POROUS SILICON AS A CL_2 GAS SENSOR AT ROOM TEMPERATURE WITH DIFFERENT CURRENT DENSITIES.

Nilesh R Thakare[a],*Y.S.Sakhare[b]Roshani N. Bhagat[c], Manisha C. Golchha[d], Amol V.Nande[e] S.D.Wakde[f]

aAssociate Professor & Head, Department of Engg Physics, P.R. Pote College of Engineering and Management, Amravati, India.

b Late P.G.Arts and Science College Shrirpur (Jain) Dist Washim India

cAssistant Professor, Department of Engineering Physics, P.R. Pote College of Engineering and Management, Amravati, India.

dAssistant Professor, Department of Engineering Physics, P.R. Pote College of Engineering and Research, Amravati, India.

e Gurunanak College of Science, Ballarpur Dist Chandrapur India.

f Principal and ProfessorP.R. Pote College of Engineering and Management, Amravati, India.

A B S T R A C T

Porous silicon exhibits characteristics of interest for sensor device. Porous structure was formed on silicon wafer under various anodizing conditions in ethanol solution containing aqueous hydrofluoric acid. The observed photoluminescence at room temperature depends on the anodization time and different current densities. The porous structure formation has been confirmed by the photoluminescence as well as by scanning electron microscopic studies. In this paper we report the sensing characteristics of porous silicon at different current densities for chlorinegas.

Keywords: Porous Silicon, Photoluminescence, Current Densities, Sensing

1. Introduction

Porous silicon (P-Si) has recently been discussed as a novel material for chemical sensor and biosensor (Arakelyan V.M etal, 2007). Porous silicon has been proposed as a new material for solid state gas sensor. The sensing mechanism of gas sensor is based on change in the physical properties of P-Si when it is exposed to gas. P-Si based sensors have been proposed in the literature or several applications, such as for detection of the humidity level, amount of NO2 in ambient air and organic vapors concentration. The revealing of different gases like NOX, CH4, LPG, CO, H2, etc. has become extremely essential for the reason that of the unbroken increase in the environmental pollution (Jayachandranm M et al, 2001, Bhave T.M. et al, 1996).A number of hard works have been made in this trend over the whole humankind during the previous five decades. It essentially includes investigate for and growth of innovative resources that will give the capable outcome for the gas-sensing uniqueness (Moseley P.T. et al, 1987, Morrison S.R. et al, 1987, Sberveglieri G. et al, 1988). This study is based on discovery of the change in the electrical conductivity of P-Si when it is expose to chlorine gas. In present work, we probe the effect of anodization parameter on P-Si sensor.

2. Experimental

P-Si films were grown on the surface at p-type Si with a resistivity of 2 ohm cm. Ohmic contact was established a one of the surface of each sample.P-Si was obtained by anodic etching of silicon in an electrolyte containing 48% HF and 99.86% absolute ethyl alcohol in the proportion of 1:1 ratio using spec pure graphite as the cathode (Khoshnevis S et al, 2006). Anodization was carried out at current density between 30 to 70 mA/ cm^2 for constant time at 45 min. After anodization sample were put in HF for 1 or 2 min and dry in air. Scanning electron microscope (JEOL, Analytical Scanning Electron Microscope, and Model JSM-6360A) was used to obtain the microstructure of P-Si. All the photoluminescence characterizations were carried out using a PERKIN ELMER LS 55 spectrometer. X – Ray diffraction (XRD) pattern for all the samples was recorded using an X-ray diffractometer (model Bruker D8 Advance) using

Cu Ka radiation. The electrical resistively is measured by using two probe methods. The resistively measurements were carried out by using keithely multimeter (model-2000) at room temperature.

2.1. *Sensitivity for gas sensing*

Electrical resistivity dimensions were recorded for P-Si when they were subjected to environment of Chlorine gas. The proportion sensitivity is defined as,

$$S\ (\%) = \frac{Ro - Rg}{Ro} \times 100 \qquad (1)$$

Where *R*g is the resistance in presence of Chlorine gas and *R*o is the resistance in the air (in absence of Cl_2 gas).The variation over 60 s after exposure indicates that the sample is extremely sensitive to chlorine. Fig. 4 shows the variation of sensitivity for different concentrations in parts per million (ppm) of chlorine over first 60 s. Although the samples require long periods (of around few minutes) for reaching the saturation levels, it is suitable to take the measurements at fixed interval of time.

