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Optical and Electrical Characterization of Synthesized Nanostructures of Silicon

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Abstract— In this paper, nanostructures have been developed on silicon wafer and thus synthesized to characterize optical and electrical properties. The wafer was synthesized using electro-less metal deposition and dissolution (EMD) process leading to one-dimensional (1-D) growth of single-crystalline nanowire. from the optical characterization curve it can be determined that a nanowire has the same property possessed by any of optical filters as light of certain wavelength cannot pass whereas other wavelength in a different range can easily transmit through it. In I-V characteristics curve, a rapid current flow was found after a certain input voltage (4.17v for Cu and 4.32v for Ag samples respectively).

Index Terms— Absorption Curve, Ag Nanowire, Cu Nanowire, Electrical Characteristics, Electro-less Metal Deposition, Reflectance Curve, Transmittance Curve.

1 Introduction

Bulk materials and atomic or molecular structures have a close link with each other. Though bulk materials have constant physical properties regardless of its size, among nanoparticles the size often dictates different physical and chemical properties. The properties of materials change as their size approaches the nanoscale [1] and the percentage of atoms at the surface of a material becomes significant [2-4]. Nanotechnology finds scopes for the designing, characterization, production and application of structures, devices and systems by controlling shape and size at the nanoscale [5]. Nanostructures of Silicon material can be used to fabricate electronic devices.

2 Approaches for Nanomaterials Fabrication

There are two approaches for synthesis of nanomaterials [6-7]. Top down approach refers to slicing or successive cutting of a bulk material to get nano-sized particle and bottom up approach refers to the build up of a material from the bottom: atom by atom, molecule by molecule or cluster by cluster. The problem with top down approach is the imperfection of surface structure and significant crystallographic damage to the processed patterns. This approach most likely introduces internal stress, in addition to surface defects and contaminations. On the contrary, bottom up approach promises a better chance to obtain nanostructures with less defects and more homogeneous chemical composition.

3 Sample Preparation

For synthesizing nanowire, the materials and chemicals used for preparation of samples are silicon wafers, rectified water, acetone (CH_3COCH_3), Ferric Nitrate ($Fe(NO_3)_3.9H_2O$), Cupric Nitrate Trihydrate ($Cu(NO_3)_2.3H_2O$)), Hydrofluoric acid (HF), Silver Nitrate ($AgNO_3$). The instruments and components used for sample preparation are digital weight meter, glass beaker, teflon beaker, sample holder, gum, gloves, diamond cutter, hair dryer etc. As per requirement of the characterization process of silicon wafers are needed to be in a certain shape. These wafers should be adjustable with the sample holders of the instruments. The shape of the wafer used here is 2.2 cm by 2.0 cm. BUEHLER 351-IS-8143 Precision Sectioning Saw has been used for this purpose at Atomic Energy Center, Dhaka (AECD).

It has been found that native oxide was developed on to the surface of silicon wafers due to the exposure to air. So, Si wafers were cleaned by immersing in acetone for five minutes. After that they were washed by the rectified water and those wafers were dipped into the acetone for the next five minutes again for better cleaning.

4 Deposition of Metal Particles

The samples were dipped in HF / ($Cu(NO_3)_2.3H_2O$)) solution for Cu and HF / $AgNO_3$ solution for Ag nanoparticle deposition on individual wafers. They were dipped for 60 sec. The concentration of HF, (($Cu(NO_3)_2.3H_2O$)) and $AgNO_3$ taken for preparing solution is as listed below. Generally, HF attacks glass reacting with silicon dioxide to form gaseous or water-soluble silicon fluorides. So, normal glass beaker cannot be used here. Teflon beaker can be a better alternative of this.

5 Etching of Metal Deposited Samples

After the deposition process, etching on the samples was needed to be performed. The solution of 5M HF and 0.02M ($Fe(NO_3)_3.9H_2O$) were taken for etching. This process was performed at room temperature for 60 min.

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6 AMOUNTS OF CHEMICALS REQUIRED FOR METAL PARTICLE DEPOSITION AND ETCHING

Table: The amount of required chemicals for the particle deposition

Metal deposition	Solution	Amount taken		
		$(Cu(NO_3)_2.H_2O)$	$AgNO_3$	HF
For Cu particle deposition	Solution of $(Cu(NO_3)_2.3H_2O))$ and (HF)	0.24gm	-	10gm
For Ag particle deposition	Solution of $(AgNO_3)$ and (HF)	-	0.17gm	10gm

For etching, Amount of (Fe $(NO_3)_3.9H_2O$) was taken =0.404gm.

