Lateral Inhomogeneity Effects in Polycrystalline Chalkopyrite Absorbers and Heterodiodes on the Sub-Micron Scale

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Polycrystalline CIGS-films and heterodiodes, as well show substantial local variations of structural, optical and optoelectronic properties in the sub-micro-meter scale, detected by highly laterally resolved analyses of topography (afm), optical properties (reflection) and quasi-Fermi level-splitting (photoluminescence). Photoluminescence and optical reflection with lateral resolutions (0.85 µm, and 0.65 µm) close to the diffraction limit have been monitored simultaneously and exhibit different lateral features, as outlined in figs. 1, and 2.

The local variation of pl-yields recorded at 80 K of a factor of 5 corresponds to a local fluctuation of the splitting of the quasi-Fermi-levels of about 12 meV, which we extrapolate into a room temperature variation of about 50 meV or more. The pronounced variation in pl-yield mainly depends on the lateral variation of minority carrier life time, since only a marginal influence of the luminescence light flux may result from a potential lateral variation of refractive index, and from the angles for laser, and pl-photons coupled in, and out respectively due to the morphological structure of the CIGS surface.

The considerable variation in pl-yield according to an extension of SRH-recombination under "high injection" conditions furthermore indicates a variation of the rate of nonradiative recombination of at least a factor of 5 as well, which we attribute to a lateral variation of defect sites of the same order.

Two-dimensional fourier transforms of laterally resolved features (afm-scans, scans of optical reflection, and of photoluminescence yields) (figs.3-6) exhibit distinct features at particular spatial frequencies, and moreover give clear evidence on the necessary size of the sampling area to allow for statistically representative conclusions.

On the basis of laterally resolved pl-yields we finally are discussing entropic terms in solar light conversion by mixing of regimes with differing quality of photoexcited states.

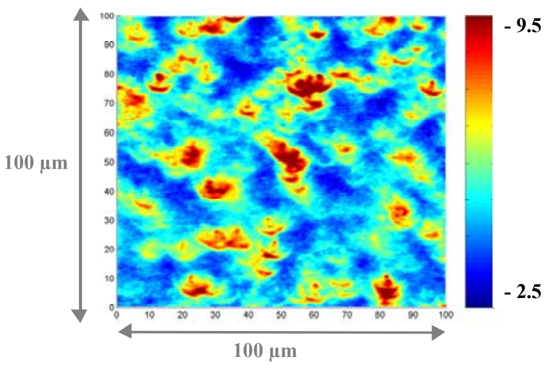

Fig.1. Pl-yield of a CIGS thin film ((100x100)µm^2, 80 K) with 0.85 µm lateral resolution /1/.

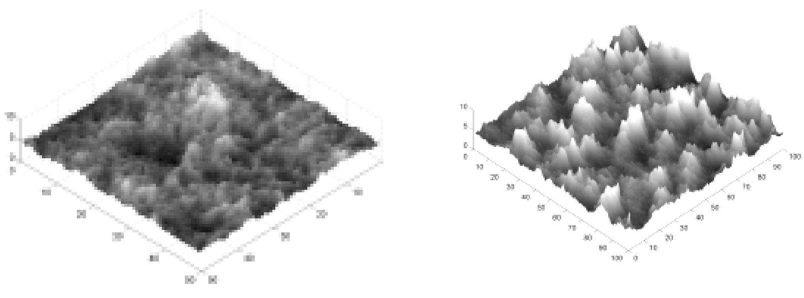

Fig.2. Scans of optical reflection (l.h.s; (50x50)µm^2, 0.65 µm resolution) of pl (r.h.s.; ((100x100)µm^2), 80 K; 0.85µm resolution) of a CIGS thin film /1,2/.

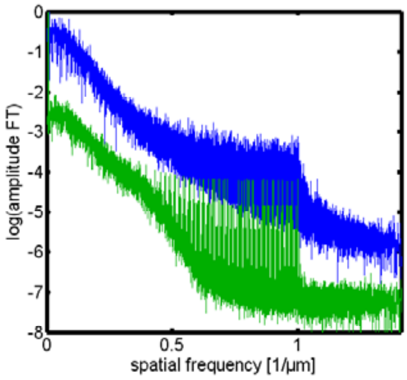

Fig.3. 2-D fourier transform of CIGS (scan (100x100)μm^2), blue:afm; green: optical reflection)

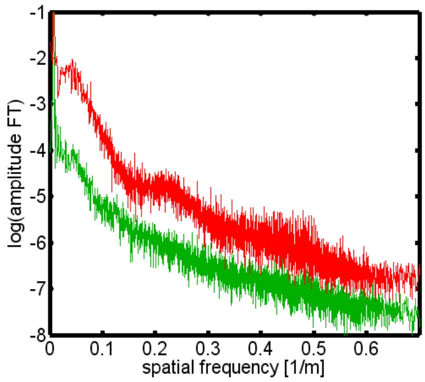

Fig. 4. 2-D fourier transform of CIGS (scan (100x100)μm^2), green optical reflection; red:pl-yield).

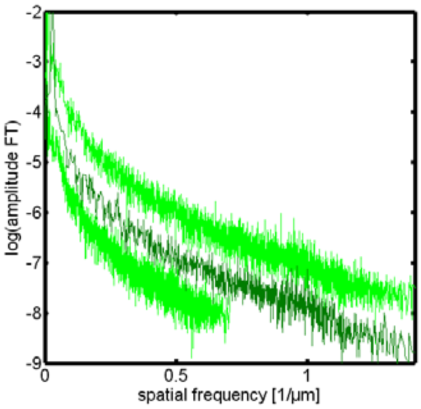

Fig. 5. 2-D fourier transform confocal optical reflection from a CIGS film (Ga-content 0.32) for different scan ranges (up.:(50x50)mm^2, mid. (100x100)μm^2, low.: (200x200)μm^2)

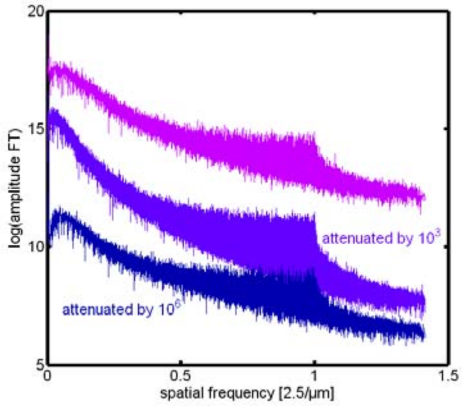

Fig. 6. 2-D fourier transform pl-yields in CIGS films (Ga-content/ up.:1.0, mid.: 0.68, low.:0.32) (scan (100x100)μm^2)

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References

/1/ T. Unold, K. Bothe, G.H. Bauer, Thin Solid Films, **403/404** (2002) pp. 453-456

/2/ G.H. Bauer, K. Bothe, T. Unold, Conf. Rec. 29 IEEE PVSC, IEEE Publ. 2002, pp. 700-703.