

# SOLAR ENERGY RESEARCH AT HELMHOLTZ-ZENTRUM BERLIN

The main goal is the development of future generations of cost-effective thin-film solar cells and of systems to produce fuels such as hydrogen by direct photoelectrochemical conversion of solar radiation into chemical energy. To reach this objective, research is focused on achieving high efficiencies and substantial reductions in the costs of solar power generation. Translating the fundamental research results at HZB into industrial applications is the purview of PVcomB. PVcomB's main goal is to support worldwide growth of thin-film photovoltaic technologies and products by providing top level technology transfer.

## Three Key-Missions

- Keeping the balance between improving existing thin-film technologies to a stage where industrial applications can follow as the next step while also exploring new materials and new concepts for future devices for solar cells.
- Basing scientific and technological progress upon both empirical work and basic research, taking into account fundamental aspects which are becoming increasingly important for the design of innovative nano-technological materials and devices.
- Applying outstanding analytical tools for investigating materials, cells and modules. The combination of two large-scale facilities – the Berlin Synchrotron Radiation Source (BESSY II) and the Berlin Neutron Research Reactor (BER II) – make the Helmholtz-Zentrum Berlin für Materialien und Energie (HZB) a unique research partner within the scientific community.

# HELMHOLTZ-ZENTRUM BERLIN (HZB)

Besides the particular competence in Solar Energy Research, HZB is one of the few centres world-wide to offer the whole range of instruments for neutron and synchrotron radiation within one laboratory structure. The HZB operates two scientific large scale facilities for investigating the structure and function of matter: the research reactor BER II for experiments with neutrons and the synchrotron radiation source BESSY II, producing an ultrabright photon beam ranging from Terahertz to hard X-rays.

## HZB Quick Facts

- Approximately 1,100 staff (800 at Wannsee and 300 at Adlershof)
- Total budget of about 110 million Euros
- About 100 doctoral candidates from neighbouring universities
- HZB cooperates with more than 400 partners at German and international universities, research institutions and in companies.

## Contact Advanced Analytics and Modelling

### Advanced surface and interface analysis

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### Charge carrier dynamics

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### Device and material characterisation

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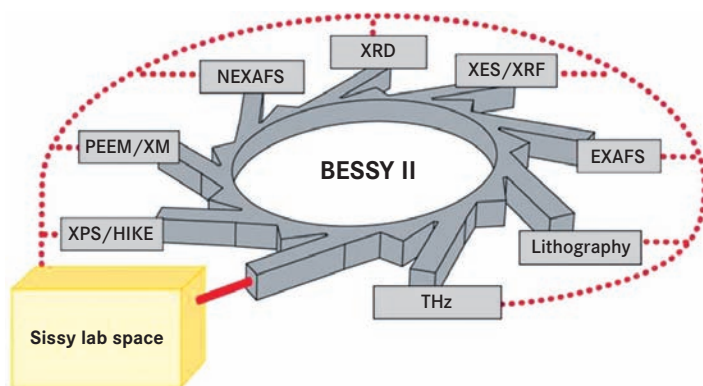


## ADVANCED ANALYTICS AND MODELLING

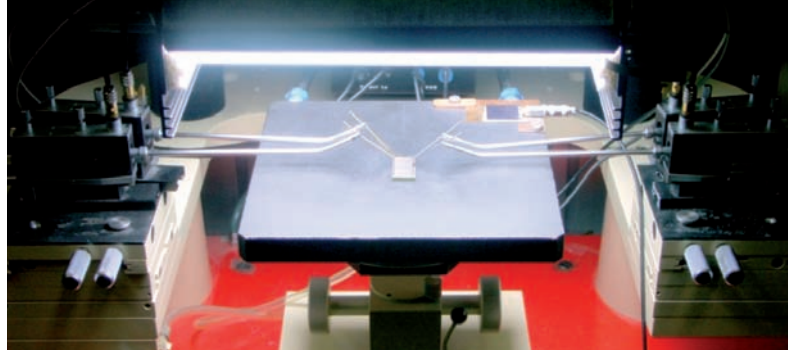
Solar Energy Research

# ADVANCED ANALYTICS AND MODELLING

Optimum performance of solar cells currently in production and future solar cell concepts can only be achieved with the aid of advanced simulation and characterization tools. Dedicated tools are mandatory to monitor the physical processes that capture, store and release energy and thereby assist strategies to control these processes in tomorrow's pv devices. HZB's large-scale facilities – the Berlin Neutron Research Reactor (BER II) and Berlin Synchrotron Radiation Source (BESSY II) in combination with dedicated analytical labs at the centre provide unique research facilities that combine neutrons and photons for pv research from the surface deep into the bulk of the sample.



