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Numerous studies have been made in order to localize the Co impurity atoms in the silicon lattice [1/18]. First, Norem and Wertheim [1/1] suggested for Co diffused silicon samples that their Mössbauer spectrum could be analysed in terms of substitutionally and interstitially located Co atoms. Other authors offered different explanations, e.g. segregated Co metallic clusters. We performed Mössbauer studies on various Co intermetallic compounds of Si doped with $^{57}$Co, and on $^{57}$Co implanted Si samples subsequently annealed at 1000°C.

Our aim was to get information whether the intermetallic phases do appear in diffused CoSi and annealed $^{57}$CoSi implanted samples. CoSi, CoSi$_2$, CoSi$_3$ intermetallic compounds were prepared by using the method described in ref [9/]. The samples were annealed at 900°C to ensure the maximum phase homogeneity. $^{57}$Co activity was diffused into the lattices in hydrogen atmosphere and in vacuo, but no difference in the spectra could be observed by using either hydrogen or vacuum. A single line absorber of K$_4$Fe(CN)$_6$·3H$_2$O with 0.2 mg/cm$^2$ $^{57}$Fe was used. The $\delta$ values are given relative to metallic iron.

The Mössbauer spectra are shown in Fig. 1 and 2. All spectra measured are very similar except CoSi. The shape of the spectrum of the latter compound was found to be the same as it was published in ref. [10/]. The isomer shift ($\delta$) and quadrupole splitting ($\Delta E$) values are $-0.33$ (1) mm/s and $0.17$ (2) mm/s respectively. These values are very near to what was found in ref. [10/] ($\delta = -0.29$ mm/s, $\Delta E = 0.20$ mm/s). The spectra of CoSi$_2$ and CoSi$_3$ are very similar to each other in H = 0 and in H = 80 kOe (H // $\gamma$) as well. The spectra in H = 0 could be fitted by assuming two single lines and also with one single line + a quadrupole doublet. The values obtained: $\delta_1 = -0.48$ (2) mm/s, $\delta_2 = 0.02$ (1) mm/s with two single lines and $\delta_3 = -0.30$ (1) mm/s, $\delta_4 = 0.03$ (2) and $\Delta E = 0.40$ (2) mm/s with one singlet and one doublet. The spectra measured in H = 80 kOe external field could be fit-

![Figure 1: Measurements in zero external field.](image-url)
Figure 2: Measurements in 80 kOe external field.

...ted well by two magnetically split spectra with $\Delta E = 0$. The fit gave $H_1 = 70$ kG and $H_2 = 75$ kG values. These values are less than that of the applied field probably because of a small magnetic moment on the Fe atoms in these lattices similarly as it was found in CoSi$_2$ /10/. The fit with $\Delta E \neq 0$ would result in a larger ($\sim 15$ kG) difference in $H_1$ an $H_2$. The structure of CoSi$_2$ is cubic of type $C_{I}$ /11/. Therefore, no electric field gradient is expected for substitutional Co sites. We attribute the line with $\delta = 0.02$ mm/s to this site (relative intensity is 70 %). The origin of the line with $\delta = -0.48$ mm/s cannot be known for sure. It would be tempting to assign this line to CoSi existing as an impurity phase in CoSi$_2$ and CoSi$_3$ but an X-ray diffraction study did not support this idea. Furthermore, the spectra in $H = 80$ kOe could not be fitted well with the $\delta$ and $H$ values found for CoSi + a Zeman split spectrum with $\Delta E = 0$. Therefore we believe this line belongs to a site of high point symmetry. The structure of CoSi$_3$ has not been determined yet up to our notice, but because of the similar spectrum obtained suggest that the structure around the Co atoms is similar as it is in CoSi$_2$.

The spectra of Co diffused in Si and Co implanted in Si and subsequently annealed at 1000°C are very similar to the spectra of CoSi$_2$ and CoSi$_3$. The values at $H = 0$ are the same but in $H \neq 0$ the spectra are only qualitatively similar. In the latter case this is not surprising if we attribute the spectra to Co sites in segregated clusters where the sizes of clusters could bear the responsibility for these small discrepancies. Also it has to be noted that contrary to ref. /7/ no any other lines appears in the spectra which could be attributed to Fe in metallic clusters.

In summary, we conclude that the Co atoms diffused in Si and implanted in Si and subsequently annealed form segregated intermetallic phases with Si, similarly to Fe implanted and subsequently annealed Si samples /13~/14/.

References
/9/ Náray Szabó, I., Szerettei Kálmán, Akadémiai Kiadó, Budapest.