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Mössbauer study of ^{119}Sn in ^{119}In* implanted 3C-SiC

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Abstract ^{119}Sn Mössbauer measurements have been made on a 3C-SiC single crystal implanted with 60 keV precursor radioactive ^{119}In* ions at ISOLDE/CERN. Spectra collected at sample temperatures of 300–670 K have been analysed in terms of two single lines and a quadrupole split doublet, which based on their isomer shifts are assigned respectively to Sn ions located on substitutional Si sites (Sn_{Si}) and interstitial sites (Sn_I) and in defect complexes near substitutional sites. The substitutional Sn_{Si} fraction increases from 25% at room temperature to 60% at 680 K.

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1 Introduction

The physical properties of SiC such as its wide band gap and its radiation hardness is expected to lead to enhanced performance in a wide variety of applications, in particular in conditions where conventional silicon-based devices cannot function. However planar surface devices are difficult to realize by doping during epitaxial growth [1]. As an alternative, ion implantation offers accurate control of both the dopant profile and depth, thus making possible the fabrication of planar SiC devices with tailored doped areas. Ion implantation of Sb^+ ions into Si, however, was found to produce considerable displacement of the lattice atoms, which increased with implantation and resulted in the formation of an amorphised layer at a dose of $\sim 10^{14}$ /cm^2 [2].

The present ^{119}Sn Mössbauer spectroscopy (MS) measurements were therefore aimed at investigating the lattice location of the implanted ions and the defect complexes they form in SiC implanted with extremely low dose ^{119}In* ions. In earlier ^{119}Sn-Mössbauer studies on SiC [3–5], the structure of the defects and their annealing characteristics have been investigated on samples implanted with radioactive precursor ^{119}In$^+$, ^{119m}Sn$^+$, ^{119}Sb$^+$ and ^{119m}Te$^+$, and were observed to display strong dependence on the chemical nature of the implanted impurities. The investigations on ^{119}In* implanted SiC, however, were conducted only with implantation at 300 K, and instrumental problems yielded spectra with rather broad lines. The present measurements are an extension of the MS study on ^{119}In* implanted SiC.

2 Experimental details

Radioactive ^{119}In* ions, produced at ISOLDE/CERN by 1.4 GeV proton-induced fission in a UC_2 target and elemental selective laser ionization, were implanted with 60 keV energy at an angle of 30° into a 3C-SiC single crystal sample held at 300–670 K in an implantation chamber. The maximum implantation fluence was 10^{12} ions/cm^2. ^{119}In* ($t_{1/2} = 140$ s) decays to the ^{119}Sn 780 keV excited state, which in turn decays through the 23.8 keV Mössbauer state. Mössbauer emission spectra were collected with a resonance detector, equipped with a ^{119}Sn-enriched $CaSnO_3$ electrode, mounted outside the chamber on a conventional constant-acceleration drive system at 90° to the beam direction.

3 Results and discussion

Mössbauer spectra, measured at the temperatures indicated, are shown in Fig. 1. They have been analysed in a simultaneous fitting procedure with two single lines, S1 and S2, and a quadrupole split doublet component, D1, with Voigt profiles of Lorentzian line-width (FWHM) $\Gamma = 0.67$ mm/s and Gaussian broadening σ. The temperature dependence of the line positions were assumed to follow a second order

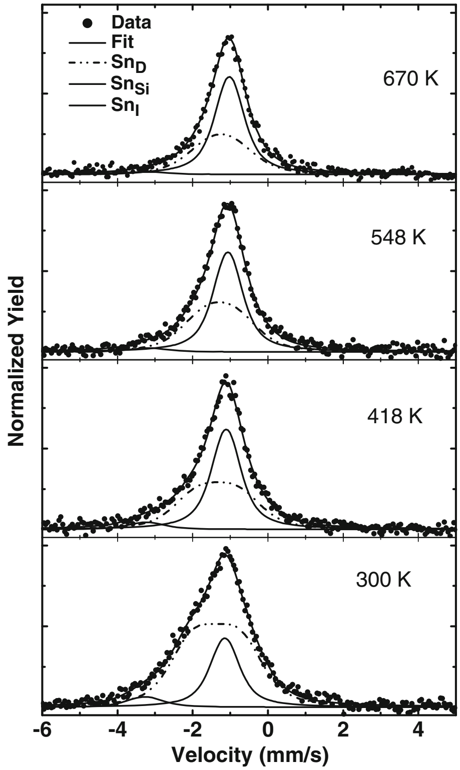

Fig. 1 Mössbauer spectra of ^{119}Sn in 3C-SiC observed at the temperatures indicated

