DETERMINATION OF FREE EXCITON CAPTURE CROSS SECTION OF Si:Al BY PHOTOLUMINESCENCE

G. SCHRAMM

VEB Spurenmetalle Freiberg-WIB im VEB Kombinat Mikroelektronik Erfurt
PSF 211, 9200 Freiberg, Germany

(Received April 9, 1990)

The free excitons capture rate and capture cross-section of the neutral Al atom in silicon were determined at 4.2 K. The obtained values are of the same order of magnitude as reported values of other shallow dopants.

PACS numbers: 78.55.–m

Free exciton (FE) capture cross-section (σ_0) in silicon was determined for In [1, 2], B [2, 3], P [3, 4], Li [5] and Sb [6]. The σ_0 value for Si:Al seems to be absent in the literature. The aim of this note is to calculate this quantity at 4.2 K.

The FE capture rate (c_0) of Al is evaluated from the changes of the relative intensities of photoluminescence (PL) spectra as a function of excitation density according to [4]. Two samples with different concentrations of Al (N_{Al}) were measured. In Fig. 1 the PL spectrum of the higher doped sample is shown. The analysis, with the help of calibration curves, yields $N_{Al} = 5.3 \times 10^{14}$ cm^{-3} and $N_{Al} = 1.4 \times 10^{13}$ cm^{-3} for the two samples. The capture rate c_0 is calculated according to

$$c_0 = \sigma_0 v_{th} = \frac{R^0_{b/f}(q, q')}{W_{b/f}(q, q') N_{Al} \tau^{BE}_{Al}},$$

where v_{th} is the average thermal velocity of FE, $R^0_{b/f}(q, q')$ is the ratio of the peak heights of bound exciton (BE) and FE-related luminescence for diminishing excitation density, q and q' are the participating phonons in recombination and $W_{b/f}(q, q')$ denotes the ratio of radiative transition rates of BE relative to FE. The nonradiative Auger transition rate of an exciton bound to Al (τ^{BE}_{Al} = 76 ns) was taken from [7]. To calculate $W_{b/f}$(NP,TO) one needs the intrinsic full width at half maximum (FWHM) of the corresponding peaks. These values are sample-dependent and have to be evaluated. FWHM of the Al_{NP}(J = 0) peak

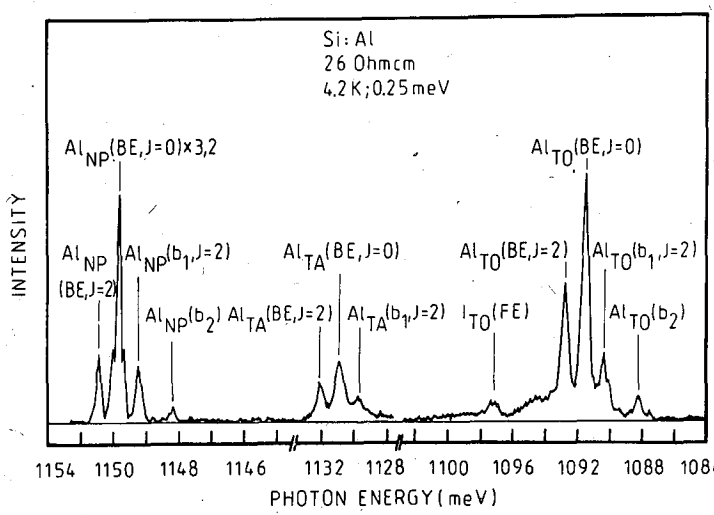

Fig. 1. PL spectrum (uncorrected for system response) of a Al-doped sample (resistivity $\varrho = 26$ Ohm cm, $N_{Al} = 5.3 \times 10^{14}$ cm^{-3}).

0.10 meV and FWHM of the intrinsic peak I_{TO}(FE) 0.63 meV were determined for the higher doped sample. $W_{b/f}$(NP,TO) was calculated using these values, the oscillator strenght given by Dean et al. [8] and the relative NP oscillator strengths [9]. The computation gives

$$W_{b/f}(\mathrm{NP,TO}) = 2.3 \pm 0.7.$$

The excitation power dependence of the peak heights of BE- and FE-related luminescence is depicted in Fig. 2. Figure 3 shows the reciprocal peak height ratios $R^{-1}_{b/f}$(NP, TO) and $R^{-1}_{b/f}$ (TO, TO) of the higher doped sample as functions of the excitation power P. From the intersection of $R^{-1}_{b/f}$(NP,TO) with the vertical axis (diminishing excitation power) one obtains $R_{b/f}$(NP,TO). The capture rate c_0 was evaluated with the above mentioned τ^{BE}_{Al}, $W_{b/f}$(NP,TO) and $R^0_{b/f}$ (NP,TO) corrected for "spectrometer broadening". This gives

