Analysis Of Semiconducting Nano-crysrtalline Structure With Various Techniques

Vikas Kashyap [a], Sushil Kumar [b]

[a]*Department of Physics, Panjab University, Chandigarh, 160014, India,*
[b]*Department of Physics, Hans Raj Mahila Maha Vidyalaya, Jalandhar, India,*

Abstract : The field of nanomaterials is a vastly growing field with a plan to ease the society in giving a revolutionary performance in industrialization. In our article we are exploring the nanostructural domain of the most influential material silicon, the reason for its valuable performances in optoelectronics and energy harvesting. Here we report, fabrication of silicon nanowires on N type silicon wafer having resistivity lies between 0.001-0.1 Ohm cm by metal electrode less wet chemical etching (MEWCE). Here we are presenting the cage-like structure of Silicon nanowire. Surface morphology were extensively investigated by using technique such as field electron scanning electron microscopy (FESEM).The MEWCE method has been widely explored for developing silicon based photovoltaic devices with its benefits for low-cost and large-area fabrication of silicon nanowire (SiNWS) of high aspect ratios (height to volume). According to FESEM images, the morphology and particle size are influenced by augmentation in etching. Here we have used the etching duration of 45 minutes. The diameter of the wire has been measured using imageJ software and the gaussian fitting gave the result diameter of 9 nm(approx.) which is of great use in the sensor application also it introduces the quantum confinement effect.

Keywords: SiNWs; MEWCE; FESEM.

1. Introduction:

Semiconductor nanowires are emerging as promising in electronics and photonics for potential applications. Due to its technological feasibility with current semiconductor technology, silicon nanowires are increasingly attracting attention[1–3]. In field effect transistors, chemical sensors and field emitters, silicon nanowires have been effectively incorporated. Nonetheless, one significant problem that needs to be solved for device applications is effective control of the nanowires' thickness, crystallographic orientation, location, and manner of packing [4–6]. Due to unique properties, including low thermal conductivity, nanostructures have attracted considerable attention over the past decades. The most widely used approach is to lower thermal conductivity by phonon scattering at surfaces and interfaces that play a large role over intrinsic scattering as the nanostructure length scales drops [7,8]. As earlier reported that by taking silicon nanowires (SiNWs) as a specific material, thermal conductivity reduction was achieved through increased phonon scattering on surfaces due to a high surface-to - volume ratio. The number of research works have been carried out to further decrease thermal conductivity of SiNW by surface roughness, inner holes, dopants and kinks. Si clusters of various sizes were used as subunits for structures of the nanowires [9,10]. The thinnest nanowire structure consisting of uncapped trigonal prisms was proposed in earlier research work, and the stability of wires consisting of multi-coordinated Si atoms was studied till now. There is one important fact that serves in line with the spirit of these models: the anisotropic structure of nanowire for developing the one-dimensional structure in vapor phase which serves as the spirit of these models [11–13].

A lot of work has been done so far as from the prior reported work that structured subwavelength serves as an anti-reflection layer. In particular, the subwavelength structure (SWS) forms a barrier with a deep compact form grating which suppresses reflection [14–16]. The antireflective properties (commonly antireflection coating) are improved by reducing the grating time and increasing the grating size, as given by the study reported so far. For this purpose silicon SWS surfaces are synthesized using an electron beam or laser interference lithographies. Anti-reflective films are or intended for use in a variety of applications, including the exit faces of front panels of liquid-crystal (LC) display, LEDs and surface of solar array panels. A thin film with such a single-layer coating or a multilayer coating is normally used as an antireflective film. In recent times, attempts were made in forming

antireflective films using a relief structure with an average period less than the wavelength of incident light [17–20]. Si nanostructures gain huge attention due to their unique optical and electrical characteristics for energy harvesting applications. The SiNW or Si nanopillar (SiNP) studies for energy storage applications are promising materials due to the feasibility of decoupling the light trapping and photon-generated carrier extraction which also allows the use of low-grade Si raw materials, thereby reducing production costs which is the main focus of our study that how we can make our outcomes cost effective. Solar energy absorption using the SiNW / SiNP arrays has been experimentally demonstrated also in the previous reported research [21].

