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Increasing PSi Photodetector Responsiveness by Incorporation $AgNP_s$

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Abstract: The Nanocrystalline Porous Silicon (PSi) is developed by using method of electro-chemical etching of n-type silicon chip with orientation (100) by using teflon cell, HF with 40% concentration and ethanol with purity (99.9%) in (1:1) ratio at etching current density (5 mA/cm^2) for 22 min etching time. The chemical structure of (porous layer) was analyzed by using SEM, FTIR, XRD and UV-Vis. The electrical properties of AgNP/PSi/c-Si junction was studied using illuminated I-V, C-V measurement, dark I-V and responsivity. The current study demonstrates improvement in electrical properties of PSi photodetector after embedding AgNPs.

Key words: Porous silicon, silver nanoparticles, photodetector, SEM and responsivity, demonstrates improvement, orientation

INTRODUCTION

Nanotechnology is a science or technology that is widely involved in the study of engineering and science conducted at the nanoscale which is approximately 1-100 nm. Nanoscience and nano technology application of extremely teeny things and it is possible to enter into the industry, many techniques in all other scientific fields such as Physics, Chemistry, Materials Science, Biology and Engineering. Porous silicon produced by electrochemical etching of silicon the method has become one of the famous materials used in a wide range of scientific applications because it has an unparalleled set of physical and chemical properties and cost-competitive fabrication processes. Silver with the symbol Ag (from the Latin Argentum: "shining" or "white"), Ag is a chemical element with 47 as atomic number. A velvet, white, transition prismatic metal (Lehmann, 2002) it appearvery high electrical conductivity, thermal conductivity and reflectivity of any metal. The metal is found in the Earth's crust in the refined, free elemental form ("native silver") as an alloy with gold and other metals (Sailor, 2012). Porous silicon structures are created by electrochemical etching ofsilicon wafers in organic solutions of acetonitrile (CH_3CN) or dimethyl form amide (C_3H_7NO) containing Hydrofluoric acid (HF) (Kern, 1984). To cognize the electrochemical mechanisms taking place in the course of the etching of silicon is a key factor to controland modify the structure of this versatile porous material (Nayef and Muayad, 2013). This electrochemical technique produce a wide range of structures which can range from a porous matrix to arrays of nanowires. These structures are unique and fetch new opportunities for applications such as Optoelectronics, Biotechnology, Medicine, Chemistry and so forth and multiple research fields.

MATERIALS AND METHODS

PSi samples were prepared by electrochemical etchin technique of boron doped, N-type (100) oriented Si wafer $\rho = 10\ \Omega$ cm in a (1:1) HF (40%): ethanol (99.9%) solution at a current density 5 mA/cm^2 for 22 min etching time" at room temperature in a Teflon single tank anodizing system as illustrated in Fig 1.

AgNPs were prepared by chemical reduction method 0.0016 M of AgNO which heated to 50° by the magnetic stirrer heater and 3 mL of 2% NaOH as a reduction agent was added to the solution drop by drop until color change to yellow, then removed from the heat and leave to cool room temperature. After that the suspension was sonicated for 10 h by ultrasonic water path to overcome the AgNPs agglomeration.

In this research, the XRD (Shimadzu-XRD6000, Shimadzu company/Japan) system for XRD" measurements was used. The Cu-Kα radiation has been the source of X-ray radiation with wavelength 0.15406 nm. The device worked at 30 mA emission current and 40 kV", the sample was scanned from (20-60°). The SEM study is taking by scanning electron microscope inspect S50 FEI company made in "Netherlands". The UV-Vis is spectro photometer N. 21-1884-01-0041 spectral band width 2.00 nm. The Fourier Transform Infrared (FTIR) spectroscopy it measurement by Bruker/OPUS-7.5.18/Data/Meas/A.22 the (Shimadzu- 8400S) scan of the FTIR measurements are carried out over the range between (400-4000) cm^{-1} for the preparation" sample. The optical properties were measured by using the (Elico",

