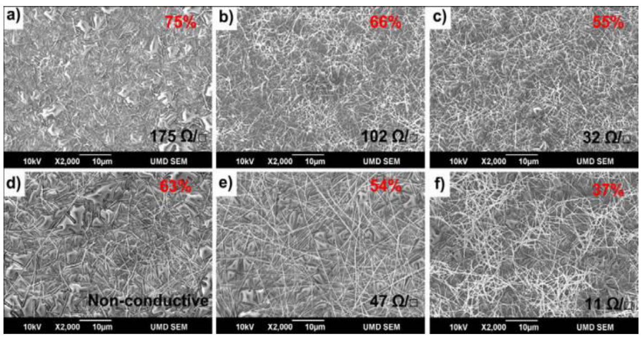

Fig. 2. SEM images for various thickness of silver nanowires

5. OPTICAL AND ELECTRONIC PROPERTIES OF SILVER NANOWIRES

A typical optical transmission spectrum in visible light region is shown in Figure given above for Ag NW thin film with surface resistivity of 170 Ω/sq indicated an average transmittance of 74 %. Silver nanoparticles have been found have optical characteristics for sizes less than 60 nm.

From transmission spectra, it can be seen that Ag NWs do not have any characteristic absorption peaks except of periodic intensity oscillation which is a feature for the light reflection of uniform thin film [14]. Because the diameters of Ag NWs or NW bundles are large (approximately 100 nm), the reflection and scattering of light on NW film increase, and hence, decrease the film transmittance. However, reflection and scattering benefit the application of Ag NW films in photovoltaic devices [6, 14], in which the Ag NW electrode-contained solar cells show larger photocurrent than the one using ITO film as electrode.

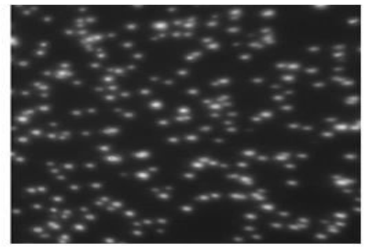

Fig. 3. Dark field microscopy image of 60 nm silver nanoparticles

Electron transport of one-dimensional structures can be divided as two categories: ballistic transport and diffusive transport. In ballistic transport, the electrons travel from end-to-end of nanowires without scattering. Ballistic transport is possible if the length of nanostructure is less than the mean scattering length of the material. The electronic conduction in ballistic nanostructures is purely quantum based on the universal conductance G0 = 7.727 x 10-5 S [15]. This quantization happens when the diameter of nanowires is equivalent to Fermi length of electron which is approximately 0.5 nm. This effect has been found in many nanowires such as gold, copper, silver, sodium, mercury, etc.

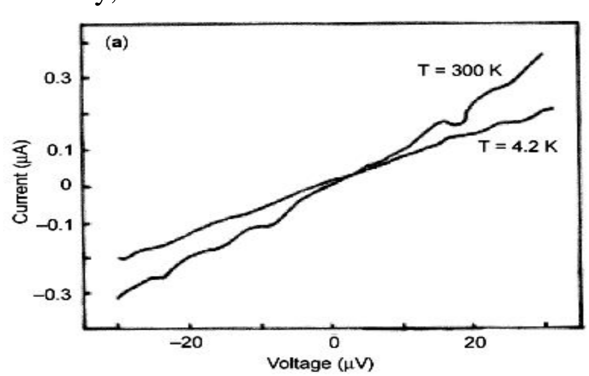

Fig. 4. Current-voltage characteristic of copper nanowires at 4.2 K and 300 K

The electronic characteristics of nanowires are determined by wire diameter, crystal structure, chemical composition and wire surface composition. Various nanowires of different size and chemical composition have different conductance and optical transmission. Copper and silver nanowires are well known for their conductivity. The current voltage characteristics of copper nanowire at different temperatures are given in figure 4.