Street et al. further suggested that SiNW arrays which are very ordered exhibited lower optical reflection contrasted with disordered ones. Through simulation, Hu and Chen revealed that the light absorption for the SiNW array could be increased relative to the Si thin film for the same given thickness, the enhancement occurred but only in the high-energy region, that is 2.8 eV [21,22]. The light absorption decrease to around zero was recorded for SiNW arrays in the low energy region , i.e., 2 eV due to the absence of the absorber layer , here absorber layer are the Si layers with sufficient thicknesses, for the light with longer wavelengths [23–25]. The combination of SiNP arrays and Si thin films should therefore be a possible alternative for realizing effective light absorption. In other words, the goal is that SiNP or SiN could be promising for effective solar energy harvesting. The study of thermoelectric energy production uses the Seebeck effect to extract electrical power from a difference in temperature (dT). Because of their millimeter square footprint, the latest thermoelectric power generator (TEG) technologies are not very vast [26]. Recent studies have both experimentally and theoretically predicted excellent thermoelectric properties of silicon nanowires (SiNWs).

Research effort has been focused on manufacturing of silicon nanowires and their applications. Typically, silicon nanowires are grown with random orientations and more processing is needed to assemble the nanowires for particular applications. Recently, the orientation controlled growth of siNW arrays has been demonstrated and the controlled growth of SiNW in predetermined configurations. We demonstrate large-scale silicon nanowire arrays that have a broad variety of applications including light emitters, photonic crystals and vertical field effect transistors. The diameter, height of individual nanowires, and the center-to-centre distance between nanowires were precisely regulated. Scientists and engineers have been able to recreate some of the natural structures in the laboratory and in real-world applications which have great use to this world.In the article we are presenting the fabrication of cage like structure of the one dimensional Silicon nanostructures on n type silicon wafer that have resistivity lies between 0.001-0.1 Ohm Cm by metal electrode less wet chemical etching (MEWCE) [2,27,28] .Furthur the diameter is analyzed by the imageJ software and both structures are elaborated briefly .There are many reason to use the MEWCE method It is a simple and low-cost method for fabricating various Si nanostructures with the ability to control various parameters (e.g., cross-sectional shape, diameter, length, orientation, doping type, and doping level). In this method (MEWCE) all procedures can be accomplished in a chemical lab without expensive equipment. This method (MEWCE) enables control of the orientation of Si nanostructures (e.g. nanowire, pore) relative to the substrate. In contrast, in VLS-based growth of Si nanowires, the crystallographic orientation of Si nanowire depends upon the diameter of nanowire [4,5]. Therefore, MEWCE has become increasingly important in the last decade. The method has been utilized to fabricate various Si or Si/Ge nanostructures.

2. Experimental Details

Here electroless deposition occurs, (a non-galvanic deposition type) which involves multiple simultaneous reactions in an aqueous solution. Depositing is the first step in silicon nanowire synthesis using this process. Here we have taken silver as the depositor.The etching of a cleaned Si wafer is done very slowly at low temperature in aqueous HF solution. However, Si etching occurs quickly and effectively when a Si substrate covered with Ag nanoparticles immersed in HF solution. Formation of SiNW arrays as the Ag particles continue to sink.

2.1 Preparation of the solution:

Firstly, the silicon wafer is reduced by cutting in the square dimension of 2cm*2 cm. These are cleaned by dipping for the duration of 20 min in each that is in ethanol, deionized water and acetone Here the N type silicon

wafer has been taken which has the resistivity lies between 0.001-0.1 Ohm cm and with the approach of the MACE method we proceeded for making SiNW. MEWCE mainly involves the two-step (i) deposition process and (ii) etching process. Silver nitrate (0.5 mM.), combined with HF(4.8 M),to form the deposition mixture. The solution for etching is made by combining 4.6 M HF & 0.5 M H_2O_2. Then we left with the fabricated sample (having silicon nanowire) on them and the sample was treated with nitric acid to remove extra silver ions.

3. Result and discussion

`

Here we have used the FESEM (Field Effect Scanning electron microscopy) to study the surface morphology (SiNW diameter).. Here N type Sample with resistivity lies between 0.001-0.1 ohm cm was taken and the top view of the Si NSs (nanowire) so obtained was shown in the figure below which gives us the nanowires cluster, followed by a 45 minute etching time. FESEM solves the difficulty that arises from the images obtained from an optical magnifying lens. Similarly, it is quite sufficient to see the structure as small as 1 nm on the outside surface of the material. In the below figure 1 the four images clearly demonstrate the FESEM images of the samples having resistivity lies between 0.001-0.1 Ohm Cm for the etching time of 45 min. at different resolutions.