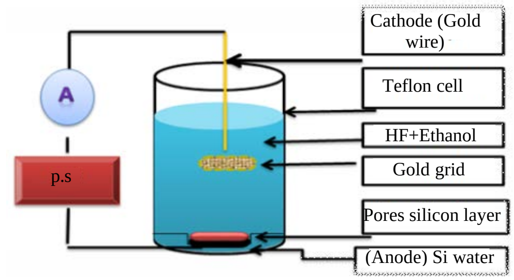

Fig. 1: The mechanism of the electrochemical etching

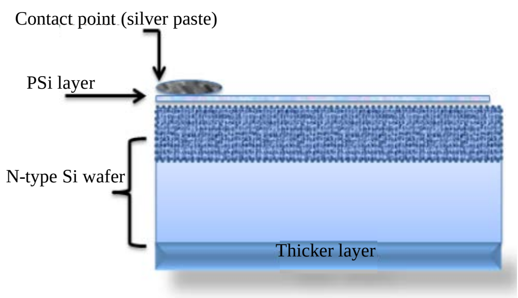

Fig. 2: PSi/c-Si sandwich structure

SL174", spectrophotometer, Xe LAMP power supply"). The electrical properties of nanostructure of photodetector were readed. All measurements were carried out in both "dark room and daylight illumination". The electrical measurement involved "Current-Voltage" (I-V), "Capacitance-Voltage (C-V) measurements" and spectral, responsivity was studied.

Silver paste is dropped at the surface of "PSi layer" while 1 μm aluminum layer are deposited on bottom side of silicon substrate by using "thermal evaporation equipment" as illustrated in Fig. 2 as ohmic contact.

RESULTS AND DISCUSSION

XRD measurements: To be sure the crystallographic perfection of the starting material with resulting porous structure, "XRD measurement" has shown in Fig. 3, X-ray diffraction of crystalline silicon and PSi samples (Wasnaa *et al*., 2015). A sharp peak of PSi at 5 mA/cm^2 "current density" shows the peak are split at $2\theta = 33°$ which indicates the single nature of silicon of prepared sample, from this figure it is clear that the intensity of PSi reduce as compare with C-Si and this attributed to decrease the crystallite size to nano-size and that agree with (Hadi *et al*., 2013).

SEM investigation: Figure 4 shows the SEM image of AgNPs, the magnification (9880 X), this figure exhibits that the particles are nearly spherical identical in form, the diameters of the crystalline particles was calculated by using the size described within the every micrograph. The

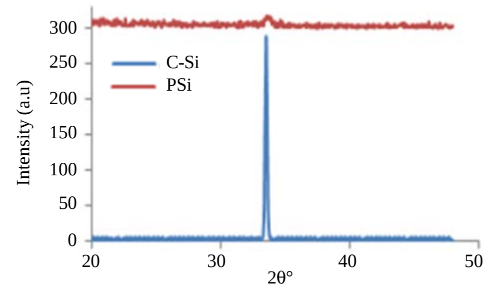

Fig. 3: "XRD" spectra of C-Si and PSi

typical diameter of the nanoparticles taken from the figure is 50 nm which accept as true with (Lorusso *et al*., 2009; Labrenz *et al*., 2000).

UV-Vis spectra: Figure 5 shows that the UV-Vis is spectra of AgNP colloidal. The Surface Plasmon Resonance band (SPR) was founded around 240 nm, so, the absorption = 0.360 at wavelength 191,00 nm.

FTIR measurements: Figure 6 illustrates the Fourier Transform Infrared (FT-IR) analysis which used to identify the chemical constituents in the Mid Infrared (MIR) region of 600-4000 cm^{-1}, FTIR measurement were carried out in order to identify the presence of different functional group of AgNP. Figure 6 shows distinct peak 1461, 1643, 2363 cm^{-1} (Rajeshkumar and Malarkodi, 2014; Mishra *et al*., 2013). The peak of carboxylic acids is present at 1643, 3681 and 3852 cm^{-1} (Vasquez-A *et al*., 2007; Labrenz *et al*., 2000; Devika *et al*., 2012).

