Extended Abstracts of the 1993 International Conference on Solid State Devices and Materials, Makuhari, 1993, pp. 639-341 **PC-3-1**

Visible Light from the Anodic Oxidated Polycrystal Silicon

Zhou Yongdong, Jin Yixin, Ning Yongqiang, Zhang Baoling, Zhou Tiangming
Changchun Institute of Physics,
Chinese Academy of Sciences.
No,1 Yan-an Road, Changchun 130021, China.

The homogeneous visible light emitting samples were fabricated on the surface of unpolished polycrystalline silicon wafer using the standard anodic oxidation method of porous silicon fabrication. The photoluminescence (PL)spectrum of the sample was measured to be the characteristic one of the porous silicon. The surface morphology and the cross-section microstructure of the sample were studied using the scanning electron microscopy (SEM) and compared with those of the porous silicon. The SEM study shows that the sample's microstructure is different from that of the porous silicon. The experiments suggest that the porous layer has no effect to the visible luminescence.

Recently, a wide attention has been paid to the phenomenon of the efficient visible luminescence from the porous silicon in the solid-state physics, material research and device technology communities because of the possibility of silicon-based optoelectronics. The current-induced light emitting device of porous silicon[1] and the highly sensitive photodetector of porous silicon[2] were fabricated in some laboratories. But the origin of the visible light emitting from the porous silicon is still in researching. The main current points of view are: 1, two-dimensional quantum confinement effects in the free-standing silicon quantum wires (some consider the quantum dots)[3]; 2,siloxene and its derivatives are produced during anodization[4]; 3, the luminescence originates from the amorphous phase[5)6)]; 4,the luminescence is related to stresses in the porous material[7]. There are still some other opinions, and F.Buda et al. even calculated the electronic states based on the opinion of Canham[8]. We have reported the experiments of obtaining the fluorescent powder from the porous silicon and the measurements of the photoluminescence, scanning electron microscopy, X-ray photoelectron spectroscopy (XPS). The experiments suggest that the visible luminescence of the porous silicon is from the fluorescent powder-like material[9].

Recently, the visible light emitting samples were achieved on the unpolised surface of polycrystalline silicon wafer using the standard anodic oxidation method of porous silicon fabrication. Here, we report the results of PL and SEM measurements to the samples.

Two kinds of silicon wafers were used in the experiments. Polished single crystal silicon wafers used here are (100) n-type (24 ~ 3.6 Ω · cm in resistivity). Polycrystalline silicon wafers are p-type (several Ω · cm in resistivity) with both the surfaces unpolished. Prior to anodization, the wafers were cleaned and an ohmic contact was formed on the back side by evaporating a thin film of Al. Anodization was carried out in HF (49wt%)-C_2H_5OH solution (1:1 by volume) at a constant current density of 20mA/cm^2 or 80mA/cm^2 using Pt as a counter-electrode. During anodization the sample was illuminated uniformly by a infra-red lamp. After

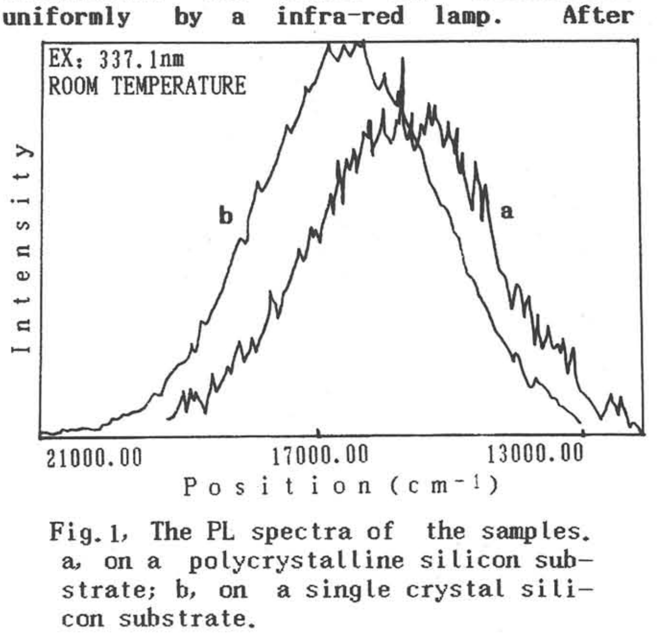

Fig. 1, The PL spectra of the samples. a, on a polycrystalline silicon substrate; b, on a single crystal silicon substrate.