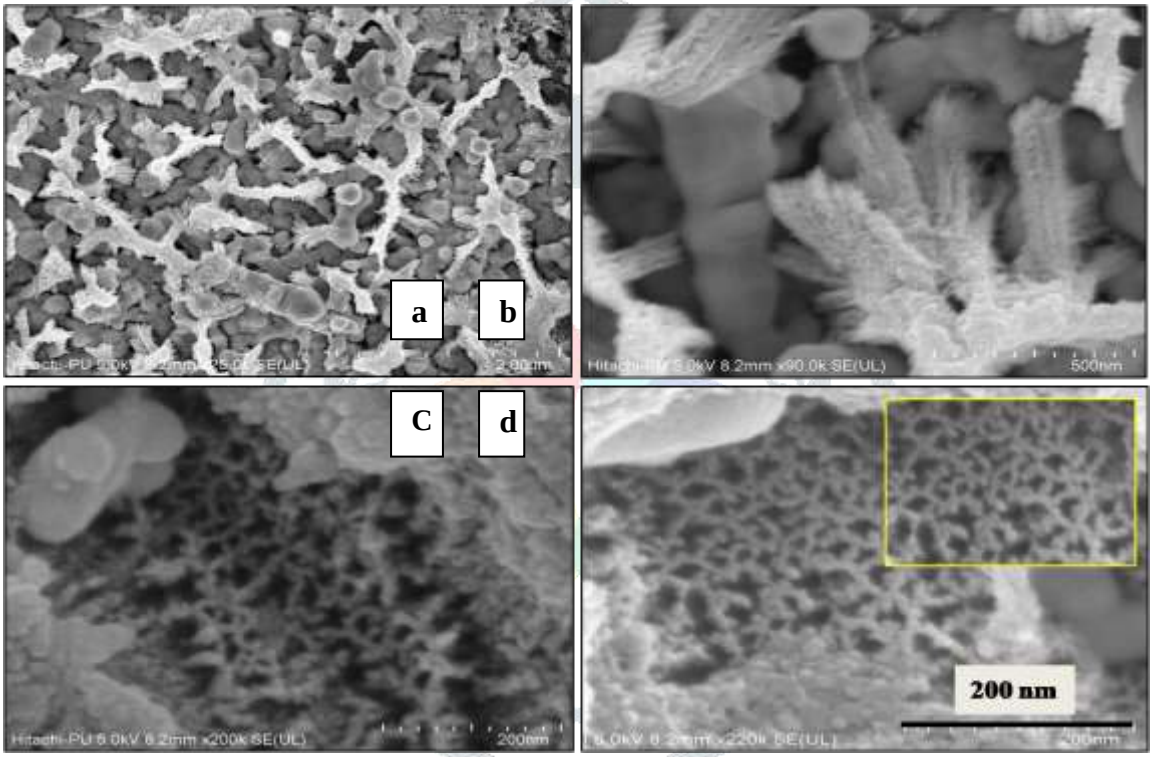

Figure1:FESEM images of the samples having resistivity lies between 0.001-0.1 Ohm cm for the etching time of 45 min. at different resolutions

The FESEM images by using the imageJ software depicts the exact value of diameter that is 9 nm the below given figure 2 gives the clear variation of the diameter which is shown in fig a and the fig (b) gives the diameter distribution by gaussian fitting .