Current-voltage characteristics: Figure 7 shows the I-V (forward and reverse bias in dark) measurement of PSi/c-Si/Al, the dark forward current of PSi photodetector (PSi/c-Si/Al) was (350 μA/cm^2) and increased to 720 μA/cm^2). After incorporation AgNPs (AgNPs/PSi/c-Si/Al). The increment in the dark forward current of AgNPs/PSi/c-Si/Al The increment in the dark forward current of AgNPs/PSi/c-Si/Al means that the sensitivity of the heterojunction increased when embedding AgNPs and this result agree with.

Figure 8 reveals that the illuminated reverse current of PSi/c-Si/Al photodetector was increased after incorporation AgNPs and this attributed to the action of AgNPs as a photogeneration layer which capture the photons and release the electrons and this result mean that the adding of AgNPs layer improving the electrical properties of PSi/c-Si/Al photodetector, this result agree with (Hadi *et al*., 2013).

Capacitance-Voltage measurements (C-V): Figure 9 shows value of V_{bi} for both PSi/c-Si-Al and Ag NPs/PSi/c-

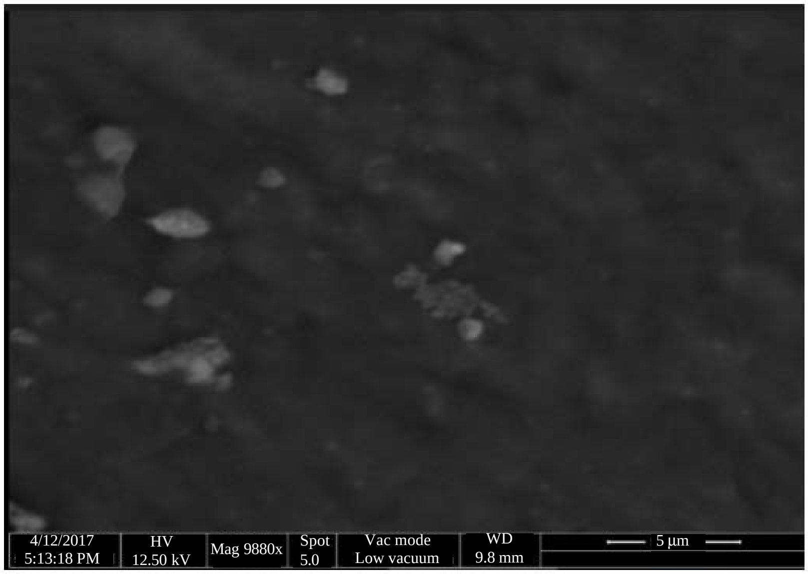

Fig. 4: SEM image of AgNP; Scan spectrum curve (University of Kufa)