3. Result and Discussion

3.1. XRD Study

To reading the phase transparency of the resultant samples, the X-ray diffraction patterns were recorded in the 2θ range of 20–90^0. The bulk XRD patterns for all the samples of different Current density of P-Si show the presence of only one phase i.e. cubic (Fig.1).

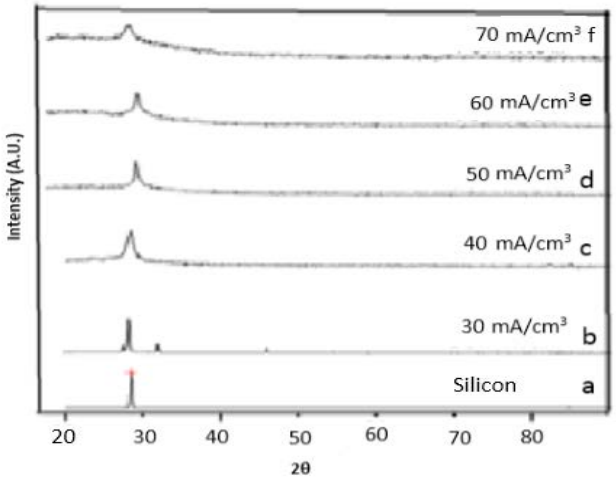

Fig.1. XRD Spectra of a) Crystalline silicon b)P-Si at current density 30mA/cm^2 c)40mA/cm^{2}d)50mA/cm^{2}e)60mA/cm^{2}f)70mA/cm^2.

3.2. Scanning Electron Microscopy Study

From the SEM photographs of all these samples (Fig.2), it is clear that the particle sizes are in the range of 0.5–1 μm. A random distribution and large agglomeration of particles are observed for the samples modified with Current densities. At 60mA/cm^2 and 70mA/cm^2 the particle distribution is more uniform with less agglomeration nature. This may have some correlation with the higher sensing performance value for the sample having 60mA/cm^2 and 70mA/cm^2 since the microstructure is more uniform and less agglomerated.

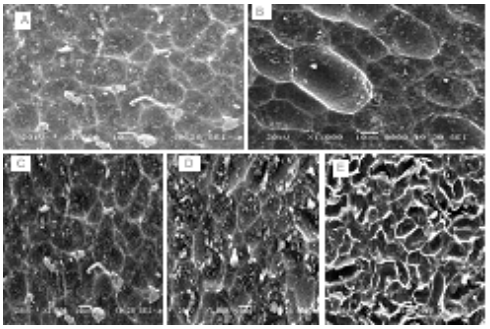

Fig: 2- SEM Image of all porous silicon at different current density A) P-Si at current density 30mA/cm^2 B) 40mA/cm^2 C)50mA/cm^{2}D) 60mA/cm^2 E) 70mA/cm^2.

3.3. Photoluminescence Study

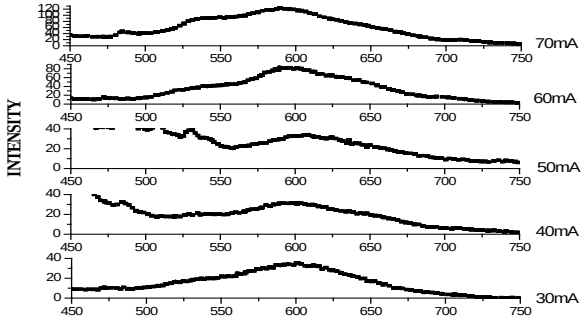

Fig.3-Photoluminescence Spectra at different current densities a) P-Si at current density 30mA/cm^{2}b) 40mA/cm2 c) 50mA/cm^2 d) 60mA/cm^{2}e) 70mA/cm^2