Semiconducting nanotubes and nanowires are excellent candidates for the audition of channels in nanoscale transistors. Nanowire Field Effect Transistors (FET) [16] can be configuraed by depositing the nanomaterials onto insulating substrate surface and making drain and source contacts on the ends of the nanowires. Silicon nanowires can be prepared with single-crystal structures, diameters as small as several nanometers and controllable hole and electron doping, and thus represent powerful building blocks for nanoelectronics devices such as field effect transistors. Nanowires transistors have been very successful. Figure 5 shows the current-voltage characteristics of Silicon nanowires FET [17].

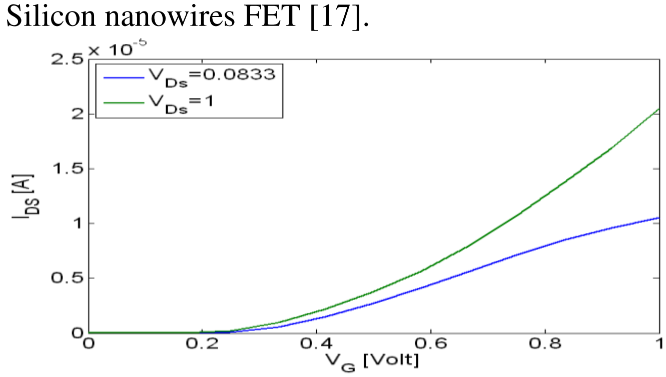

Fig. 5. Current – gate voltage characteristics for different drain voltages [17]

Gallium nitride nanowires have been found to have excellent conducting properties. As it is a part of III-V compound semiconductor family, it is not a surprise to find such good qualities even in nanoscale. The current-voltage characteristics of Gallium nitride nanowires transistor is given in figure 6. The figure shows how gallium nitride nanowires ha suited well as a FET channel by comparing it to the characteristics of MOSFET.

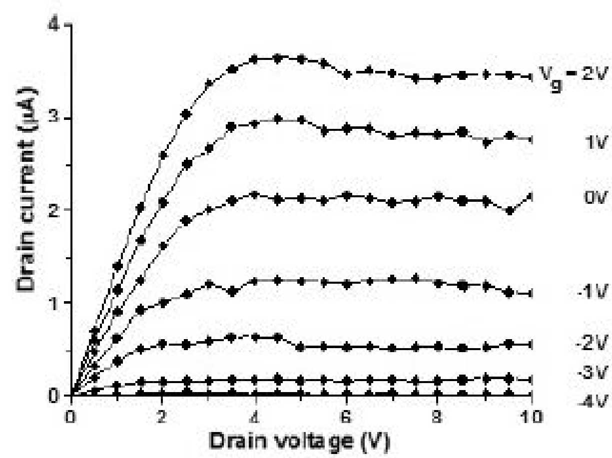

Fig. 6. Drain Voltage characteristics of GaN nanowires transistors [18].

6. COMPARATIVE STUDIES OF EFFICIENCY OF NANOWIRES

Silver nanowires have been found to have wonderful properties as discussed above. Copper nanowires of 10 – 30 nm have been found to have good characteristics to suite the solar applications. Copper nanowires have been found have extremely flexible property. With the advantage of copper being an abundant material and cheap, mass production of efficient and reliable solar cells are not far in the future

[19]. Smaller nanostructures yield efficient conducting materials.

Copper nanowires have been recognized with smaller temperature coefficients of resistance and higher failure current density [20]. Compared to silver nanowires, copper nanowires have good properties. It fails at very high temperatures. There is a possibility of nanowires of alloys of copper and silver to express actual qualities required for space applications. If the mechanical instability of copper nanowires at high temperatures can be reduced, then it can be used as a good solar cell material in outer space.

7. CONCLUSION

Nanowires are of high significance in recent days and have proved to be worthy for such honor on various levels. Some of the details have been discussed in this paper. Silver, copper and zinc oxide nanowires have been found to have excellent capacity to act as solar cells. Silicon nanowires have been used as channels in transistors. Copper nanowires, due to their cheap cost and thin flexible film will be better alternative for silver and other nanowires. They are thin compared to silver. As the structural properties have their effect on the conductivity, thus they are far more efficient than silver and other nanowires. Many more applications are yet to be invented.

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