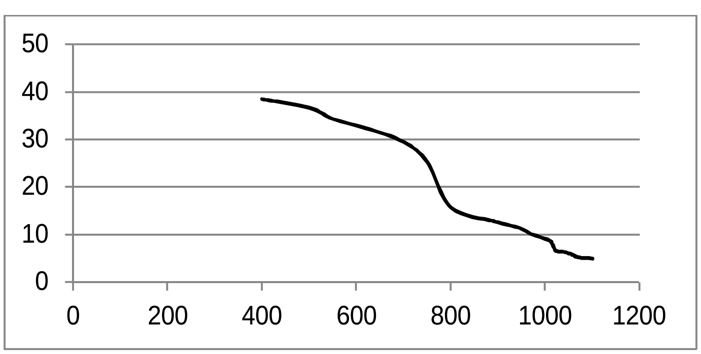
7 RESULTS

7.1 Optical Charateristics

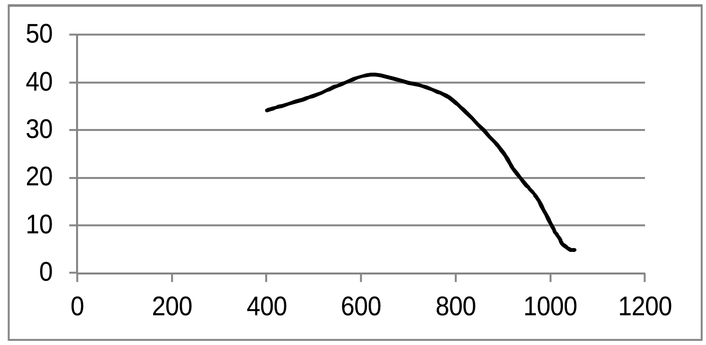
The absorption measurement was carried out over a range of wavelengths 400nm to 1100nm, which cover most of the spectrum useful for a silicon based solar cells [8-10]. The nanowire film shows significantly stronger absorption across a certain spectrum [11,12]. Therefore, synthesized nanowires are very promising for solar cell [13].

7.1.1 Transmittance behavior

The following figures show only the transmittance behavior of Cu and Ag samples for radiation of wavelength 400nm to 1100nm obtained from UV-1201 spectrophotometer.



(a)

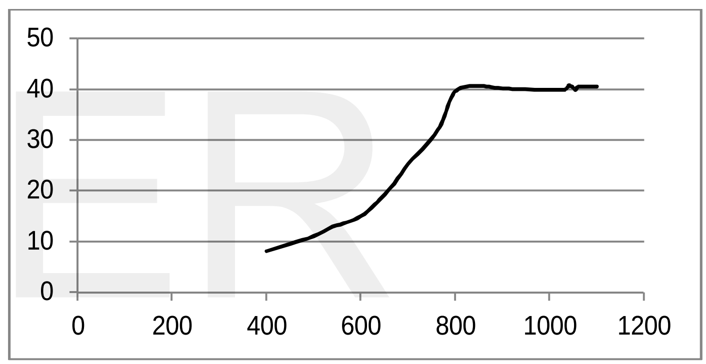


(b)

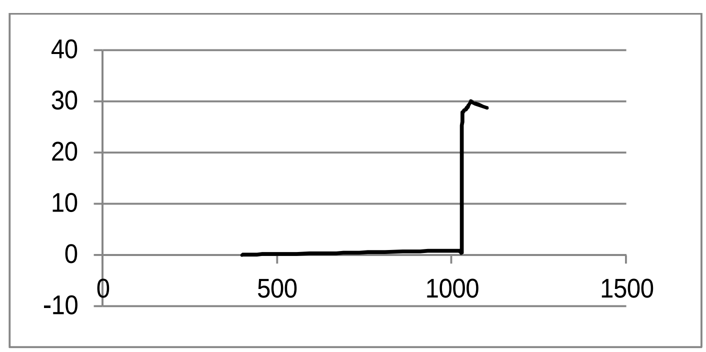
Fig 1. Transmittance curves of the (a) Cu sample and (b) Ag sample in wavelength range of 400nm to 1100nm Along X axis the wavelength of the ray or beam and along Y axis the transmittance (%) are represented.

7.1.2 Reflectance Behavior

The following figures show only the reflectance behavior of Cu and Ag samples for radiation of wavelength 400nm to 1100nm obtained from UV-1201 spectrophotometer.



(a)

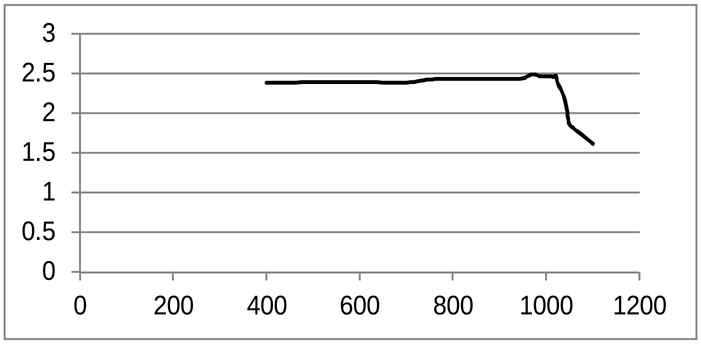


(b)

