

# PUBLICATIONS

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DR. ROLAND MAINZ

## Publications in peer-reviewed journals:

S. Zakel, B. Pollakowski, C. Streeck, S. Wundrack, A. Weber, S. Brunken, R. Mainz, B. Beckhoff and R. Stosch. *Traceable Quantitative Raman Microscopy and X-ray Fluorescence Analysis as Nondestructive Methods for the Characterization of Cu(In,Ga)Se<sub>2</sub> Absorber Films*. Appl. Spectrosc. **70**, 279-288 (2016), doi: [10.1177/0003702815620131](https://doi.org/10.1177/0003702815620131).

R. Mainz, H. Rodriguez-Alvarez, M. Klaus, D. Thomas, J. Lauche, A. Weber, M. D. Heinemann, S. Brunken, D. Greiner, C. A. Kaufmann, T. Unold, H.-W. Schock, and C. Genzel. *Sudden stress relaxation in compound semiconductor thin films triggered by secondary phase segregation*. Phys. Rev. B, **92**, 155130 (2015), doi: [10.1103/PhysRevB.92.155310](https://doi.org/10.1103/PhysRevB.92.155310).

H. Stange, S. Brunken, H. Hempel, H. Rodriguez Alvarez, N. Schäfer, D. Greiner, A. Scheu, J. Lauche, C. A. Kaufmann, T. Unold, D. Abou-Ras, R. Mainz. *Effect of Na presence during CuInSe<sub>2</sub> growth on stacking fault annihilation and electronic properties*. Appl. Phys. Lett., **107**, 152103 (2015) doi: [10.1063/1.4933305](https://doi.org/10.1063/1.4933305).

N. Carter, R. Mainz, B. Walker, C. Hages, J. Just, M. Klaus, S. Schmidt, A. Weber, W.-C. Yang, O. Zander, E. Stach, T. Unold, R. Agrawal. *The role of interparticle heterogeneities in the selenization pathway of Cu-Zn-Sn-S nanoparticle thin films for photovoltaic applications – A real-time study*. Journal of Materials Chemistry C (2015), doi: [10.1039/c5tc01139f](https://doi.org/10.1039/c5tc01139f).

R. Mainz, A. Weber, H. Rodriguez-Alvarez, S. Levcencu, M. Klaus, P. Pistor, R. Klenk and H. Schock. *Time-resolved investigation of Cu(In,Ga)Se<sub>2</sub> growth and Ga gradient formation during fast selenization of metallic precursors*. Progress in Photovoltaics **23**, 1131-1143 (2015), doi: [10.1002/pip.2531](https://doi.org/10.1002/pip.2531).

W. Witte, D. Abou-Ras, K. Albe, G. H. Bauer, F. Bertram, C. Boit, R. Brüggemann, J. Christen, J. Dietrich, A. Eicke, D. Hariskos, M. Maiberg, R. Mainz, M. Meessen, M. Müller, O. Neumann, T. Orgis, S. Paetel, J. Pohl, H. Rodriguez-Alvarez, R. Scheer, H.-W. Schock, T. Unold, A. Weber and M. Powalla. *Gallium gradients in Cu(In,Ga)Se<sub>2</sub> thin-film solar cells*. Progress in Photovoltaics **23**, 717-733 (2015), doi: [10.1002/pip.2485](https://doi.org/10.1002/pip.2485).

H. Rodriguez-Alvarez, R. Mainz, S. Sadewasser. *A one-dimensional Fickian diffusional model to predict the Ga depth-profiles in three-stage Cu(In,Ga)Se<sub>2</sub>*. J. Appl. Phys. **115**, 204913 (2014), doi: [10.1063/1.4880298](https://doi.org/10.1063/1.4880298).

R. Mainz, A. Singh, M. Klaus, C. Genzel, K. Ryan and T. Unold. *Phase-transition-driven growth of compound semiconductor crystals from ordered metastable nanorods*. Nature Communications. **5**, 3133 (2014), doi: [10.1038/ncomms4133](https://doi.org/10.1038/ncomms4133).

**HZB Press Release:** [From a carpet of nanorods to a thin film solar cell absorber ...](#)

H. Rodriguez-Alvarez, A. Weber, R. Mainz, M. Klaus, C. A. Kaufmann, T. Rissom, C. Genzel and H.-W. Schock. *Real-time observation of the phase transformations and microstructural changes during the incorporation of In into a Cu thin film at 770K*. J. Alloys Compd. **588**, 644-647 (2014), doi: [10.1016/j.jallcom.2013.11.147](https://doi.org/10.1016/j.jallcom.2013.11.147).

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*In and Ga depth profiles in Cu(In,Ga)Se<sub>2</sub> absorber films.* Appl. Phys. Lett. **103**, 113904 (2013), doi: [10.1063/1.4821267](https://doi.org/10.1063/1.4821267).