A new addition to the analytics portfolio will be the Sissy lab space. Here, in-situ growth, interface- and defect studies will be enhanced by synchrotron based spectroscopic methods. The facility Sissy (Solar Energy In Situ Laboratory at the Synchrotron) will complement and support the existing experiments for chalcopyrite semiconductor (CIGSe) interface engineering and film growth (CISSY and EDDI-beamline) and will enable the national and international silicon PV community to overcome limitations in diagnostics of interface and material properties existing today.



## Advanced surface and interface analysis

A variety of surface-sensitive methods are in use at the HZB, including photoemission spectroscopy, scanning probe microscopy methods and highly sophisticated electron microscopy, combined with chemical microanalysis and ion beam milling. Some dedicated systems, mostly located at BESSY II to utilize synchrotron radiation, allow in-system preparation and analysis, avoiding sample contamination. Major tools are:

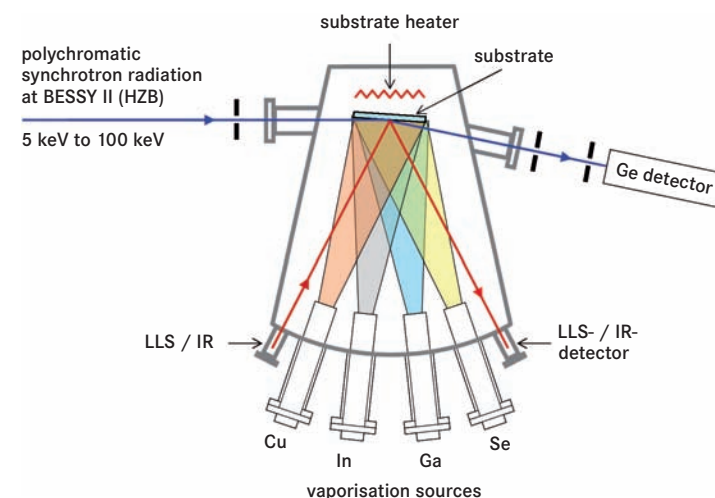
- Photoemission (PES) and Inverse Photoemission (IPES)
- X-ray Emission Spectroscopy (XES)
- Hard X-ray Photoemission Spectroscopy (HAXPES)
- Angle Resolved Ultraviolet Photoelectron Spectroscopy (ARUPS)
- Photoemission Electron Microscopy (PEEM)
- Scanning Probe Microscopy (SPM, KPFM)
- Electron Microscopy (REM, TEM)
- Sissy (details on the left)

## Charge carrier dynamics

HZB has established state-of-the-art analytical tools and expertise to investigate the dynamic processes of excited charge carriers. Femtosecond pump-probe transient absorption in the 0.5–5eV and the GHz to THz energy range is used to monitor carrier cooling, exciton migration, charge separation, and recombination in inorganic and organic materials. Femtosecond time-resolved 2-photon photoemission (2PPE) measures the energetic relaxation of carriers at the surface. In the ps-s time range, photoluminescence, surface photovoltage, microwave reflectivity, admittance spectroscopy are available. Cutting edge pulsed electrically and optically detected magnetic resonance (ODMR/EDMR) techniques are employed to study the faith of charge carriers at interfaces and in disordered materials.

## Microstructure and defect analysis

The performance of thin-film photovoltaic materials crucially depends on their microstructure electronic defects. HZB's large scale facilities allow research at the forefront of photovoltaic materials science to investigate growth kinetics and paths of thin films using in-situ energy dispersive X-ray diffraction (EDXRD), or to reveal cation disorder in compound semiconductors by using high resolution neutron diffractometry. The genesis and structure of device limiting defects in pv materials and devices is explored in HZB's electron paramagnetic resonance (EPR)/EDMR centre equipped with one of it's kind instrumentation.



## Device and material characterisation

In addition to standard device characterisation of I-V characteristics (sun simulator) and spectral response there are a number of techniques available at the HZB for making more detailed analyses. Imaging the infrared emission (IR thermography), luminescence and locally excited currents (EBIC/LBIC) allows inhomogeneities in solar cells to be assessed on a micrometer scale. One-dimensional electronic device models are used to foster our understanding of the performance-determining factors of thin-film heterojunction solar cells and to more precisely evaluate complex electronic measurements, such as admittance spectroscopy. Researchers in this field have developed and published its own code (AFORS-HET) to carry out such calculations.