

# PUBLICATIONS

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DR. ROLAND MAINZ

## Publications in peer-reviewed journals:

H. Stange, S. Brunken, D. Greiner, M. D. Heinemann, M. Daniel Antonio Barragan Yani, M. Leonard Alwin Wägele, S. S. Schmidt, M. Jan-Peter Bäcker, C. A. Kaufmann, M. Klaus, R. Scheer, C. Genzel and R. Mainz. *Stacking fault energy as driving force for grain growth in CuInSe<sub>2</sub>*. Submitted (2018).

D. Abou-Ras, M. Bär, R. Caballero, R. Gunder, C. Hages, M. Heinemann, C. Kaufmann, M. Krause, S. Levchenko, R. Mainz, J. Márquez, A. Nikolaeva, A. Redinger, N. Schäfer, S. Schorr, H. Stange, T. Unold and R. Wilks. *Advanced characterization and in-situ growth monitoring of Cu(In,Ga)Se<sub>2</sub> thin films and solar cells*. Solar Energy **170**, 102 - 112 (2018), doi: <https://doi.org/10.1016/j.solener.2018.04.032>.

J. Márquez, H. Stange, C. Hages, N. Schaefer, S. Levchenko, S. Giraldo, P. Pistor, E. Saucedo, K. Schwarzburg, D. Abou-Ras, A. Redinger, T. Unold and R. Mainz. *Chemistry and dynamics of Ge in kesterite: towards band gap graded absorbers*. Chem. Mater. **29**, 9399-9406 (2017), doi: [10.1021/acs.chemmater.7b03416](https://doi.org/10.1021/acs.chemmater.7b03416).

E. Simsek Sanli, Q. M. Ramasse, R. Mainz, A. Weber, D. Abou-Ras, W. Sigle and P. A. van Aken. *Evidence for Cu<sub>2-x</sub>Se platelets at grain boundaries and within grains in Cu(In,Ga)Se<sub>2</sub> thin films*. Appl. Phys. Lett. **111**, 032103 (2017), doi: [10.1063/1.4993917](https://doi.org/10.1063/1.4993917).

E. Simsek Sanli, D. Barragan-Yani, Q. M. Ramasse, R. Mainz, D. Abou-Ras, A. Weber, H.-J. Kleebe, K. Albe and P. A. van Aken. *Point defect segregation at Frank loops in Cu(In,Ga)Se<sub>2</sub> thin-film absorbers*. Phys. Rev. B **95**, 195209 (2017), doi: [10.1103/PhysRevB.95.195209](https://doi.org/10.1103/PhysRevB.95.195209).

M. D. Heinemann, R. Mainzsmain, F. Österle, H. Rodriguez-Alvarez, D. Greiner, C. A. Kaufmann and T. Unold. *Evolution of opto-electronic properties during film formation of complex semiconductors*. Scientific Reports **7**, 45463 (2017), doi: [10.1038/srep45463](https://doi.org/10.1038/srep45463).

S. S. Schmidt, C. Wolf, H. Rodriguez-Alvarez, C. A. Kaufmann, J.-P. Bäcker, M. Hartig, S. Merdes, F. Ziem, I. Dorbandt, C. Köble, S. Cinque, D. Abou-Ras, R. Mainz and R. Schlatmann. *Fast Atmospheric Processing of Cu(In,Ga)Se<sub>2</sub> Solar Cell Absorber Layers Using Elemental Selenium Vapor*. Progress in Photovoltaic **25**, 341-357 (2017), doi: [10.1002/ppp.2865](https://doi.org/10.1002/ppp.2865).

J.-P. Bäcker, S. S. Schmidt, H. Rodriguez-Alvarez, M. Hartig, C. A. Kaufmann, C. Wolf, R. Mainz and R. Schlatmann. *Lateral phase separation in Cu-In-Ga precursor and Cu(In,Ga)Se<sub>2</sub> absorber thin films*. Sol. Energy Mater. Sol. Cells **162**, 120-126 (2017), doi: [10.1016/j.solmat.2016.12.034](https://doi.org/10.1016/j.solmat.2016.12.034).