R. Mainz, B. C. Walker, S. S. Schmidt, O. Zander, A. Weber, H. Rodriguez-Alvarez, J. Just, M. Klaus, R. Agrawal and T. Unold. *Real-time observation of Cu<sub>2</sub>ZnSn(S,Se)<sub>4</sub> solar cell absorber layer formation from nanoparticle precursors.* Phys. Chem. Chem. Phys. **15**, 18281-18289 (2013), doi: [10.1039/C3CP53373E](https://doi.org/10.1039/C3CP53373E).

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H. Rodriguez-Alvarez, N. Barreau, C. Kaufmann, A. Weber, M. Klaus, T. Painchaud, H.-W. Schock and R. Mainz. *Recrystallization of Cu(In,Ga)Se<sub>2</sub> thin films studied by X-ray diffraction.* Acta Mater. **61**, 4347-4353 (2013), doi: [10.1016/j.actamat.2013.04.006](https://doi.org/10.1016/j.actamat.2013.04.006).

H. Rodriguez-Alvarez, R. Mainz, R. Caballero, D. Abou-Ras, M. Klaus, S. Gledhill, A. Weber, C. Kaufmann and H.-W. Schock. *Real-time study of Ga diffusion processes during the formation of Cu(In,Ga)Se<sub>2</sub>: The role of Cu and Na content.* Sol. Energy Mater. Sol. Cells **116**, 102-109 (2013), doi: [10.1016/j.solmat.2013.04.008](https://doi.org/10.1016/j.solmat.2013.04.008).

S. Merdes, D. Abou-Ras, R. Mainz, R. Klenk, M. Lux-Steiner, A. Meeder, H. Schock and J. Klaer. *CdS/Cu(In,Ga)S<sub>2</sub> based solar cells with efficiencies reaching 12.9% prepared by a rapid thermal process.* Progress in Photovoltaics **21**, 88-93 (2013), doi: [10.1002/pip.2165](https://doi.org/10.1002/pip.2165).

S. Schorr, R. Mainz, H. Mönig, I. Laueremann and M. Bär. *The complex material properties of chalcopyrite and kesterite thin-film solar cell absorbers tackled by synchrotron-based analytics.* Progress in Photovoltaics **20**, 557-567 (2012), doi: [10.1002/pip.1256](https://doi.org/10.1002/pip.1256).

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T. Rissom, R. Mainz, C. A. Kaufmann, R. Caballero, V. Efimova, V. Hoffmann and H.-W. Schock. *Examination of growth kinetics of copper rich Cu(In,Ga)Se<sub>2</sub>-films using synchrotron energy dispersive X-ray diffractometry.* Sol. Energy Mater. Sol. Cells **95**, 250-253 (2011), doi: [10.1016/j.solmat.2010.05.007](https://doi.org/10.1016/j.solmat.2010.05.007).

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- D. Abou-Ras, R. Caballero, C.-H. Fischer, C. Kaufmann, I. Lauermann, R. Mainz et al., *Comprehensive comparison of various techniques for the analysis of elemental distributions in thin films*, Microscopy and Microanalysis, **17**, 728-751 (2011), doi: [10.1017/S1431927611000523](https://doi.org/10.1017/S1431927611000523). **HZB Press Release:** [Messmethoden im Vergleich](#)
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- A. Meeder, P. Schmidt-Weber, U. Hornauer, D. Förster, T. Schubert, A. Neisser, S. Merdes, R. Mainz and R. Klenk. *High voltage Cu(In,Ga)S<sub>2</sub> solar modules*. Thin Solid Films **519**, 7534-7536 (2011), doi: [10.1016/j.tsf.2011.01.096](https://doi.org/10.1016/j.tsf.2011.01.096).
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- H. Rodriguez-Alvarez, R. Mainz, B. Marsen and H.-W. Schock. *Recrystallization of Cu-poor CuInS<sub>2</sub> assisted by metallic Cu or Ag*. J. Solid State Chem. **183**, 803-806 (2010), doi: [10.1016/j.jssc.2010.01.023](https://doi.org/10.1016/j.jssc.2010.01.023).
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- A. Weber, S. Schmidt, D. Abou-Ras, P. Schubert-Bischoff, I. Denks, R. Mainz and H. W. Schock. *Texture inheritance in thin-film growth of Cu<sub>2</sub>ZnSnS<sub>4</sub>*. Appl. Phys. Lett. **95**, 041904 (2009), doi: [10.1063/1.3192357](https://doi.org/10.1063/1.3192357).
- A. Weber, R. Mainz, T. Unold, S. Schorr and H.-W. Schock. *In-situ XRD on formation reactions of Cu<sub>2</sub>ZnSnS<sub>4</sub> thin films*. phys. stat. sol. (c) **6**, 1245-1248 (2009), doi: [10.1002/pssc.200881231](https://doi.org/10.1002/pssc.200881231).
- R. Mainz, R. Klenk and M. Lux-Steiner. *Sulphurisation of gallium-containing thin-film precursors analysed in-situ*. Thin Solid Films **515**, 5934-5937 (2007), doi: [10.1016/j.tsf.2006.12.167](https://doi.org/10.1016/j.tsf.2006.12.167).

