Semiconductor devices using the spin of electrons have attracted much attention because of their expected application in spintronics. However, the key to the spintronic’s success is availability of suitable materials for device manufacturing. Diluted magnetic semiconductors (DMS) have been shown to be the best materials for such purpose. Among them, Mn⁺ implanted Si seems to be very promising. It has been shown that it is possible to achieve above room temperature ferromagnetism in such samples [1]. What's more, the potential new spintronic devices based on the Si matrix would be easy to integrate with the existing technologies.

The investigated samples were prepared by Mn⁺ implantation into Cz-Si (grown by Czochralski method) and into Fz-Si (grown by floating zone method) wafers. The energy of Mn⁺ ions was of 160 keV and a dose of 1x10¹⁶ cm⁻². Temperature of the Si substrate was kept at 340 K in case of Cz-Si and at 610 K for Fz-Si. After the implantation, each wafer was divided into several pieces and annealed separately. Here, we present the results for the samples annealed at 275°C for 4.5 hours under the atmospheric pressure (Fz-275-1b, Cz-275-1b) as well as the samples annealed at 450°C for 10 hours under the atmospheric pressure (Fz-450-1b, Cz-450-1kb) and under the pressure of 11 kbar (Fz-450-11kb, Cz-450-11kb).

The EXAFS spectra at the Mn K-edge were measured at the E4 station using a seven element silicon fluorescence detector. The samples were cooled to liquid nitrogen temperature in order to minimize thermal disorder.

The Artemis and Athena programs [2], using IFEFFIT data analysis package, were applied in the analysis of the EXAFS data. Analysis of each spectrum was carried out in the same manner in order to enable the proper comparison between them. The passive electron reduction factor (S₀²) was fixed to the arbitrary chosen value equal to 0.9. This made possible to find the relative changes in the coordination number (N) for the investigated samples.

Figure 1 shows the Fourier Transformed EXAFS oscillations for the considered samples. In each case, first shell was fitted using a single Si path and with introducing third cumulant in order to account for the asymmetry in the distribution of the neighboring atoms. In case of the Cz-Si samples annealed at 450°C, where second shells are visible, one Mn path had to be added. The results are gathered in the table below.
As can be seen, the number of the silicon atoms in the first shell is the same within the uncertainty limits. However, their distances differ from sample to sample. The same can be said about the number and the distances of the manganese atoms in the second shell for two Cz-450 samples.

We can conclude that the formation of second shell in the samples annealed up to 450°C depends on the method of the sample growth. The samples grown by Czochralski method start to form the Mn<sub>x</sub>Si<sub>y</sub> inclusions at 450°C. In case of the samples grown by Floating zone method this temperature seems to be too low. However, it is known from the previous studies that also in this kind of samples, the Mn atoms have tendency to gather together forming Mn<sub>x</sub>Si<sub>y</sub> compounds [3].

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References