$$c_0 = (5.5 \pm 1.9) \times 10^{-7}\,\mathrm{cm^3\,s^{-1}} \quad \text{and}$$

$$\sigma_0 = (3.4 \pm 1.2) \times 10^{-13}\,\mathrm{cm^2} \quad \text{, respectively.}$$

This to our knowledge is the first estimation of the FE capture cross-section of Al in Si measured at 4.2 K. This cross-section is of the same order of magnitude as the reported values of other shallow dopants in Si [1–6]. The same values were obtained using the lower doped sample or the TO region of the BE recombination.

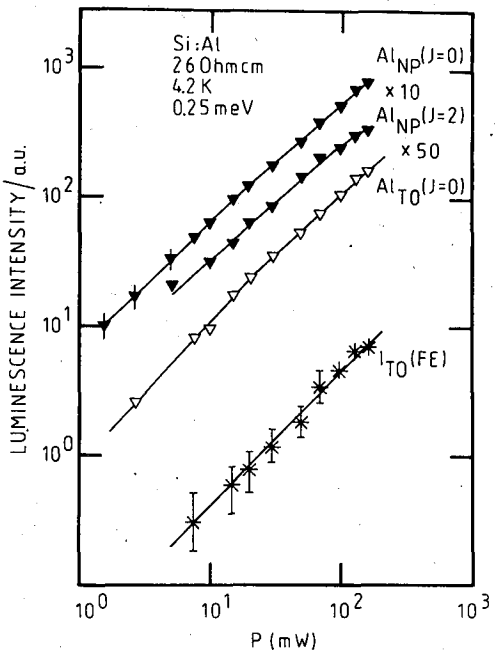

Fig. 2. Excitation power dependence of peak heights of BE- and FE-related luminescence.

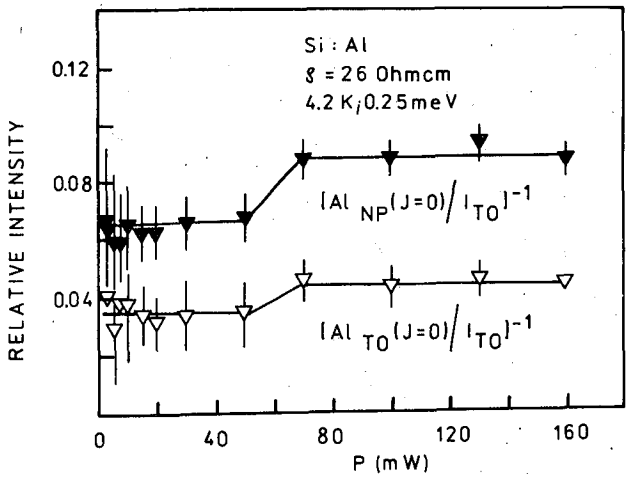

Fig. 3. Reciprocal peak height ratios $R_{b/f}^{-1}(q,TO)$ as functions of the excitation power P.

References

[1] K.R. Elliott, D.L. Smith, T.C. McGill, *Solid State Commun.* **24**, 461 (1977).

[2] R.M. Feenstra, T.C. McGill, *Solid State Commun.* **36**, 1039 (1980).

[3] R.B. Hammond, R.N. Silver, *Appl. Phys. Lett.* **36**, 68 (1980).

[4] H. Nakayama, T. Nishino, Y. Hamakawa, *Jpn. J. Appl. Phys.* **19**, 501 (1980).

[5] K. Ohnishi, H. Nakayama, T. Nishino, Y. Hamakawa, *J. Phys. Soc. Jpn.* **49**, 1078 (1980).

[6] G. Schramm, *Phys. Status Solidi A* **116**, K209 (1989).

[7] W. Schmid, *Phys. Status Solidi B* **84**, 529 (1977).

[8] P.J. Dean, W.F. Flood, G. Kaminsky, *Phys. Rev.* **163**, 721 (1967).

[9] K.R. Elliott, G.C. Osbourn, D.L. Smith, T.C. McGill, *Phys. Rev. B* **17**, 1808 (1978).