Table 1 Isomer shift (δ), quadrupole splitting (ΔE_Q) and Gaussian broadening (σ) of the spectral components determined from the spectra shown in Fig. 1

	D1(Sn_D)	S1(Sn_{Si})	S2(Sn_i)
δ (mm/s)	1.49(2)	1.27(3)	3.40(5)
ΔE_Q (mm/s)	1.18(5)		
σ (mm/s)	0.47	0.21	0.32

Doppler shift; the quadrupole splitting of the doublet was set as a free parameter, but, within errors, was found to follow a $T^{3/2}$ dependence. The line broadening and the hyperfine parameters extracted from the fits to the spectra are listed in Table 1, where the isomer shifts are given relative to $Ca^{119}SnO_3$.

For assignment of the spectral components in terms the lattice location of the Sn ions, we compare our results with those summarised in [4]. The spectra of all the SiC samples implanted with the different pre-cursor isotopes shows a dominant line with isomer shift $< \delta >= 1.30(2)$ mm/s, and which combined channelling and Mössbauer studies [6] show to be due to Sn ions in Si sites. The isomer shift value is in excellent agreement with our result for line S1. In addition, the parameters of the quadrupole split component D1 determined in the present study are consistent with those of line “3” in ref. [3] where it is attributed to ^{119}Sn atoms on Si sites but in a defect complex with a neighbouring vacancy.

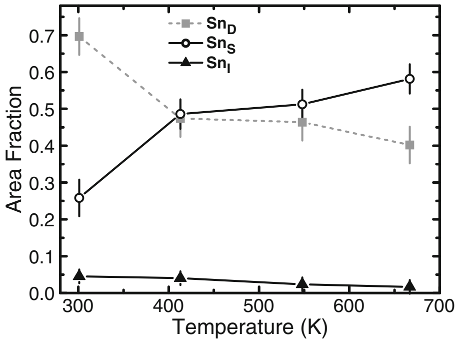

Fig. 2 Temperature dependence of area fractions of the spectral components

The isomer shift of the weak line S2 is quite large (3.4(1) mm/s), but within the range (3–4 mm/s) reported for interstitial type Sn defects in group IV semiconductors [6]. Accordingly, components S1, S2 and D1 are assigned respectively to Sn ions at substitutional Si sites (Sn_{Si}), interstitial sites (Sn_I) and in defect complexes around substitutionally located Sn (Sn_D). They are referred to in Fig. 1 by their assigned identities.

The temperature dependence of the area fractions of the spectral components is presented in Fig. 2. Strong annealing of lattice defect is evident in the temperature range 300–420 K, while there is tendency of a second stage above 550 K with the Sn_{Si} fraction increasing to 60% at 670 K.

4 Conclusions

We have conducted ^{119}Sn Mössbauer measurements on a 3C-SiC single crystal sample following the implantation of ^{119}In* at temperatures between 300 K and 670 K. The spectra have been decomposed into two single lines and a quadrupole split doublet which, after comparison with earlier MS and channelling studies, are assigned to Sn ions at substitutional Si sites (Sn_{Si}), interstitial sites (Sn_I), and in defect complexes around substitutionally located Sn (Sn_D).

There is clear evidence of an annealing stage of lattice damage in the temperature range 300–420 K; above 420 K the damage component continues to decrease with suggestion of a second annealing stage above 550 K. The substitutional Sn_{Si} fraction increases from 25% at room temperature to 60% at 670 K.

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