ENG51 SolCell: http://projects.npl.co.uk/solcell/

Summary of progress over the period June – December 2016

Highlights

In WP1, Ellipsometric modelling has been performed by REG(CEA) on single and dual FhG solar cells. Results show a general good agreement with expected thickness values but highlights the poor sensitivity of ellipsometry to thin buried layers in the case of very complex stacks such as dual junctions. In the meantime the temperature dependence of the optical constants of AlGaAs layers has been extracted from ellipsometry measurements between 20 and 220°C.
MIKES has developed a method to determine temperature-invariant band gap energy for III-V optosemiconductors. The results will lead to two peer reviewed scientific articles. The method has been verified to work with all III-V optosemiconductor compounds. The spectral responsivity and normalized emission spectrum for the GaAs/GaInP solar cell have been obtained.
METAS has demonstrated that a 50 nm lateral resolution could be achieved by scanning across a tunnel diode (width <50 nm) in TAN sample provided by FhG. An algorithm based on three known standards has been developed. This allows one to extract dopant densities of semiconductor layers. For proper references, the accuracy can be even below 10%. In the continuation of the successful SMM based measurements carried out by LNE, METAS and Keysight on GaAs staircase dopant density sample fabricated by REG(CNRS), dopant densities have been determined by METAS and compared them to SIMS results obtained by REG(CEA). Results obtained with the two techniques are in good agreement. A paper describing the results is in preparation and will be submitted soon to a peer reviewed journal. A thermal model of transport between the layers of III-V MJSC has been developed at NPL. Based on the available data for thermal conductivity of the different materials, it was predicted than no significant thermoelectric energy recover would be possible in the MJSC.
Based on the previous model published in 2016, REG(CNRS) has performed extensive simulations on different types of tunnel junction structures. The band structure modification due to the high doping was highlighted and its effect of the tunnel mechanism was quantitatively evaluated. The improved simple model was confronted and shows good agreement both with experimental measurements and with a full quantum model (developed by IM2NP Marseilles). A paper has been submitted to a peer reviewed journal.

In WP2, the hard- and software development at PTB of the LED based sun simulator were finished. Characterization experiments on this new device were started which show promising first results and the investigation of 3J-MJSC with this device began. The results from the previous measurement campaigns at PTB, INTA Spasolab and TUBITAK were compared and are found largely consistent. TUBITAK UME is now capable in determining the differential spectral responsivity of Component as well as limiting junctions in Multi Junction Solar Cells. INTA Spasolab and PTB showed that they are capable of comparable precision calibrations of Multi Junction solar cells as well as component cells.

In WP3, optical properties of GaInAsN test structures fabricated by REG(CNRS) have been determined by REG(CEA) from measurements based on spectroscopic ellipsometry. NPL has built a rig to measure electronic noise in sample a function of temperature. However, the precision of the set-up was relatively poor and the temperature can only by measure with an uncertainty of about 10% at room temperature. This uncertainty is too high and prevents the observation of potential thermal effect in MJSC.

Two additional Si implantations into ternary AlGaAs matrices with different Al content were analyzed by PTB with GIXRF in addition to the already analyzed ion implantations into III-V matrices.

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

In WP1/WP3, Keysight, LNE and METAS continue to jointly work to evaluate results, replicate results and interpret results, thus increasing confidence in results on SMM based measurements. The fruitful collaboration around REG(CNRS) staircase sample has been led to determine the active dopant concentrations of doped GaAs multilayer structures. This helped a calibration of the SMM technique using SIMS results of REG(CEA) to get active dopant concentrations in multi-layer structures. The algorithm developed to extract dopant densities is an innovation going beyond state of the art. Furthermore to our knowledge no SMM results on GaAs-based semiconductors have been published to date. Consequently a joint publication presenting the algorithm and the measurements on the GaAs sample A457 is planned.

The MIKES results on the developed method to determine temperature-invariant band gap energy for III-V optosemiconductors will lead to two peer reviewed scientific articles.

PTB published two papers with SolCell related content in the last reporting period. The first one is dedicated to the experimental determination of the oxygen K-shell fluorescence yield using thin SiO2 and Al2O3 foils while the second deals with the determination of X-ray fluorescence fundamental parameters relevant for the quantification.

In WP2, The LED based sun simulator will enable a combined spectrally resolved as well as integral analysis of the MJSC under test. Hereby innovative calibration methods for MJSC can be examined and compared against classic methods.