



## Thin Films

## Helmholtz-Zentrum Berlin für Materialien und Energie GmbH

<b>Location of the infrastructure :</b>	Berlin, Germany	<a href="http://www.helmholtz-berlin.de/forschung/enma/si-pv/methoden/defektanalytik/esr/index_en.html">http://www.helmholtz-berlin.de/forschung/enma/si-pv/methoden/defektanalytik/esr/index_en.html</a>
<b>Contact person :</b>	Dr. Alexander Schnegg	Phone : ++49 30 806241373 E-mail : <a href="mailto:alexander.schnegg@helmholtz-berlin.de">alexander.schnegg@helmholtz-berlin.de</a>

<b>Objectives :</b>	<p>The Electron Paramagnetic Resonance Facility at HZB (EPR@HZB) allows for the characterization of paramagnetic states such as many known defects in materials implemented in solar cells. One of the most prominent defects characterized by this technique are broken silicon bonds, (dangling bonds) in thin-film silicon, c-Si and <math>\mu</math>-Si. The unique feature of the EPR analysis is that defects and impurities in semiconductor materials can be quantified at levels as low as <math>10^{13}/\text{cm}^3</math> depending on the specific nature of the paramagnetic specimen involved. The EPR signature allows a microscopic identification of the involved specimen through their characteristic EPR fingerprint.</p>
<b>Main features :</b>	<p>EPR@HZB has several spectrometers covering the microwave frequencies from 9 GHz up to 263 GHz with multi-frequency options such as ENDOR (Electron Nuclear Double Resonance). Typical samples sizes suitable for EPR measurements are <math>4 \times 10 \times 4 \text{ mm}^3</math>.</p>
<b>Limitations or constraints :</b>	<p>EPR characterization is generally limited to paramagnetic states or defects. It is routinely used to characterize powder samples relevant for pv applications like non-crystalline silicon of varying morphology but also organic pv blends. Characterization of fully processed solar cell structures by electrically or optically detected EPR is feasible, but requires special sample structures.</p>
<b>Typical services or results :</b>	<p>EPR@HZB is regularly used for the characterization of silicon and organic solar cells and their components, for surface analysis of silicon and has applications in related fields such as physical chemistry (catalysts for solar fuel production) and biology (Photosynthesis). Typical examples of PV applications are the determination of the defect density in thin-film Si absorber layers or measurement of impurity concentration (e.g. phosphorous, metals) in crystalline silicon. Apart from the Institute of Silicon Photovoltaics, which runs the facility, numerous other groups in the field of thin-film PV are involved in using this equipment, mainly from research institutions in Germany through the network project EPR-Solar but also from the PV industry and from partners in Spain, Switzerland, France, Netherlands, the Czech Republic, and the US.</p>
<b>Examples of research projects :</b>	<p>EPR applications to PV materials are described in more details on our web page: <a href="http://www.helmholtz-berlin.de/forschung/enma/si-pv/methoden/defektanalytik/esr/index_en.html">http://www.helmholtz-berlin.de/forschung/enma/si-pv/methoden/defektanalytik/esr/index_en.html</a></p>