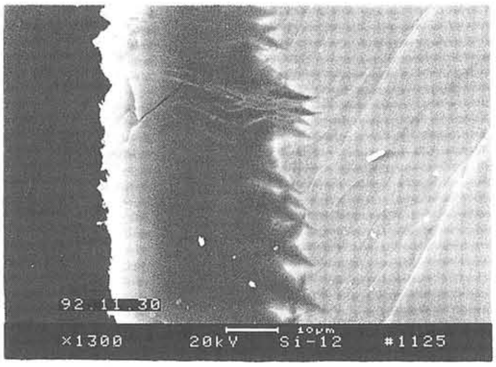

Fig. 2a

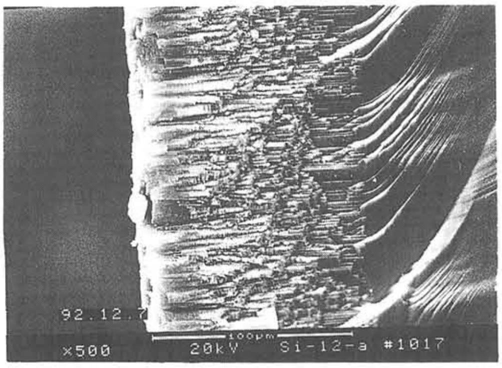

Fig. 2b

Fig. 2, SEM photographes of the cross section microstructure. a, The cross section of sample A, reveals two different layers: surface layer and polycrystalline silicon substrate. b, The cross section of sample B, reveals three different layers: surface layer, porous layer and crystalline silicon substrate.

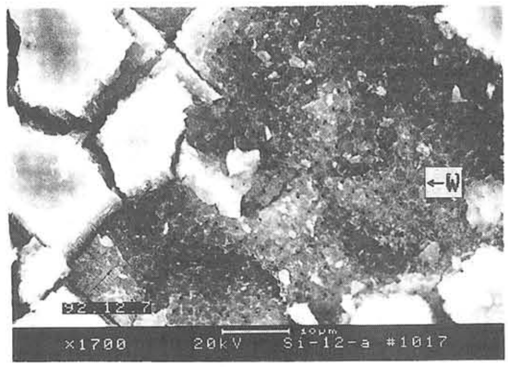

Fig. 3a

Fig. 3b

Fig. 3, SEM photographes of the surface morphology. a, The surface morphology of sample B (W indicate the large number of micropores of the porous layer). b, The surface morphology of sample A (X indicate many dots correlated to the rough situation of the interface).

anodization, the wafers were rinsed in pure alcohol and then blown dry in the air.

During the PL measurements, the samples were excited by a N_2 laser (wavelength=337. 1nm) of a pulse width of about 10ns and the luminescence was detected by using a Spex-1403 type monochromator, a R-928 type photomultiplier and a Parc-162 type box-car integrator. All the data were inputted into a computer and the PL spectra were drawn out. All the measurements were carried out at room temperature.

The micrographes of the surface morphologies and the cross-section microstructures of the samples were obtained by using a 1000B type SEM.

Fig.1 shows the PL spectra of the samples. Fig. 1a is the PL spectrum of the sample fabricated on the surface of p-type polycrystalline silicon wafer (sample A) . The spectrum peaks at 15560cm^{-1} (642nm) with the FWHM of 2800cm^{-1} (126nm). Fig.1b is the PL spectrum of the porous silicon fabricated on the surface of n-type single crystal silicon wafer (sample B). The spectrum peaks at 16400cm^{-1} (609nm) with the FWHM of 3080cm^{-1} (115nm). The peak position of the spectrum 1a shifts toward the long-wavelength direction by about 33nm compared with the spectrum 1b. But the spectrum 1a is still a typical spectrum of porous silicon (PL spectra of p-PS appear in the long-wavelength region more frequently than those of n-PS[10]).

