Summary of progress in first six months

Highlights

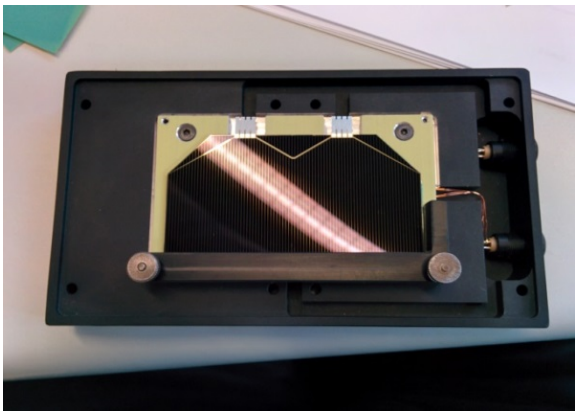
In WP1, single-junction, dual-junction, as well as triple-junction, structures lattice-matched to GaAs have been designed, fabricated and distributed to all partners for determining the complete material properties layer by layer. Similar junctions fabricated by MOVPE and MBE will be compared. Initial Scanning Kelvin Probe results have been acquired.

To measure the reflected light from the antireflection coating, a high gain, low noise and traceable transimpedance amplifier has been developed for measuring photo detector currents with a resolution of 10 fA with an adjustable gain from 10^3 to 10^{11}.

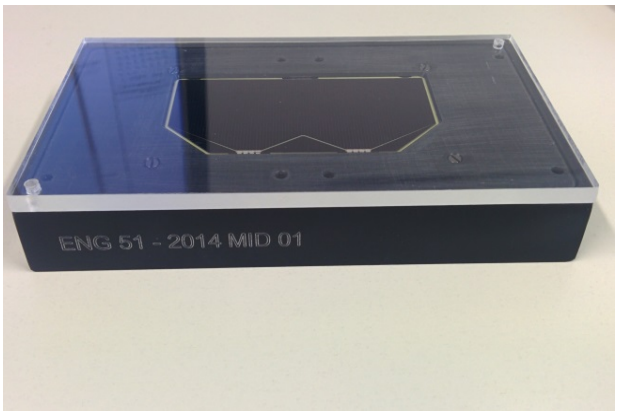
In WP2, a newly designed assembly for solar cells allows the reproducible calibration of triple junction solar cells and their corresponding component. The assembly further allows the safe transfer between different test laboratories.

The component cells were calibrated with laser-based differential spectral responsivity (laser-DSR) measurements traced to irradiance standards and under simulated sunlight against balloon flight traced component solar cell standards.

We have successfully reduced the relative measurement uncertainty of the short circuit current under standard test conditions (I_{STC}) of the top and middle component cells to 0.5%, the I_{STC} of bottom cells were calibrated with a measurement uncertainty of 1%.



Assembly of Solar Cells for characterization



Final Solar cell sample

Effective cooperation

The JRP includes a team with different, yet complementary, expertise, to focus on specific aspects in III-V material solar cell development and calibration. In practice, different JRP Partners will are making comparative measurements to establish the accuracy of the metrological tools and methodologies used.

From the beginning of the project, the cooperation between the JRP-Participants is effective with close collaboration between the partners to define sample structure and visit between laboratories to establish standard operating procedures.

The challenges addressed in this JRP are multidisciplinary in nature and involve the combined talents of NMIs, the industrial JRP-Partners and the Researcher Excellence Grants which have broad experience and expertise in the complementary areas needed to ensure the success of this project. It is obvious that a complete characterization of the constitute layers of the multi-junction solar cell leading to the understanding of the key physical mechanisms behind the high conversion efficiency could not be done without a strong collaboration between the JRP partners.

Scientific excellence

Even if the JRP is at a beginning stage, some progress beyond the state of the art has already been achieved.

A low noise, high gain transimpedance amplifier for measuring photo detector currents with a resolution of 10 fA has been developed. This development based on a metrological approach is already available for purchase and it is sold on 'store.hasseb.fi'.

Initial electrical characterisation results

For the nanoscale electrical characterization, three techniques will be used and compared: Scanning Spreading Resistance (SSRM), Scanning Microwave Microscopy (SMM) and Scanning Kelvin Probe Microscopy - with and without photoexcitation.