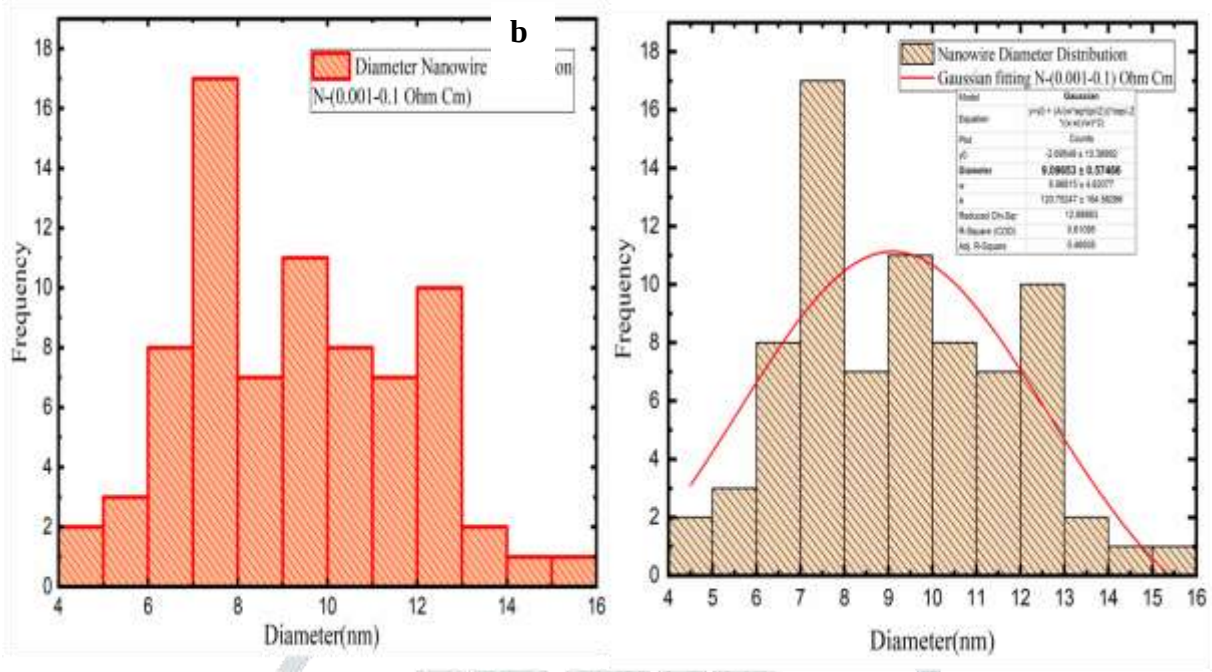

Figure 2: Diameter nanowire distribution of the N type samples having resistivity lies between 0.001-0.1 Ohm cm for the etching time of 45 min. at different resolutions fig (a) Diameter Nanowire distribution and fig (b) Gaussian fitting of the diameter

As we know the production of nanowire uses several common laboratory techniques, including suspension, electrochemical deposition, vapor deposition, and VLS growth. The reason for their high aspect ratio, nanowires are also uniquely suited to integrating suspended dielectric metal oxide nanowires in electronic devices such as UV, water vapor, and ethanol sensors. The below given figure 3. depicts the data points taken to calculate the diameter of the nanowire.

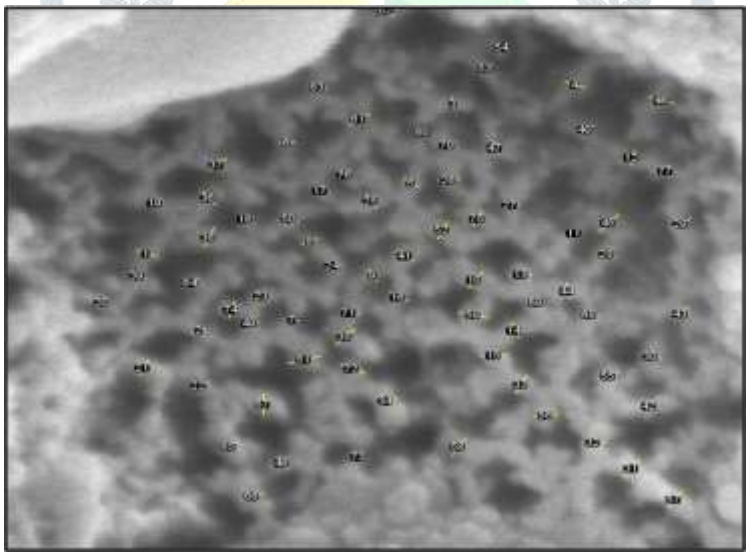

Figure 3: The data points taken to calculate the nanowire diameter distribution

Conclusion

Several physical reasons already predict that the conductivity of a nanowire will be much less than that of the corresponding bulk material. The SiNW size (diameter) fabricated by MEWCE technique on the Si substrate for N type sample that have resistivity lies between 0.001-0.1 Ohm cm with an etching time of 45 min is 9 nm (approx.) using Image J software. By using MEWCE technique we have also investigated the mechanism formation of SiNW. Electronic industry originates by using these one-dimensional nanostructures, through a

transformation from light energy to electric energy. The etching time and concentration of oxidants have also had a strong influence on nanostructural morphology. The SiNWs can be widely used as biosensors, microwave devices, field emission devices, PH sensors, gas sensors and for next-generation electronics. As they wear high aspect ratio property which makes it highly relevant to use for sensor application.

