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ERRATUM

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Erratum: "Microscopic origins of radiative performance losses in thin-film solar cells at the example of (Ag,Cu)(In,Ga)Se_2 devices" [J. Vac. Sci. Technol. A 42, 022803 (2024)]

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In a recent publication,[1] the microscopic origins of radiative losses in the open-circuit voltages (V_{oc}) of thin-film solar cells were discussed. It was highlighted that the radiative V_{oc} losses can be quantified via the band-gap broadening σ_{gap} from the first derivative of the external quantum efficiency (EQE) or absorptance spectrum around the band-gap energy (E_{gap}). The Urbach energy E_U as a function of the photon energy E_{ph} can be obtained by applying[2–4]

$$\ln[\mathrm{EQE}(E_{ph})] = C + E_{ph}/E_U. \quad (1)$$

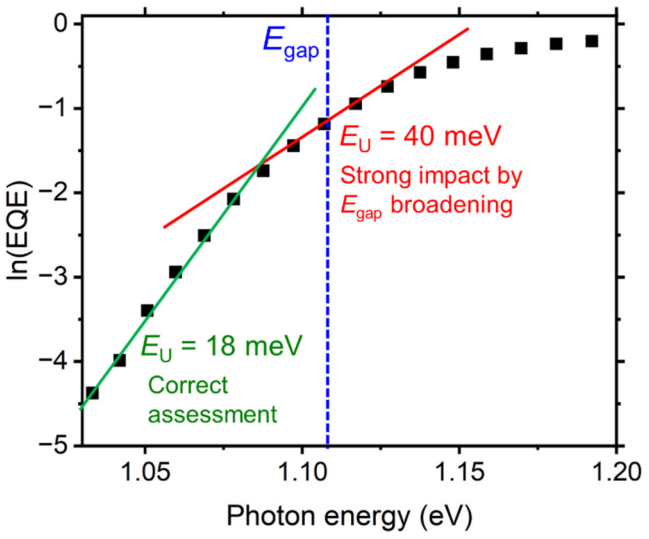

FIG. 1. Natural logarithm of the external quantum efficiency (EQE) spectrum of a high-efficiency Cu(In,Ga)Se_2 solar cell as a function of the photon energy. When extracting the Urbach energy E_U at the position of the band-gap energy (E_{gap}), the slope of ln(EQE) contains a strong contribution by the E_{gap} broadening. The Urbach energy is correctly assessed where ln(EQE) exhibits a linear dependency on the photon energy, i.e., at considerably lower photon energy values.

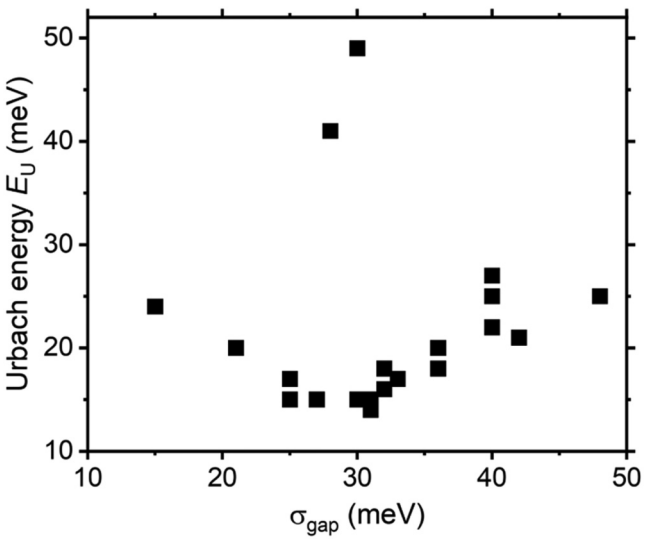

FIG. 2. Urbach energies E_U as a function of the band-gap broadening σ_{gap} from about 30 different (Ag,Cu)(In,Ga)Se_2 solar cells. No correlation was detected.

Here, C is a constant. Equation (1) describes a linear relationship between $\ln[a(E_{ph})]$ and E_{ph} with the slope E_U^{-1}. In Ref. 1, the Urbach energies were extracted close to the band-gap energy (see Fig. 1). It is apparent from Fig. 1 that the extraction of E_U close to E_{gap} (1.11 eV) results in large Urbach energy values, mainly since in this E_{ph} region, there is a strong impact by the band-gap broadening [and also since the approach depicted by Eq. (1) results in an overestimation of E_U, as already mentioned in Ref. 1]. E_U is correctly assessed in E_{ph} regions where EQE(E_{ph}) exhibits a linear dependency on the photon energy (at around 1.05 eV in Fig. 1). The corresponding is discussed more in detail in Ref. 5.

In Ref. 1, the Urbach energies E_U determined by evaluating EQE spectra of about 30 different solar cells exhibited a strong correlation with the corresponding band-gap broadening values σ_{gap} from the same EQE spectra. This finding is not astonishing since the Urbach energies were extracted close to the band-gap energy, where strong influence of the band-gap broadening is present. When correctly assessing E_U in E_{ph} regions where the ln(EQE) spectra feature linear relationships with E_{ph}, there is no correlation of E_U with σ_{gap} anymore (Fig. 2).

Thus, while the band-gap broadening σ_{gap} can be linked to microscopic features in the solar-cell stacks, as described in Ref. 1, it is still unclear which material properties in solar-cell absorbers give rise to the Urbach tails. This issue is topic of future research efforts.

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DATA AVAILABILITY

The data shown in the present work are available upon request from the author.

REFERENCES

[1]D. Abou-Ras, J. Vac. Sci. Technol. A **42**, 022803 (2024).
[2]J. Mattheis, P. J. Rostan, U. Rau, and J. H. Werner, Sol. Energy Mater. Sol. Cells **91**, 689 (2007).
[3]C. J. Hages, N. J. Carter, and R. Agrawal, J. Appl. Phys. **119**, 014505 (2016).
[4]J. Chantana, Y. Kawano, T. Nishimura, A. Mavlonov, and T. Minemoto, Sol. Energy Mater. Sol. Cells **210**, 110502 (2020).
[5]S. Gharabeiki *et al.*, "The effect of a band gap gradient on the radiative losses in the open circuit voltage of a solar cell" (unpublished).