Comment on "Direct Determination of the Electron-Electron-Hole Auger Threshold Energy in Silicon"

In a recent Letter [1], Chen *et al.* set an upper bound of 5 meV on the threshold kinetic energy E_a for direct, no-phonon electron-electron-hole (eeh) Auger recombination in Si, based upon the spectral dependence of a defect photoconversion (PC) process. This process involves the photoinduced change of the stable configuration of a sulfer-related defect which gives rise to a photoluminescence (PL) system denoted as S_A into a metastable (below 40 K) configuration of the defect giving rise to the S_B PL system.

While the spectral dependence of this PC process was initially said to follow the FE absorption [2], Chen *et al.* [1] later stated that two independent experiments revealed a 5 ± 1 meV upshift of the PC threshold from the FE threshold, which was argued to be the FE threshold kinetic energy needed for a phononless Auger PC process. In addition to this shift in the TA-phonon-assisted PC edge from the TA-phonon-assisted FE absorption edge (FE_{TA}), they reported a strong, sharp feature in the PC spectrum at 5 meV above the FE no-phonon (FE_{np}) edge.

We found this result surprising since the defect PC process involves a bound electron which arguably has the characteristics of a deep defect, thus relaxing the need for momentum conservation, and therefore for any threshold kinetic energy. We have therefore carefully reexamined the spectral dependence of the PC process and can find no evidence for the claimed [1] 5 ± 1 meV shift of the PC curve from the FE_{TA} edge, or for the sharp feature 5 meV above the FE_{np} edge.

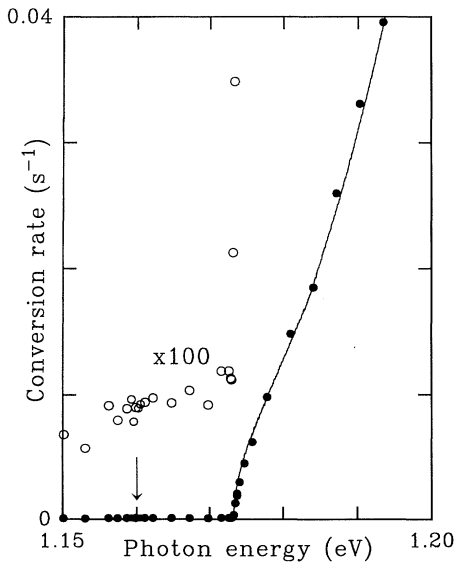

FIG. 1. The $S_A \Rightarrow S_B$ photoconversion rate vs photon energy. Data near and below the FE_{TA} edge are also shown on a $\times 100$ scale. The solid curve is not a guide to the eye but rather the measured FE_{TA} absorption edge. The arrow marks the location of the sharp feature reported by Chen *et al.*

The experiment was performed on an n-type sample described previously [3]. The PC was carried out at 4.2 K using the regulated output of a Ti-sapphire laser at a constant power density of $\cong 0.25$ W cm^{-2}, with wavelength calibrated using a wave meter. Before collecting each data point, the sample was annealed to 70 K to place all centers in the S_A state. The entire PL spectrum covering the S_A and S_B bands was then collected at 4.2 K using a Bomem DA8.01 interferometer, both before the PC process and after several carefully timed exposures to the PC laser beam. The PL was excited by a fraction of a mW of 980 nm light from a diode laser, which caused negligible PC on its own for periods much longer than those used to collect the PL spectra. Using a shorter wavelength source for the PL measurement ensured that the PC laser intensity was independent of wavelength over the sample volume probed by the PL. The decay of S_A and the buildup of S_B were verified to be well described by a single exponential time constant for any particular PC laser energy.

There is no evidence in our Fig. 1 for any shift between the PC process and normal FE absorption, to within ±0.1 meV, nor is there any evidence for the sharp line at FE_{np} + 5 meV, at a level more than 100 times lower than that reported by Chen *et al.*

Thus we conclude that for this PC process E_a is zero and that the defect PC is driven by thermal FE. The argument advanced by Chen *et al.* that the PC E_a sets an upper limit on the E_a of the free particle eeh Auger process cannot be used in this case, since it can now be argued that the absence of any E_a for the PC process reflects only the relaxation of the requirement for momentum conservation resulting from the deep nature of the defect-bound electron.

To address any issue of sample dependence, we would welcome the opportunity to study any sample said to show this effect.

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[1] W. M. Chen, B. Monemar, E. Janzen, A. M. Frens, M. T. Bennebroek, and J. Schmidt, Phys. Rev. Lett. **73**, 3258 (1994).
[2] W. M. Chen, J. H. Svensson, E. Janzen, B. Monemar, A. Henry, A. M. Frens, M. T. Bennebroek, and J. Schmidt, Phys. Rev. Lett. **71**, 416 (1993).
[3] D. J. S. Beckett, M. K. Nissen, and M. L. W. Thewalt, Phys. Rev. B **40**, 9618 (1989).

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