References:

[1] Y. Kanamori, M. Ishimori, K. Hane, IEEE Photonics Technol. Lett. 14 (2002) 1064–1066.
[2] K.A. Gonchar, A.A. Zubairova, A. Schleusener, L.A. Osminkina, V. Sivakov, Nanoscale Res. Lett. 11 (2016).
[3] L.A. Osminkina, K.A. Gonchar, V.S. Marshov, K. V. Bunkov, D. V. Petrov, L.A. Golovan, F. Talkenberg, V.A. Sivakov, V.Y. Timoshenko, Nanoscale Res. Lett. 7 (2012) 1–6.
[4] J. Goldberger, A.I. Hochbaum, R. Fan, P. Yang, Nano Lett. 6 (2006) 973–977.
[5] J. Jie, W. Zhang, K. Peng, G. Yuan, C.S. Lee, S.T. Lee, Adv. Funct. Mater. 18 (2008) 3251–3257.
[6] Y. Cui, Z. Zhong, D. Wang, W.U. Wang, C.M. Lieber, Nano Lett. 3 (2003) 149–152.
[7] I. Ponomareva, D. Srivastava, M. Menon, Nano Lett. 7 (2007) 1155–1159.
[8] D. Li, Y. Wu, P. Kim, L. Shi, P. Yang, A. Majumdar, Appl. Phys. Lett. 83 (2003) 2934–2936.
[9] D. Li, Y. Wu, P. Kim, L. Shi, P. Yang, A. Majumdar, Appl. Phys. Lett. 83 (2003) 2934–2936.
[10] E.K. Lee, L. Yin, Y. Lee, J.W. Lee, S.J. Lee, J. Lee, S.N. Cha, D. Whang, G.S. Hwang, K. Hippalgaonkar, A. Majumdar, C. Yu, B.L. Choi, J.M. Kim, K. Kim, Nano Lett. 12 (2012) 2918–2923.
[11] M. Menon, D. Srivastava, I. Ponomareva, L.A. Chernozatonskii, Phys. Rev. B - Condens. Matter Mater. Phys. 70 (2004) 1–6.
[12] A. Najar, J. Charrier, P. Pirasteh, R. Sougrat, Opt. Express. 20 (2012) 16861.
[13] T. Hoshino, M. Itoh, T. Yatagai, Appl. Opt. 46 (2007) 648–656.
[14] H. Sai, H. Fujii, K. Arafune, Y. Ohshita, M. Yamaguchi, Y. Kanamori, H. Yugami, Appl. Phys. Lett. 88 (2006) 1–4.
[15] Y. Kanamori, M. Sasaki, K. Hane, Opt. Lett. 24 (1999) 1422.
[16] S. Wang, X.Z. Yu, H.T. Fan, Appl. Phys. Lett. 91 (2007) 3–6.
[17] K.A. Salman, K. Omar, Z. Hassan, Superlattices Microstruct. 50 (2011) 647–658.
[18] M. Lipiński, S. Bastide, P. Panek, C. Lévy-Clément, Phys. Status Solidi Appl. Res. 197 (2003) 512–517.
[19] S.K. Srivastava, D. Kumar, P.K. Singh, M. Kar, V. Kumar, M. Husain, Sol. Energy Mater. Sol. Cells. 94 (2010) 1506–1511.
[20] R.R. Bilyalov, R. Lüdemann, W. Wettling, L. Stalmans, J. Poortmans, J. Nijs, L. Schirone, G. Sotgiu, S. Strehlke, C. Lévy-Clément, Sol. Energy Mater. Sol. Cells. 60 (2000) 391–420.
[21] J. Li, H. Yu, S.M. Wong, G. Zhang, X. Sun, P.G.Q. Lo, D.L. Kwong, Appl. Phys. Lett. 95 (2009).
[22] H. Lu, C. Gang, Nano Lett. 7 (2007) 3249–3252.
[23] K.X. Wang, Z. Yu, V. Liu, Y. Cui, S. Fan, Nano Lett. 12 (2012) 1616–1619.
[24] J. Zhu, C.M. Hsu, Z. Yu, S. Fan, Y. Cui, Nano Lett. 10 (2010) 1979–1984.
[25] Q. Hu, H. Suzuki, H. Gao, H. Araki, W. Yang, T. Noda, Chem. Phys. Lett. 378 (2003) 299–304.
[26] D. Dvila, A. Tarancón, M. Fernndez-Reglez, C. Calaza, M. Salleras, A. San Paulo, L. Fonseca, J. Micromechanics Microengineering. 21 (2011).
[27] A.S. Togonal, L. He, P. Roca I Cabarrocas, Rusli, Langmuir. 30 (2014) 10290–10298.
[28] X. Li, Curr. Opin. Solid State Mater. Sci. 16 (2012) 71–81.