An example of the initial scanning Kelvin probe results is shown in Figure 1 below.

The GaInP/GaAs tandem junction cell was grown by chemical vapour deposition at the Fraunhofer ISE Freiburg. The sample cross-section was obtained by cleaving; no polishing was done at this stage.

The AFM topography and SKPM image are presented in Fig 1(a) and (b), correspondingly. The large feature present in the topography had almost no effect on SKPM imaging. However, the cross-talk from the small oval protrusion was more pronounced. We were able to recognise n-GaInP emitter, p-GaInP base and n-GaAs cap layers. The contrast corresponding to the bottom GaAs cell appeared to be not as clear at this point.

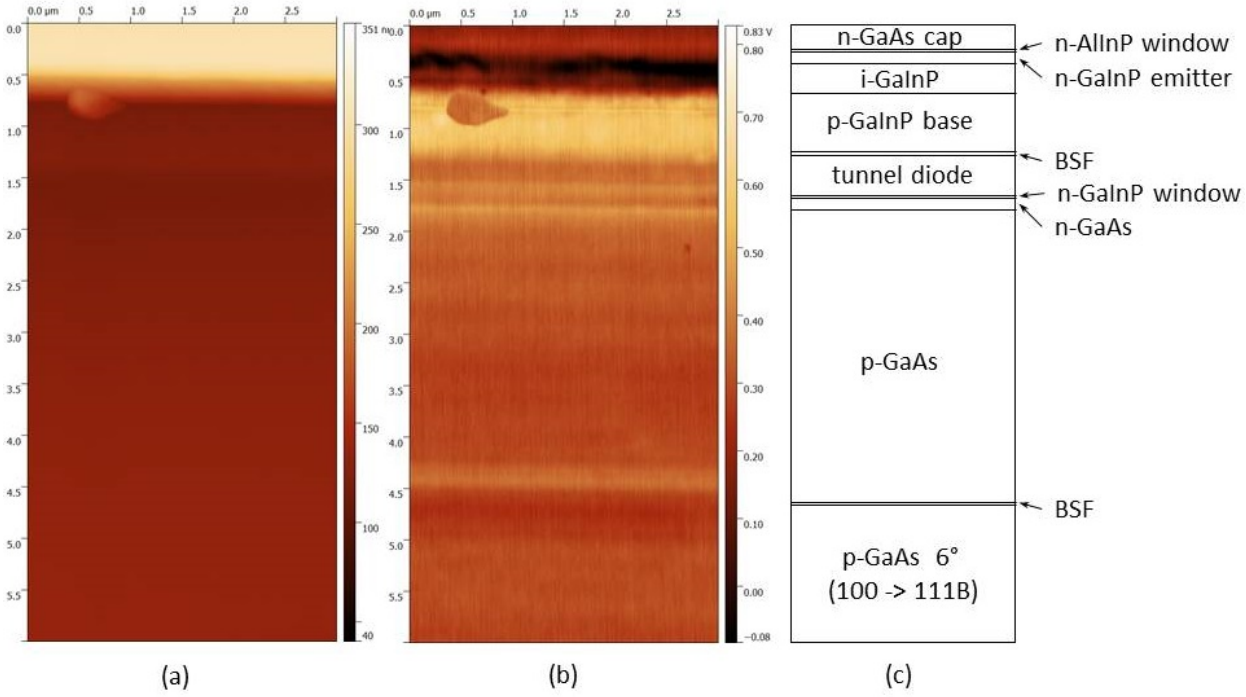


Fig 1 Cross-section of GaInP/GaAs tandem-junction cell: AFM topography image (a), corresponding SKPM image (b), and schematic structure (c)

Figure 2 demonstrates the sensitivity of the set-up to photoexcitation. At this stage the sample illumination was done by a standard light source. Upon switching on the light, we observed an instant fall in the potential profile corresponding to the GaInP cell. The very same effect was recorded also in the single-junction GaInP cell. However, no light response was detected from the GaAs cell. Preliminary results and a overview of the project were presented at the MRS Spring Meeting 2015.