## Conference proceedings:

C. A. Kaufmann, D. Greiner, H. Rodriguez-Alvarez, A. Weber, M. D. Heinemann, J. Lauche, M. Klaus, C. Genzel, H. W. Schock and R. Mainz, *Co-evaporation of Cu(In,Ga)Se<sub>2</sub> at Low Temperatures: an In-Situ X-Ray Growth Analysis*, in 39th IEEE Photovoltaic Specialists Conference, 2013.

W. Witte, M. Powalla, D. Hariskos, A. Eicke, M. Botros, H.-W. Schock, D. Abou-Ras, R. Mainz, et al. *Chemical Gradients in Cu(In,Ga)(S,Se)<sub>2</sub> Thin-Film Solar Cells: Results of the GRACIS Project*, in Proc. 27th European Photovoltaic Solar Energy Conference, Frankfurt, 2012, pp. 2166-2173, doi: [10.4229/27thEUPVSEC2012-3BO.4.1](https://doi.org/10.4229/27thEUPVSEC2012-3BO.4.1).

A. Weber, H. Rodriguez, R. Mainz, J. Klaer, P. Pistor, R. Klenk, M. Klaus, A. Meeder, A. Neisser and H. W. Schock, *Fast Cu(In,Ga)Se<sub>2</sub> formation by processing Cu-In-Ga precursors in selenium atmosphere*, in 37th IEEE Photovoltaic Specialists Conference, 2011, pp. 003315-003320 doi: [10.1109/PVSC.2011.6186649](https://doi.org/10.1109/PVSC.2011.6186649).

H. Rodriguez-Alvarez, R. Mainz, R. Scheer and H. Schock, *Reaction paths during the sulfurization of In/Cu-Ga and Cu-In-Ga thin films for the fabrication of Cu(In,Ga)S<sub>2</sub> at different heating rates*, in Proc. 24rd European Photovoltaic Solar Energy Conference, Valencia, 2010, pp. 3BV.2.69, doi: [10.4229/25thEUPVSEC2010-3BV.2.69](https://doi.org/10.4229/25thEUPVSEC2010-3BV.2.69).

S. Merdes, B. Johnson, R. Sáez-Araoz, A. Ennaoui, J. Klaer, I. Lauermann, R. Mainz, A. Meeder and R. Klenk, *Current transport in Cu(In,Ga)S<sub>2</sub> based solar cells with high open circuit voltage - bulk vs. interface*, in Mater. Res. Soc. Symp. Proc., 2009, pp. 1165-M05-15, doi: [10.1557/PROC-1165-M05-15](https://doi.org/10.1557/PROC-1165-M05-15).

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## Book chapters:

P. Pistor, R. Mainz, M. D. Heinemann, T. Unold, R. Scheer (2016), *In situ real-time characterization of thin film growth*, in Advanced Characterization Techniques for Thin Film Solar Cells, (Ed.: D. Abou-Ras, T. Kirchartz and U. Rau), **accepted**.

S. Schorr, C. Stephan, T. Törndahl and R. Mainz, *X-Ray and Neutron Diffraction on Materials for Thin-Film Solar Cells*, in Advanced Characterization Techniques for Thin Film Solar Cells, (Ed.: D. Abou-Ras, T. Kirchartz and U. Rau), Wiley-VCH, 2011, pp. 347–363, doi: [10.1002/9783527636280.ch13](https://doi.org/10.1002/9783527636280.ch13).

## Theses:

R. Mainz, *In-situ Analyse und Wachstum photovoltaischer Absorber mit Bandlückengradienten*. PhD Thesis. Freie Universität Berlin, 2008. [http://www.diss.fu-berlin.de/diss/receive/FUDISS\\_thesis\\_000000009066](http://www.diss.fu-berlin.de/diss/receive/FUDISS_thesis_000000009066)

R. Mainz, *Exklusive Prozesse und Evolution generalisierter Parton-Verteilungen*, Diploma Thesis. Ruhr-Universität Bochum, 2002.

## Project reports:

R. Mainz, D. Greiner, B. Johnson, J. Klaer, R. Klenk, I. Laueremann, M.Ch. Lux-Steiner, S. Merdes, H. Rodriguez-Alvarez, H.W. Schock. *Abschlussbericht KD-CIS-Projekt: Kontrollierte Dotierung im CuInS<sub>2</sub>-System*. (2007-2010). Funded by the German Ministry for Environment (0327589B).

R. Mainz et al. *Abschlussbericht HT-CIGS-Projekt: Entwicklung von Cu(In,Ga)S<sub>2</sub>-Dünnschichtsolarmodulen*. (2010-2012). Funded by the German Ministry for Environment (0327589F).

H. Rodriguez-Alvarez, R. Mainz. *Abschlussbericht GRACIS-Projekt*. Funded by the German Ministry for Research and Education (03SF0359D).

## Patents:

Weber, A.; Mainz, R.; Rodriguez-Alvarez, H.; Lauche, J. & Klaer, J. (2014), 'Vorrichtung zum Einstellen einer Gasphase in einer Reaktionskammer'(DE102012022744 A1), DE Patent App. DE201,210,022,744.