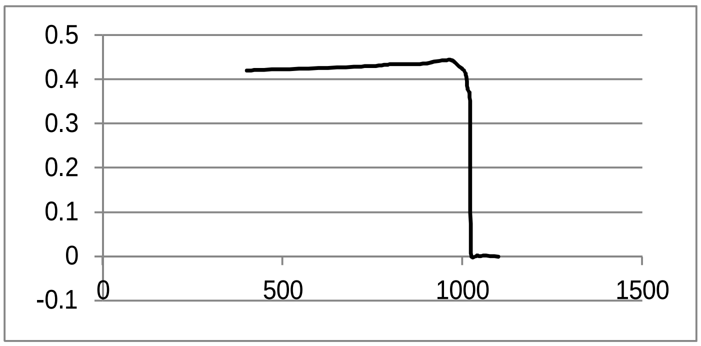
Fig 2. Reflectance curves of the (a) Cu sample and (b) Ag sample in wavelength range of 400nm to 1100nm. Along X axis the wavelength of the ray or beam and along Y axis the reflectance (%) are represented.

7.1.3 Absorption Behavior

The following figures show only the absorption behavior of Cu and Ag samples for radiation of wavelength 400nm to 1100nm obtained from UV-1201 spectrophotometer.



(a)



(b)

Fig 3. Absorption curves of the (a) Cu sample and (b) Ag sample in wavelength range of 400nm to 1100nm. Along X axis the wavelength of the ray or beam and along Y axis the absorption are represented.

7.2 Electrical Characteristics

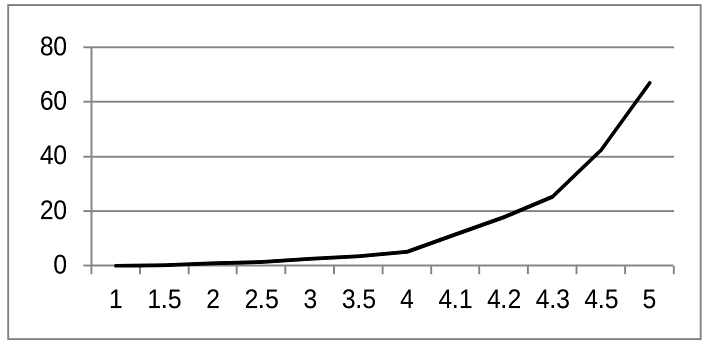
Al-Si contact displayed non linear current-voltage characteristics [14] almost like a diode. High current was obtained as the voltage across the sample increased [15]. Since Al and Si have different work function, there was a potential barrier in the contact, current flow across samples under the forward voltage was controlled by the bias voltage dependent changes of the potential barrier height in the contact region and we can conclude that the contact formed was the rectifying contact.

7.2.1 Sample Preparation for Electrical Characteristics

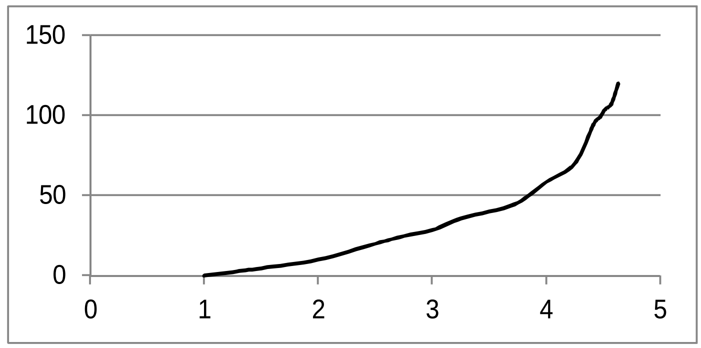
Two Al-Si contacts are required on the sample to find the IV characteristics curve. These contacts can be produced by thermal evaporation of Al. The evaporation chamber, sample holder and masks were needed to be cleaned. To allow Al coating in desired region of samples musk was used. As the coil was heated up in the evaporation chamber, the Al was gradually evaporated. Copper wires were bonded onto the evaporated Al metal layers with ‘EPOTEK H20E’ silver loaded epoxy.

7.2.2 I-V Characteristics

The characteristics curves obtained from I-V measurement is given below:



(a)



(b)

Fig 4. I-V curves for (a) Cu sample and (b) Ag sample, where along X axis the input voltage (volt) and along Y axis the current (μA) are represented.

8 CONCLUSION

In summary, electro-less metal deposition method was used for fabricating the two metal nanowires: Cu nanowire and Ag nanowire respectively. After that the samples were taken for etching and thus the samples were ready for characterization. The optical characterization was done very precisely. The synthesized nanowire showed the behaivour of an optical filter in the range ~ (500 nm -1000 nm) as it absorbs all the light in that range, not allowing any light to reflect. This feature can be used in solar cells for increasing their efficiency much significantly. So nanowires can be used in the solar cells to increase their efficiency. After each chemical reaction the samples were required to make dry by nitrogen blower to prevent samples from unwanted oxidation. Since, there was no liquid nitrogen in our laboratory; some contaminations were introduced in the samples. Even the native oxide was very critical to etch away due to the scarcity of solvents like acetone and isopropyl alcohol.

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