

restriction on  $\Delta n$  would have been  $\Delta n \ll 10^5 \text{ cm}^{-3}$ .

For the ITL model with the value of  $p_0$  and the recombination parameters as given, it turns out that, as long as (11) and (12) are satisfied, the effect of level 2 on the lifetimes is negligible anyway.<sup>10</sup> Now, conditions (11) and (12) also happen to be the linearization conditions when only level 1 is operative. We conclude, therefore, that whether we use the IDL or the ITL model, the restriction on  $\Delta n$  is the same, and is given by (12).

The above conclusions apply to more extrinsic  $p$ -type material as well, since the approximation of both the IDL and ITL models to a one-level model improves as the Fermi level moves closer to the valence band. In this connection, it is interesting to observe that according to (12), the restriction on  $\Delta n$  should be less severe the larger the value of  $p_0$ . This is contrary to what we would expect if the restriction on  $\Delta n$  is governed instead by  $\Delta n \ll n_0$ . Thus, if  $p_0 = 2 \times 10^{15}$  and  $n_0 = 10^4 \text{ cm}^{-3}$ ,

condition (12) would become  $\Delta n \ll 4 \times 10^{10} \text{ cm}^{-3}$ , whereas using  $\Delta n \ll n_0$  would require  $\Delta n \ll 10^4 \text{ cm}^{-3}$ , an impracticably low value.

As stated earlier, the value of  $c_{p1}/c_{n1}$  that we use in evaluating condition (12) is obtained from previous measurements done at unspecified values of  $\Delta n$ . However, if we take the values of  $\tau_n$  and  $\tau_p$  obtained by Beattie and Cunningham<sup>9</sup> at the smallest photon flux density they used (corresponding to a value of  $\Delta n$  less than  $10^9 \text{ cm}^{-3}$ ) and analyze them in terms of level 1 with a typical value of  $N_1$  ( $\approx 10^{14} \text{ cm}^{-3}$ ), we arrive at a ratio of  $c_{p1}/c_{n1} \approx 2 \times 10^{-5}$ , in excellent agreement with our value.

In the light of the foregoing discussion, it would appear that previous low-temperature lifetime data, which are self-consistent over a wide range of carrier concentrations, are unlikely to be seriously in error, despite the fact that they were analyzed on the basis of the small-signal PEM and PC theory.

<sup>1</sup>A. R. Beattie and R. W. Cunningham, Phys. Rev. **125**, 533 (1962).

<sup>2</sup>R. N. Zitter, A. J. Strauss, and A. E. Attard, Phys. Rev. **115**, 266 (1959).

<sup>3</sup>R. A. Laff and H. Y. Fan, Phys. Rev. **121**, 53 (1961).

<sup>4</sup>S. C. Choo and A. C. Sanderson, Solid-State Electron. **13**, (1970).

<sup>5</sup>J. E. L. Hollis, S. C. Choo, and E. L. Heasell, J. Appl. Phys. **38**, 1626 (1967).

<sup>6</sup>As pointed out in Ref. 5, the difference between the

value of 0.071 eV used here and the value of 0.055 eV given by Laff and Fan is due simply to the different values of hole effective mass used.

<sup>7</sup>J. Okada, J. Phys. Soc. Japan **13**, 793 (1958).

<sup>8</sup>S. C. Choo, Phys. Rev. B **1**, 687 (1970).

<sup>9</sup>A. R. Beattie and R. W. Cunningham, J. Appl. Phys. **35**, 353 (1964).

<sup>10</sup>For the IDL model with  $N_1$  comparable to  $N_2$ , the same conditions would also make the effect of level 2 negligible.

## ERRATA

Quantum Dielectric Theory of Electronegativity in Covalent Systems. II. Ionization Potentials and Interband Transition Energies, J. A. Van Vechten [Phys. Rev. **187**, 1007 (1969)]. There are six errors among the values of the spectroscopic or Phillips fraction of ionic character,

$$\frac{f_i}{\text{Phillips}},$$

quoted in Table IV. The values of the energy gaps  $E_h$ ,  $C$ , and  $E_g$  and of the other parameters are correct. These errors do not affect the results of this paper, but should be noted when applying the ion-

icity concept to the compounds involved. A table of the quoted and corrected values follows.

Crystal	$f_i$ (quoted) Phillips	$f_i$ (corrected) Phillips
BeSe	0.299	0.261
BeS	0.312	0.286
GaP	0.374	0.327
ZnTe	0.546	0.609
CdTe	0.675	0.717
ZnSe	0.676	0.630