M. Olgar, J. Klaer, R. Mainz, L. Ozyuzer and T. Unold. *Cu<sub>2</sub>ZnSnS<sub>4</sub>-based thin films and solar cells by rapid thermal annealing processing*. Thin Solid Films **628**, 1-6 (2017), doi: [10.1016/j.tsf.2017.03.008](https://doi.org/10.1016/j.tsf.2017.03.008).

R. Mainz, E. Simsek Sanli, H. Stange, D. Azulay, S. Brunken, D. Greiner, S. Hajaj, M. D. Heinemann, C. A. Kaufmann, M. Klaus, Q. M. Ramasse, H. Rodriguez-Alvarez, A. Weber, I. Balberg, O. Millo, P. A. van Aken and D. Abou-Ras. *Annihilation of structural defects in chalcogenide absorber films for high-efficiency solar cells*. Energy Environ. Sci. **9**, 1818-1827 (2016), doi: [10.1039/c6ee00402d](https://doi.org/10.1039/c6ee00402d).

**HZB Press Release:** [Thin-film solar cells: how defects appear and disappear in CIGSe-cells](#).

H. Stange, S. Brunken, D. Greiner, M.-D. Heinemann, C. A. Kaufmann, S. S. Schmidt, J.-P. Bäcker, M. Klaus, C. Genzel and R. Mainz. *Diffusion-induced grain boundary migration as mechanism for grain growth and defect annihilation in chalcopyrite thin films*. Acta Materialia **111**, 377-384 (2016), doi: [10.1016/j.actamat.2016.03.073](https://doi.org/10.1016/j.actamat.2016.03.073).

E. Simsek Sanli, Q. M. Ramasse, W. Siegle, D. Abou-Ras, R. Mainz, A. Weber, H.-J. Kleebe and P. A. van Aken. *Elemental redistributions at structural defects in Cu(In,Ga)Se<sub>2</sub> thin films for solar cells*. J. Appl. Phys. **120**, 205301 (2016), doi: [10.1063/1.4967731](https://doi.org/10.1063/1.4967731).

**Featured article.**

D. Abou-Ras, S. S. Schmidt, N. Schäfer, J. Kavalakkatt, T. Rissom, T. Unold, R. Mainz, A. Weber, T. Kirchartz, E. Simsek Sanli, P. A. van Aken, Q. M. Ramasse, H.-J. Kleebe, D. Azulay, I. Balberg, O. Millo, O. Cojocaru-Mirédin, D. Barragan-Yani, K. Albe, J. Haarstrich and C. Ronning. *Compositional and electrical properties of line and planar defects in Cu(In,Ga)Se<sub>2</sub> thin films for solar cells – a review*. physica status solidi (RRL) – Rapid Research Letters (2016), doi: [10.1002/pssr.201510440](https://doi.org/10.1002/pssr.201510440).

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).

M. Olğar, J. Klaer, R. Mainz, S. Levenco, J. Just, E. Bacaksız and T. Unold. *Effect of Precursor Stacking Order and Sulfurization Temperature on Compositional Homogeneity of CZTS Thin Films*. Thin Solid Films **615**, 402-408 (2016), doi: [10.1016/j.tsf.2016.07.058](https://doi.org/10.1016/j.tsf.2016.07.058).

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).

R. Mainz, A. Weber, H. Rodriguez-Alvarez, S. Levencu, 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).

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).

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).

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, 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).

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).

H. Rodriguez-Alvarez, A. Weber, J. Lauche, C. A. Kaufmann, T. Rissom, D. Greiner, M. Klaus, T. Unold, C. Genzel, H.-W. Schock and R. Mainz. *Formation of CuInSe<sub>2</sub> and CuGaSe<sub>2</sub> thin-films deposited by three-stage thermal co-evaporation: a real-time X-ray diffraction and fluorescence study*. Adv. Energy Mater. **3**, 1381-1387 (2013), doi: [10.1002/aenm.201300339](https://doi.org/10.1002/aenm.201300339).  
**HZB Press Release:** [Watching Solar Cells Grow](#).