Fig. 2 shows the SEM photographes of the cross-section microstructures. Fig. 2a reveals the cross-section microstructure of the sample A. There are two different layers :surface layer and polycrystalline silicon substrate. The porous layer haven't been formed. The interface between the two layers is not flat. Fig. 2b reveals the cross-section microstructure of the sample B. The sample have three layers: surface layer, porous layer and crystalline silicon substrate. The micropores about 100μm in length and 1 μm in diameter extend perpendicularly to the crystalline silicon substrate.

Fig. 3 shows the SEM photographes of the surface morphology of samples. Fig.3a is the photograph of the sample B. There are no micropores appearing on the surface layer (similar to that in literature[5)8)]). But there are a large number of micropores at the place (indicated by the arrow W) where the surface layer has been moved off. Fig.3b is the photograph of the sample A. The surface layer is similar to that on sample B (shown in Fig.3a). But there are only many dots on the polycrystalline silicon substrate appearing at the place (indicated by the arrow X) where the surface layer has been moved off. The dots may be correlated to the rough situation of the interface shown in Fig.2a.

We have also obtained the visible light emitting porous silicon fabricated on the unpolished surface of the n-type single crystal silicon wafer (sample C)[9)]. The PL spectra of the sample C and the fluorescent powder show the same peak position,the same shape and the same FWHM as that of the spectrum in Fig.1b. Considering the spectra of Fig. 1, it is obvious that the visible light emitting samples can be fabricated on various kinds of silicon wafers, and even on unpolished polycrystalline silicon wafer. The luminescence from the anodically oxidized silicon is from the powder-like material on its surface. The experiments of XPS prove that the composition of the fluorescent powder in the surface of porous silicon is complicated[9)].

The SEM photographes of Fig.2 suggest that the porous silicon sample can be divided into three layers: surface layer, porous layer and crystalline silicon substrate. It would be still able to emit the same visible fluorescence without the porous layer. The efficient visible light from the porous silicon is from the fluorescent powder in the surface layer of the samples and the porous layers have no effect on the PL process of the porous silicon.

In conclusion, the visible light emitting samples were fabricated on the unpolised surface of the polycrystalline silicon wafer using the standard anodic oxidation method of porous silicon fabrication. The microstucture of the sample is different from the porous silicon. But the sample can emit the typical visible light of the porous silicon without the existence of porous layer. The experiments suggest that the visible light from the porous silicon is from the powder-like material in the surface layer of the porous silicon and the porous layer may have no effect on the PL process.

Acknowlegment:

The authors thank professor Shihua Huang for the help on the PL measurements and the helpful discussion.

Refferences:

1) Axel Richter, P.Steiner, F.Kozlowski and W. Lang, IEEE ELECTRON DEVICE LETTERS, 12(1991) 691.
2) J. P. Zheng, K. L. Jiao, W. P. Shen, W.A.Anderson and H.S.Kwok,Appl.Phys.Lett. 61(1992) 459.
3) L.T.Canham, Appl. Phys. Lett. 57(1990) 1046.
4) M. S. Brandt, H.D.Fuchs, M. Stutzmann, J. Weber and M. Cardona, Solid State Communications, 81(1992) 307.
5) N.Noguchi,I.Suemune, M.Yamanishi, G.C.Hua and N.Otsuka, Jpn.J.Appl.Phys. 31(1992) L490.
6) T. Matsumoto, M.Daimon, T. Futagi and H.Mimura, Jpn.J.Appl.Phys. 31(1992) L619.
7) L.E.Friedersdorf, P.C.Searson,S.M.Prokes, O. J. Glembocki and J. M. Macaulay, Appl.Phys.Lett. 60(1992) 2285.
8) F.Buda, J.Kohanoff and M. Parrinello, Physical Review Letters, 69(1992) 1272.
9) Z.Yongdong, J.Yixin, N. Yongqiang and Y. Jinshan, MRS'93 Spring conference, San Francisco, April 1993, B5.11.
10) N.Koshida and H.Koyama,OPTOELECTRONICS-Devices and Technologies, 7(1992) 103.