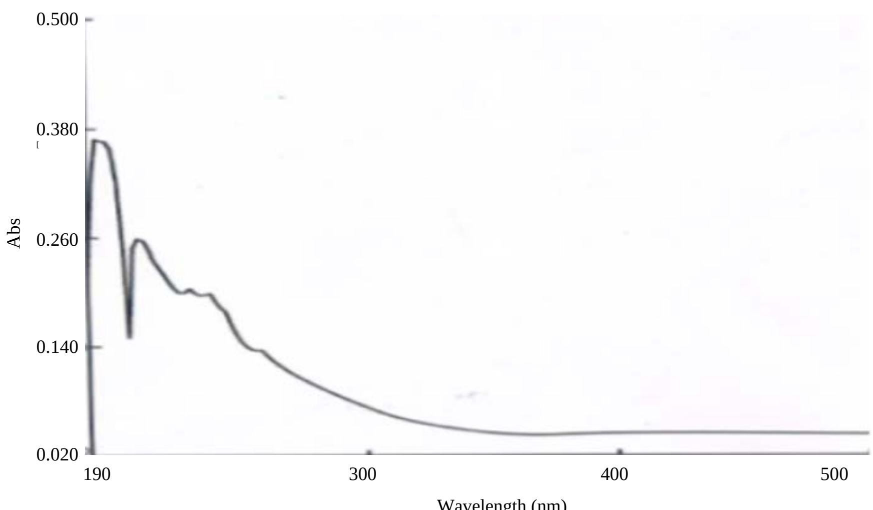

Fig. 5: UV-Vis spectra AgNP

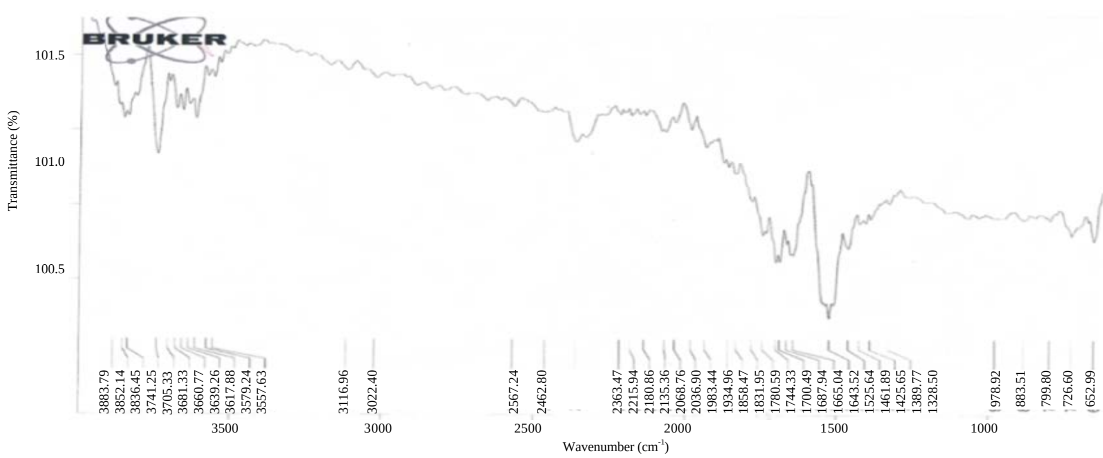

Fig. 6: FTIR spectra of AgNP samples

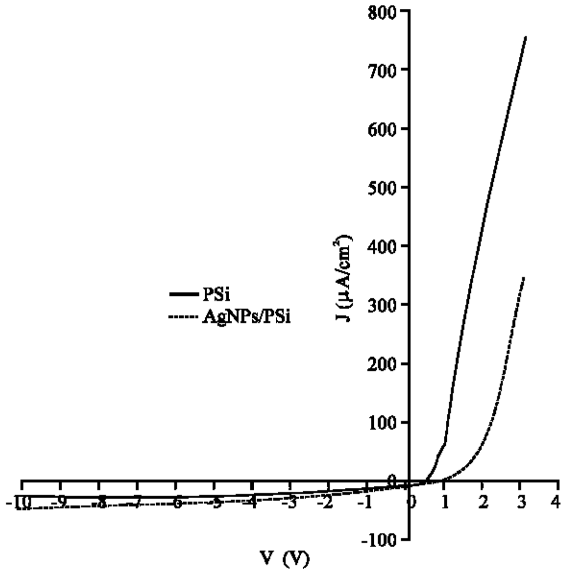

Fig. 7: Current-voltage of PSi photodetector before and after incorporation

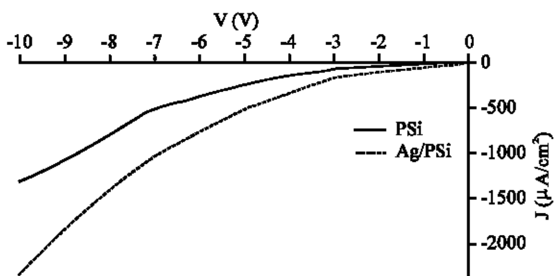

Fig. 8: Illuminated I-V characteristics of PSi-photodetector before and after incorporation AgNPs; p = 6424 (μW/cm²)