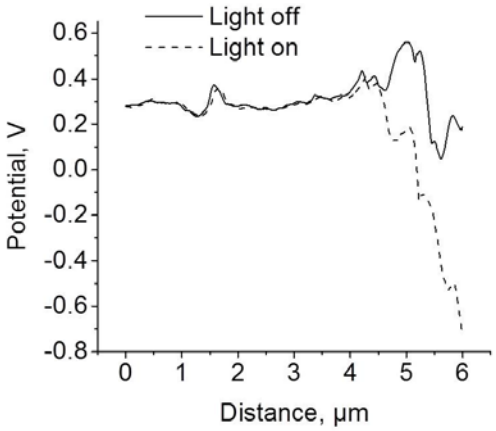


Fig 2: Potential profiles of GaInP/GaAs tandem-junction cell taken with and without illumination

Traceable characterisation of cells

Our aim is to establish new calibration methods for multi junction solar cells, as well as component cells.

Azur Space delivered state-of-the-art components, as well as multi-junction solar cells to support the project. Housings for reproducible measurements had to be developed for these bare solar cells. PTB Braunschweig investigated in detail the properties of the housing; a solution for stable temperature control, as well as reproducible sample contact has been developed - see Figure 3:

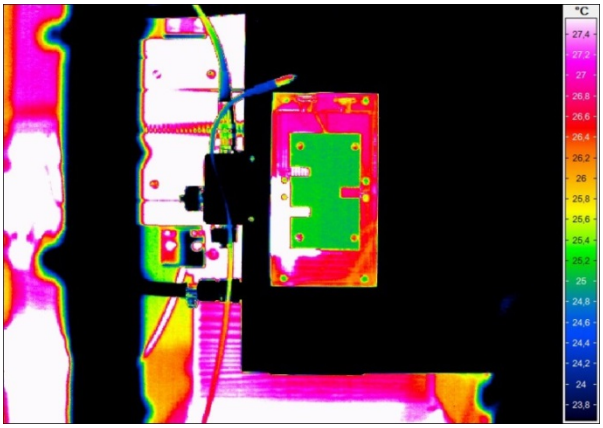


Fig 3: Thermal image of sample holder heat distribution

PTB Braunschweig performed beyond state-of-the-art calibrations on component cells with their laser based differential spectral responsivity setup leading to a significant reduction of the measurement uncertainty of the photo current of such cells (see Figure 5).

INTA performed high precision calibrations with multi source sun simulator to complete the experiments. It is planned to present the promising results at this year's EU-PVSEC, a photovoltaic conference reaching an audience of 3,000 people of the field.

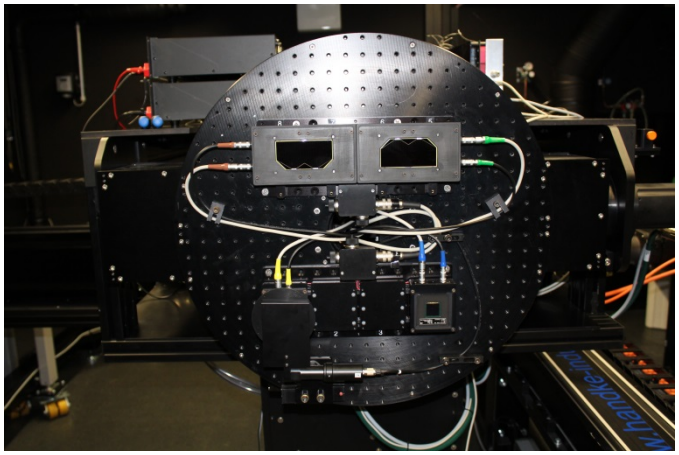


Fig 4: Solar cells mounted at laser-DSR setup

Tubitak UME has developed a new set-up to measure the differential spectral responsivity of solar cells. INTA and PTB Braunschweig will continue their experiments on characterization of component multi junctions, as well as their efforts on establishing a direct calibration.

Both measurement techniques are exclusive to each partner so that this comparative study is only possible within this JRP. Results of these deliverables will be presented at 2015th EU-PVSEC conference in Hamburg.