- 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  $\text{Cu}_2\text{ZnSn}(\text{S},\text{Se})_4$  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).
- C. Streeck, S. Brunken, M. Gerlach, C. Herzog, P. Hönicke, C. Kaufmann, J. Lubeck, B. Pollakowski, R. Unterumsberger, A. Weber, B. Beckhoff, B. Kanngießner, H.-W. Schock and R. Mainz. *Grazing-incidence X-ray fluorescence analysis for non-destructive determination of In and Ga depth profiles in  $\text{Cu}(\text{In},\text{Ga})\text{Se}_2$  absorber films*. Appl. Phys. Lett. **103**, 113904 (2013), doi: [10.1063/1.4821267](https://doi.org/10.1063/1.4821267).
- H. Rodriguez-Alvarez, N. Barreau, C. Kaufmann, A. Weber, M. Klaus, T. Painchaud, H.-W. Schock and R. Mainz. *Recrystallization of  $\text{Cu}(\text{In},\text{Ga})\text{Se}_2$  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  $\text{Cu}(\text{In},\text{Ga})\text{Se}_2$ : 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.  *$\text{CdS}/\text{Cu}(\text{In},\text{Ga})\text{S}_2$  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).
- R. Mainz and R. Klenk. *In situ analysis of elemental depth distributions in thin films by combined evaluation of synchrotron X-ray fluorescence and diffraction*. J. Appl. Phys. **109**, 123515 (2011), doi: [10.1063/1.3592288](https://doi.org/10.1063/1.3592288).
- S. Merdes, R. Mainz, J. Klaer, A. Meeder, H. Rodriguez-Alvarez, H. Schock, M. Lux-Steiner and R. Klenk. *12.6% efficient  $\text{CdS}/\text{Cu}(\text{In},\text{Ga})\text{S}_2$ -based solar cell with an open circuit voltage of 879 mV prepared by a rapid thermal process*. Sol. Energy Mater. Sol. Cells **95**, 864-869 (2011), doi: [10.1016/j.solmat.2010.11.003](https://doi.org/10.1016/j.solmat.2010.11.003).
- T. Rissom, R. Mainz, C. A. Kaufmann, R. Caballero, V. Efimova, V. Hoffmann and H.-W. Schock. *Examination of growth kinetics of copper rich  $\text{Cu}(\text{In},\text{Ga})\text{Se}_2$ -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).
- D. Thomas, R. Mainz, H. Rodriguez-Alvarez, B. Marsen, D. Abou-Ras, M. Klaus, C. Genzel and H.-W. Schock. *In-situ studies of the recrystallization process of  $\text{CuInS}_2$  thin films by energy dispersive X-ray diffraction*. Thin Solid Films **519**, 7193-7196 (2011), doi: [10.1016/j.tsf.2010.12.229](https://doi.org/10.1016/j.tsf.2010.12.229).
- S. Merdes, R. Mainz, H. Rodriguez-Alvarez, J. Klaer, R. Klenk, A. Meeder, H. W. Schock and M. C. Lux-Steiner. *Influence of precursor stacking on the absorber growth in  $\text{Cu}(\text{In},\text{Ga})\text{S}_2$  based solar cells prepared by a rapid thermal process*. Thin Solid Films **519**, 7189-7192 (2011), doi: [10.1016/j.tsf.2011.01.397](https://doi.org/10.1016/j.tsf.2011.01.397).
- S. Schorr, C. Stephan, R. Mainz, H. Rodriguez-Alvarez and M. Tovar. *Neutrons and photons in materials research for thin film solar cells*. Adv. Eng. Mater. **13**, 737-741 (2011), doi: [10.1002/adem.201000290](https://doi.org/10.1002/adem.201000290).
- R. Klenk, J. Klaer, C. Köble, M. Lux-Steiner, R. Mainz, S. Merdes, H. Rodriguez-Alvarez, R. Scheer and H. Schock. *Development of  $\text{CuInS}_2$ -based solar cells and modules*. Sol. Energy Mater. Sol. Cells **95**, 1441-1445 (2011), doi: [10.1016/j.solmat.2010.11.001](https://doi.org/10.1016/j.solmat.2010.11.001).
- D. Abou-Ras, R. Caballero, C.-H. Fischer, C. Kaufmann, I. Laueremann, 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**

C. Genzel, I. A. Denks, R. Coelho, D. Thomas, R. Mainz, D. Apel and M. Klaus. *Exploiting the features of energy-dispersive synchrotron diffraction for advanced residual stress and texture analysis*. J. Strain Anal. Eng. Des. **46**, 615-625 (2011), doi: [10.1177/0309324711403824](https://doi.org/10.1177/0309324711403824).

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).