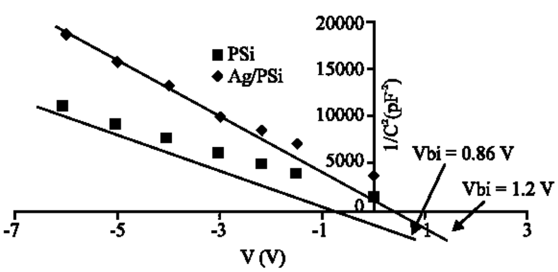

Fig. 9: $1/C^2$ versus bias voltage of PSi/c-Si/Al and AgNPs/PSi/c-Si/Al

Si-Al photodetectors. As stated previously, the V_{bi} value decreased after incorporation AgNPs from (≈ 1.2 V to ≈ 0.86 V) and this attributed to increase the barrier height.

Responsivity: Figure 10 shows the spectral responsivity of PSi photodetector before and after incorporation

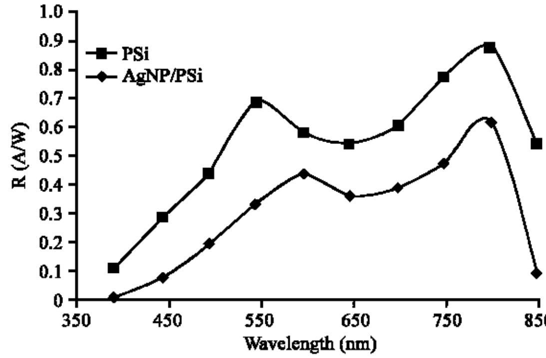

Fig. 10: Responsivity as function of wavelength of PSi/c-Si/Al and $AgNP_s$/PSi/c-Si/Al

AgNPs, the spectral responsivity increased after incorporation AgNPs to 0.87222 A/W and this ocuure because of the sensitivity of the prepared photodetector to the incident light and agree with the result of I-V measurment.

CONCLUSION

In this research, PSi/Si/Al photodetector was prepared by electrochemical etching technique of the boron doped silicon wafer. AgNPs were synthesized by the chemical reduction method and then the nanoparticles were incorporated on PSi layer by drop casting method to prepare AgNPs/PSi/Si/Al photodetector. The results obtained are as follows: XRD measurement of both crystalline silicon and PSi samples showed a peak at 2θ = 33° with splitting at the top of the peak of PSi which reveals that the structure converted from bulk to nanostructure. The SEM image of AgNPs with magnification (9880X), showed the mean diameter of nanoparticles 50 nm. The Surface Plasmon Resonance band (SPR) of AgNPs was founded around 240 nm with absorbance = 0.360 at 191 nm. FTIR measurement of AgNPs revealed the presence of different functional group at 1461, 1643, 2363 cm^{-1} while the peaks of carboxylic acids are present at at 1643, 3681 and 3852 cm^{-1}. The dark forward current of PSi/c-Si/Al photodetector was found to be (350 $\mu A/cm^2$) and increased to (720 $\mu A/cm^2$) after incorporation AgNPs which means that the sensitivity of the heterojunction increased after embedding process. The spectral responsivity increased after incorporation of AgNPs to 0.87222A/W it was observed that the electrical properties were improved after the addition of AgNPs, this gives a good indication that these nanoparticles act as a photogeneration layer that capture photons and release electrons, thus, improving the electrical properties of the PSi/c-Si/Al photodetector.

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