P-Si structures have been reported to luminescent efficiently in the near infrared (IR) in the whole visible range and in the near ultraviolet (UV). The absorption coefficient has been measured in P-Si by photoluminescence. Transmission spectra

are shifted towards higher energy compared to bulk Si with a shift which increases with increasing porosity. This observation is consistent with quantum confinement model. P-Si is a two-fold promising material for sensor applications. On one side, its electrical and optical properties strongly depend on the environment, because of its large specific area. Useful sensing parameters include, for example, the electrical conductivity and photoluminescence. Most sensing parameters can effectively work at room temperature. From photoluminescence spectral range blue-red with peak wavelength 400-800 nm which is related to slow (S) band. The S band can be tuned from close to the bulk silicon band gap through the whole visible range. The large spectral width comes from inhomogeneous broadening and vibronic coupling of the radiative transitions. The S -band efficiency is not proportional to the inner surface area, porosity has to be exceeded to achieve an efficient luminescence. Post-anodization chemical etching in HF, corresponding to a porosity increase, results in a strong rise in PL efficiency and a blue shift of the visible band (Gaburro Z et al, Sakhare Y.S. et al, 2014, Tank C.M. et al, 2011).

3.4. Sensor study

Table 1shows the average particle size data for all samples estimated by XRD and SEM measurements. The sample with $60mA/cm^2$&$70mA/cm^2$ showed the smallest particle size and the highest sensing performance for Cl_2 gas. This may be due to the smallest particle size as it offers higher surface area and enhances the sensitivity very effectively. The surface area plays an important role. Higher surface area leads to the higher concentration of chemisorbed air species which further increases the change in the conductance during the adsorption of reducing gases

Table1. Porous silicon sensesitivity for Cl_2 gas at different current densities (mA/cm^2) and time (min.)

.PL peak band gap and intensity values observed at different current densities

Current Density at mA/cm^2	Time (min)	PL wavelength (nm)	PL Peak Band Gap(eV)	PL Peak Intensity (a.u.)
30	45	590	2.10	36.544
40	45	595	2.08	32.509
50	45	600	2.06	35.397
60	45	610	2.03	84.119
70	45	620	2.00	126.33

Finally, this gives the higher sensitivity values to the semiconducting material. Variation in the resistivity, with changes in the ambient conditions was used as the parameter for determining the sensitivity of the conducting polymer based sensor. Planar electrical resistivity was monitored across the two parallel strip electrodes separated by 6 mm. The resistivity of the sample was seen to increase with exposure to chlorine gas. Sensitivity is determined from the modulus of change in the value of resistance as shown in Eq. (1). Variation in the resistance between the two electrodes was measured as a function of time after introducing the gas, in the 20 l enclosure, which was kept in a normal ambient pressure and temperature. This parameter was useful for understanding the time response for various levels of injection for chlorine gas, ranging from 100 to 500 ppm, in terms of sensitivities of the samples as shown in Fig. 4. As expected the sensitivity increases with the concentration of gas. The resistance of the sensor is seen to increase rapidly up to 60 s, which is followed by slow saturation. The percentage sensitivity was therefore determined from the value of resistance recorded at 60 s, for each ppm level of gas studied. Variation in the sensitivity as a function of different ppm levels at 60 s for chlorine gas is plotted in Fig. 4. This plot shows almost linear response of the sensor for

the concentrations of chlorine gas varying from 100 to 500 ppm at 60 s. The recovery of the sample in the ambient condition (25^0C) was seen to be quite slow (in h). Looking at this constraint it is felt that such a sample can serve the purpose of efficient sensing materials if it is employed in one-time sensors or for threshold detectors. However, recovery time was reduced from 24 h to 5 s when the sample was heated to about 45–50^0C. Moreover, the resistance of the sensor returned to its base value after the heating cycle. In such situation (elevated temperatures), the sensor need not be called as one-time sensor and can be repeatedly used for number of cycle.

4. Conclusion

We have successfully prepared porous structure on silicon wafers under various anodization conditions and different current densities. Photoluminescence at room temperature was observed to be maximum for current density of 70mA/cm^2 and anodizing time of 45 minutes. XRD studies reveal that an optimum pore size is found at this anodizing condition and the crystal structure is cubic. The P-Si sample show good sensitivity to Cl_2 gas at different current density and also the sensitivity.

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