I. Riedel, J. Riediger, J. Ohland, J. Keller, M. Knipper, J. Parisi, R. Mainz and S. Merdes. *Photoelectric characterization of Cu(In,Ga)S<sub>2</sub> solar cells obtained from rapid thermal processing at different temperatures*. Sol. Energy Mater. Sol. Cells **96**, 270-273 (2011), doi: [10.1016/j.solmat.2010.05.013](https://doi.org/10.1016/j.solmat.2010.05.013).

A. Weber, R. Mainz and H. W. Schock. *On the Sn loss from thin films of the material system Cu-Zn-Sn-S in high vacuum*. J. Appl. Phys. **107**, 013516 (2010), doi: [10.1063/1.3273495](https://doi.org/10.1063/1.3273495).

H. Rodriguez-Alvarez, R. Mainz, B. Marsen, D. Abou-Ras and H. W. Schock. *Recrystallization of Cu-In-S thin films studied in situ by energy-dispersive X-ray diffraction*. J. Appl. Cryst. **43**, 1053-1061 (2010), doi: [10.1107/S0021889810025860](https://doi.org/10.1107/S0021889810025860).

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).

R. Mainz, F. Streicher, D. Abou-Ras, S. Sadewasser, R. Klenk and M. C. Lux-Steiner. *Combined analysis of spatially resolved electronic structure and composition on a cross-section of a thin film Cu(In<sub>1-x</sub>Ga<sub>x</sub>)S<sub>2</sub> solar cell*. phys. stat. sol. (a) **206**, 1017-1020 (2009), doi: [10.1002/pssa.200881216](https://doi.org/10.1002/pssa.200881216).

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:

R. Mainz, H. Stange, C. A. Kaufmann. *Defect Annihilation by Preferential Grain Growth during Cu(In,Ga)Se<sub>2</sub> Co-evaporation*, in 7th World Conference on Photovoltaic Energy Conversion, Hawaii, 2018.

S. Levchenko, C. J. Hages, S. H. Hadke, H. Stange, R. Mainz, L. H. Wong, R. Agrawal, T. Unold. *Modulation spectroscopy characterization of Cu based chalcopyrites and kesterites*, in 7th World Conference on Photovoltaic Energy Conversion, Hawaii, 2018.

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).

S. Merdes, R. Kaigawa, J. Klaer, R. Klenk, R. Mainz, A. Meeder, N. Papathanasiou, D. Abou-Ras and S. Schmidt, *Increased open circuit voltage in Cu(In,Ga)S<sub>2</sub> based solar cells prepared by rapid thermal processing of metal precursors*, in Proc. 23rd European Photovoltaic Solar Energy Conference, Valencia, 2008, pp. 2588-2591, doi: [10.4229/23rdEUPVSEC2008-3BV.5.1](https://doi.org/10.4229/23rdEUPVSEC2008-3BV.5.1).

H. Rodriguez-Alvarez, R. Mainz, A. Weber, B. Marsen and H. Schock, *Copper Sulfide Assisted Recrystallization of Cu-poor CuInS<sub>2</sub> Observed in-situ by Polychromatic X-ray Diffraction*, in Mater. Res. Soc. Symp. Proc., 2009, pp. 1165-M02-07.

R. Hesse, H. Rodriguez-Alvarez, R. Mainz, J. Lauche, P. Herdin, D. Abou-Ras, T. Unold and H.-W. Schock, *In-situ monitoring of rapid thermal processes (RTP) of Cu(In,Ga)(S,Se)<sub>2</sub> by optical methods*, in Proc. SPIE 7045, 2008, pp. 704505, doi: [10.1117/12.794489](https://doi.org/10.1117/12.794489).

R. Mainz, J. Klaer, R. Klenk and N. Papathanasiou, *Solar cells based on Cu(In,Ga)S<sub>2</sub> prepared by a two-step process*, in Proc. 22nd European Photovoltaic Solar Energy Conference, Milan, 2007, pp. 2429-2433.

#### 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. Lauermann, 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 Reserach and Education (03SF0359D).

**Patents:**

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

M. D. Heinemann, T. Unold, R. Mainz. (pending), '*Verfahren zur optischen in-situ-Kontrolle zumindest einer auf einem Substrat aufwachsenden Schicht aus Verbindungshalbleitern*' (DE102015115117.0)