SOVIET PHYSICS – SEMICONDUCTORS VOL. 4, NO. 9 MARCH, 1971

EPR OF PHOSPHORUS IN COMPENSATED n-TYPE Si SUBJECTED TO UNIAXIAL COMPRESSION

V. B. Ginodman, P. S. Gladkov, B. G. Zhurkin,
V. G. Mikhalevich, and N. A. Penin

P. N. Lebedev Physics Institute, Academy of Sciences of the USSR, Moscow
Translated from Fizika i Tekhnika Poluprovodnikov, Vol. 4, No. 8,
pp. 1736-1739, September, 1970
Original article submitted March 25, 1970

The influence of uniaxial compression on the magnitude of the hyperfine splitting A in the EPR spectrum of phosphorus in n-type silicon was investigated at 1.3°K. This investigation was carried out on samples in which the phosphorus concentration was $N_D = (5-7) \cdot 10^{17}$ cm^{-3} and whose degree of compensation was 60-99%. The dependence of the value of A on the uniaxial compression of these silicon crystals was identical with that for lightly doped silicon. This indicated that the compensation of heavily doped silicon resulted in the formation of localized states. The value of A decreased with increasing degree of compensation at zero applied pressure because of a correlation in the distribution of impurity atoms. It was established that the two causes of the fall in the value of A (uniaxial compression and compensation) were independent in the investigated range of uniaxial pressures (up to 30 kgf/mm^2).

The magnitude of the hyperfine splitting A in the EPR spectra of shallow donors in silicon may be reduced in two ways. First, the value of A may be reduced by uniaxial compression along the [100] and [110] axes. This effect is due to the admixture of an excited doublet state to the ground singlet state of a donor impurity because of the compression-induced change in the populations of the conduction-band valleys [1]. Secondly, the strong compensation of heavily doped n-type silicon may alter the value of A because of the Stark effect [2]. It is not clear whether there is any relationship between these two types of the reduction in the value of A. The purpose of our experimental investigation was to find whether such a relationship existed.

TABLE 1

Sample No.	Phosphorus concentration, cm^{-3}	Degree of compensation K, %	ρ, Ω·cm	HFS splitting, Oe
1	$3.5 \cdot 10^{16}$	< 0.1	0.20	42
2	$5 \cdot 10^{17}$	< 0.1	0.03	42
3	$5 \cdot 10^{17}$	60	0.06	41
4	$7 \cdot 10^{17}$	95	0.35	37 ± 0.5
5	$7 \cdot 10^{17}$	99	0.45	37 ± 0.5

EXPERIMENTAL INVESTIGATION AND RESULTS

Our experiments were carried out on n-type silicon, doped with phosphorus ($N_D \sim 5 \cdot 10^{17}$–$7 \cdot 10^{17}$ cm^{-3}) and compensated with boron (K ~ 60-99%). The properties of the investigated samples and the hyperfine splitting at zero pressure, A_0, are given in Table 1.

The EPR spectra were recorded by means of a spectrometer with direct amplification and high-frequency (100 kHz) modulation. These spectra were recorded at 1.3°K. The uniaxial compression was applied along the [100] crystallographic axis at right angles to the static magnetic field.

The values of A_0 were determined as a function of the degree of compensation, keeping the phosphorus concentration approximately constant. The results are presented in Table 1. It is evident that, in the absence of compensation, A_0 is 42 Oe.