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SYNCHROTRON STUDIES OF HP-HT TREATED SILICON IMPLANTED WITH 42 MeV NITROGEN IONS

K. Wieteska[1], W. Wierzchowski[2*], D. Żymierska[3], J. Auleytner[3], W. Graeff[4], A. Misiuk[5], and J. Choiński[6]

[1]*Institute of Atomic Energy, PL-05-400 Świerk, Poland*
[2]*Institute of Electronic Materials Technology, ul. Wólczyńska 133, PL 01-919Warsaw, Poland*
[3]*Institute of Physics of PAS, Al. Lotników 32/46, PL-02-668 Warsaw, Poland*
[4]*HASYLAB at DESY, Notke str. 85, D-22603 Hamburg, Germany*
[5]*Institute of Electron Technology, Al. Lotników 32/46, PL-02-668 Warsaw, Poland*
[6]*Heavy Ion Laboratory of the University of Warsaw, ul. Pasteura 5a, PL-02-093 Warsaw, Poland*

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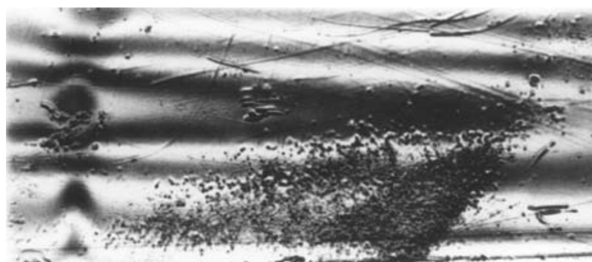
) e-mail: wierzc_w@sp.itme.edu.pl

The aim of present research is an attempt to explore physical mechanisms affecting transformations of nitrogen-implanted silicon crystals if annealed under enhanced pressure. The previously reported results concerned pressure-treated Si:N prepared by nitrogen implantation with a 2×10^{16} cm^{-2} dose of total energy up to 150 keV [1-3].

The dislocation-free silicon single crystal was grown by the Czochralski method. The (100)-oriented samples were implanted with a 5×10^{14} ions·cm^{-2} dose of N ions, with the total energy 42 MeV (corresponding to 3 MeV/nucleon) of the ion beam, from a *K=160 Cyclotron* at the Heavy Ion Laboratory of the Warsaw University. The beam current was equal to 50 enA. The implantation was performed at room temperature by a uniformly defocused beam. The calculated mean range of 42 MeV N ions in silicon is equal to 37 μm. The buried layer is 2 μm thick. Some investigation of Si implanted with high energy ions were described in Refs. [4-6].

a.

c.



b.

d.

Figure 1. Monochromatic beam topographs from: (a) and (b) - sample 1 taken for different angular positions, (c) - sample 2, and (d) - sample 4.

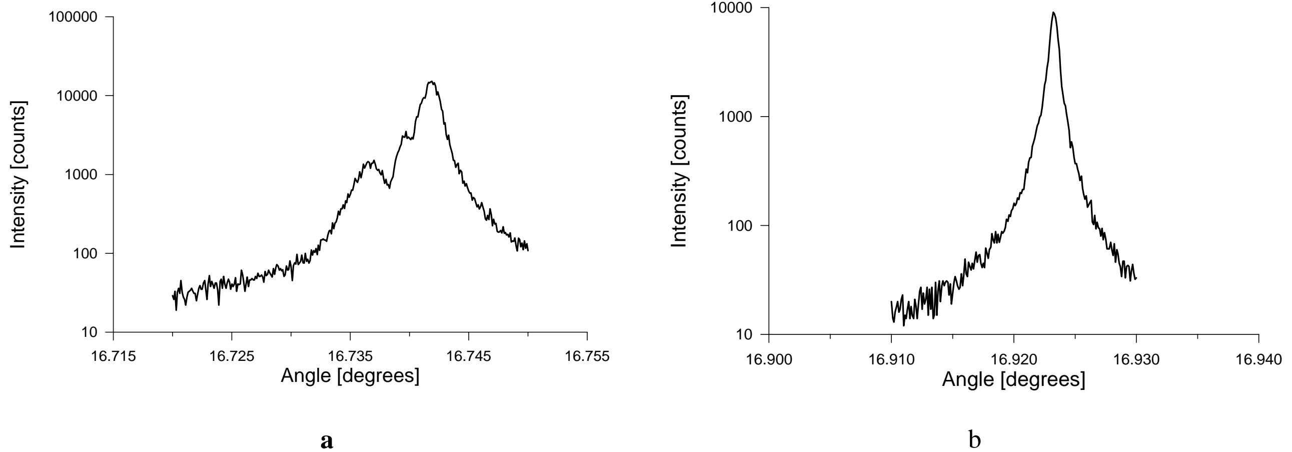


Figure 2. Rocking curves recorded in 511 asymmetric reflection of 0.115 nm radiation with small point probe beam 50×100 μm^2 from samples 1 (a) and 3 (b).

Next, the samples were subjected to annealing under enhanced hydrostatic pressure (HP-HT treatment) in inert gas (Ar) atmosphere at up to 1000°C (see Ref. [7] for details of the method). Experimental conditions applied for studied samples are given in Table 1. The HP-HT treatment is known to affect strongly the profiles of implanted ions in silicon as well as to influence the creation of clusters/precipitates containing the implanted species, *e.g*. oxygen [8].

The samples were investigated at the monochromatic-beam station E-2 at HASYLAB [511 asymmetric reflection of 0.115 nm radiation] by recording local rocking curves using the beam limited to the 50×100 μm^2 and by taking monochromatic beam topographs at various angular positions with 2×8 mm^2 beam.

Table 1. Conditions of HP–HT treatment.

Sample	HT [ºC]	HP [kbar]	Duration [h]
1	325	11.0	0.75
2	1000	11.46	1.0
3	450	10.6	10.0
4	650	11.0	10.0

It was found that only the treatment performed during 0.75 h at 325ºC (sample 1) did not remove the strain caused by ion implantation. In this case we observed the interference maxima at low angle side of the main peak (Fig. 2a), characteristic for the strain maximum located at certain depth under the surface [9, 10]. The topographs, presented in Figures 1a and 1b, taken for this sample revealed some interference fringes, forming the pattern corresponding to the irregularities of the ion dose, and changing for different angular setting. For the treatment performed at higher temperatures (samples 2, 3 and 4) we observed a single maximum only with insignificant amount of diffuse scattering (Fig. 2b). We observed some contrast at the topographs shown in Figures 1c and 1d, which may be attributed to some initial stages of the exfoliation. Almost complete exfoliation was observed in the case of the treatment performed at the temperature 650°C for 11 hours (Fig. 1d).

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