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HIGH-RESOLUTION EPR SPECTROSCOPY OF THE Si-NL10 THERMAL DONOR

T. Gregorkiewicz, H.H.P.Th. Bekman, C.A.J. Ammerlaan (a), W. Knap, L.C. Brunel and G. Martinez (b)

(a) Van der Waals - Zeeman Laboratorium der Universiteit van Amsterdam
Valckenierstraat 65-67, NL-1018 XE Amsterdam, The Netherlands
(b) Service National des Champs Intenses - CNRS, 25
Avenue des Martyrs, F-38042 Grenoble Cédex, France

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The problem of thermal donor centers (TD's) is among the most confused issues of materials science of silicon. Here, while a lot of experimental and theoretical investigations have been devoted to it over the past 30 years, still no undisputed model for the TD microscopic structure can be presented.

One of the features responsible for the complexity of this issue is the so-called ***multispecies character*** of TD centers. It has been found that TD's constitute a series of up to 15 very similar but still distinctly different centers. The initial evidence of that has been obtained from infrared absorption [1]. Later, the existence of TD species has been confirmed also by photoluminescence spectroscopy and Hall effect measurements. While the multispecies character of TD's seems to be rather well established, the microscopic identification of the development mechanism responsible for the differences between the individual species remains hidden. Many different suggestions have been made but, so far, none is capable of accounting for all the available experimental data.

In electron paramagnetic resonance (EPR) two spectra have been related to thermal donor centers in silicon, namely Si-NL8 and Si-NL10 [2]. Very little information could, however, be found on the TD development mechanism. In EPR the multiplicity of TD's manifests itself only by line broadening and a semicontinuous shifting of g values of NL8 and NL10 spectra, indicating their inhomogeneous character. Following their EPR observation both spectra have also been analyzed by the electron-nuclear double resonance technique (ENDOR) [3, 4]. For the Si-NL10 center the field-stepped ENDOR results have shown that the spectrum observed in a conventional EPR experiment (e.g. conducted in K band at 23 GHz) represents a superposition of several unresolved spectra arising from individual NL10 species. In view of this conclusion, in the present study the Si-NL10 thermal donor has been investigated by high-frequency EPR featuring a far better resolution. The experiment, conducted at the far-infrared frequency of $\approx$ 350 GHz, directly proves the multispecies character of this center as individual TD species can be resolved in the high magnetic field. In Fig. 1 the EPR spectrum of Si-NL10 as recorded for the two frequencies is shown. As can be seen the individual resonance lines, (almost) coincident in K band, are clearly resolved in the magnetic field in the 12 T range, where, in addition, the resonances of 5 species are distinguishable in the U6 high-symmetry point.

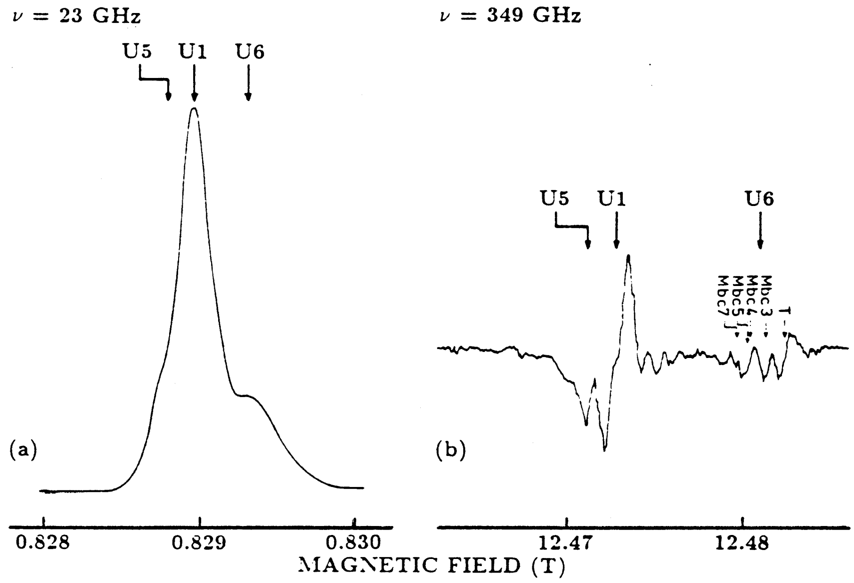

Figure 1: Comparison of Si-NL10 EPR spectrum of a 200 h annealed Cz-Si:Al sample as recorded at (a) 23 GHz and (b) 349 GHz with B || [011]. The three resonances in this field direction are labeled by U5, U1, and U6, respectively; for the high-field scan the resolved components in the U6 line due to individual NL10 species are labeled by their ENDOR designations.

On the basis of the HF-EPR measurements it was possible to determine g tensors for individual Si-NL10 TD species [5]. These are in remarkable agreement with the effective g values predicted from the earlier FStENDOR measurements and allow for a full explanation of the g-shifting effect.

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