Scalable and low cost Back End Of Line technologies for production of III-V solar cells

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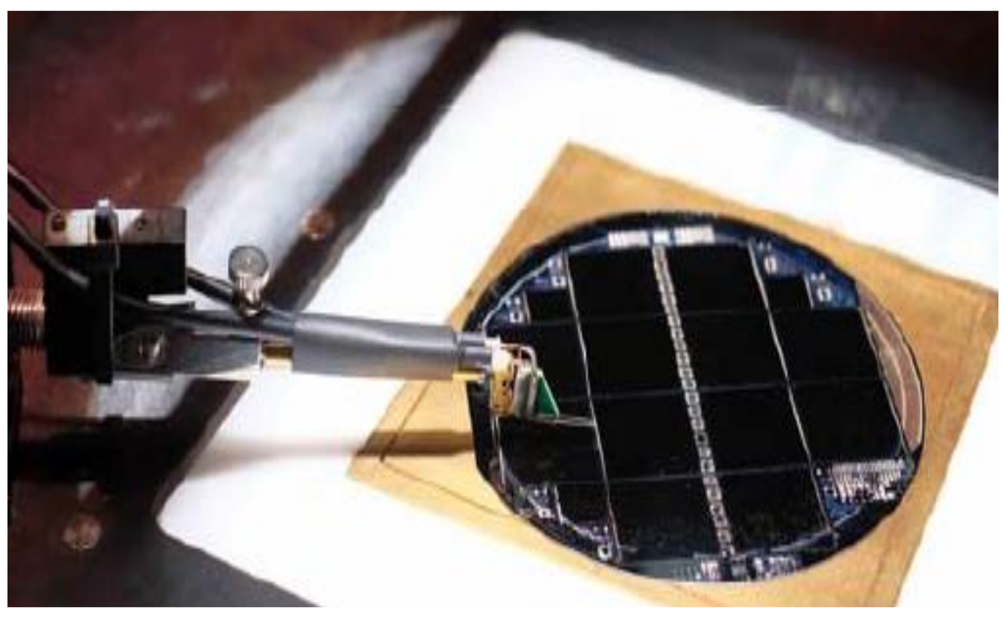
The Task

III-V compound-based solar cells reveal the highest efficiency among the other commercial solar cells. However, up to this date III-V devices are produced by using comparatively costly processes. Thus, in order to make these devices wining competitors to other commercial photovoltaics, a reduction in their high manufacturing costs is essential.

Low cost back-end of the line BEOL processes such as Aerosoljet printing and inkjet printing methods for deposition of front electrodes are capable replacements for expensive standard front contact processes like photolithography and metal evaporation.

Joanneum Research investigates these low-cost methods to make them applicable as low cost large scale BEOL processes that are suitable for replacing current expensive standard processes.



Task Goals

Main task of the activities is the development of industrially scalable low cost processes for the front contact grid and anti-reflection coating for III-V/Si tandem solar cells. In particular, the following specifications are targeted:

- Total series resistance of electrodes < 1 Ohm cm²
- Less than 2% of the front side area is shaded by electrodes and the reflection losses are < 4% (spectral average).
- Developed processes are industrially scalable and comprise no photolithography. Only non-critical materials in particular with respect to environmental impact are used.

Results

In order to manufacture printed conductors with satisfying conductivity and Ohmic contact to the wafer, for each printing method, suitable inks were employed.

For Inkjet printing, a metallic nanoparticle ink was used. The size of metallic nanoparticles in the range of nanometers provides the ink with the ability to be inkjet-printed and also decreases the nanoparticle melting point to a lower temperature compared to their bulk forms, thereby reducing manufacturing costs. Sintering of inkjet-printed contact structures by ultra-short pulsed Laser beam was applied as efficient electrode formation process (Figure 1 and 3).

For Aerosoljet printing, a gas flow is used to create an aerosol, which is subsequently focused within a nozzle by a secondary gas flow. By variation of the individual gas flows, a thin line can be formed down to about 10 µm width. A self-reducing ionic ink is used comprising of a dissolved metal salt (typically in the form of a complex) and a reducing agent. Their reduction yields pure metal, while all other generated byproducts are volatile and evaporate during the curing process (Figure 2 and 3).

A cost efficient standard electroplating process finally is applied for growth of front contact electrodes from printed seeding structures.

Electrical contact characteristics between electrodes and III-V semiconductor was evaluated by Transmission Line Method (TLM) and could be determined to be <10 mΩ cm² with an optimum total series resistance of the cell. In addition, a shading of the active front side area of less than 2% was achieved by minimizing the lateral dimensions of the electrodes (Figure 4 and 5).

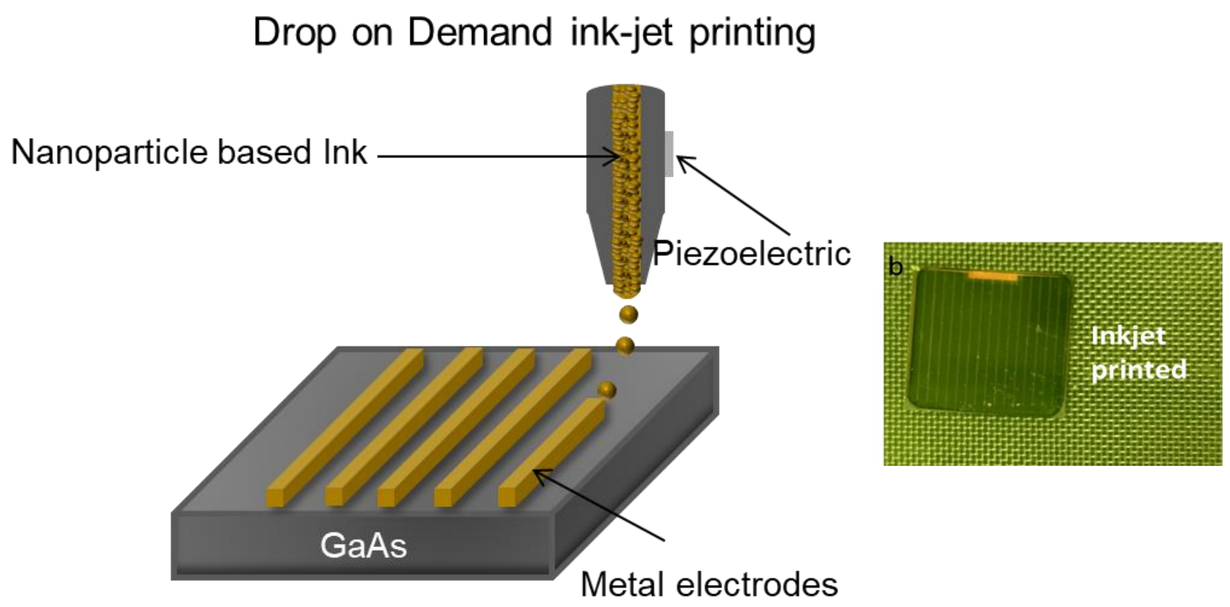


Figure 1-Inkjet printing process(left), Inkjet printed cell (right)

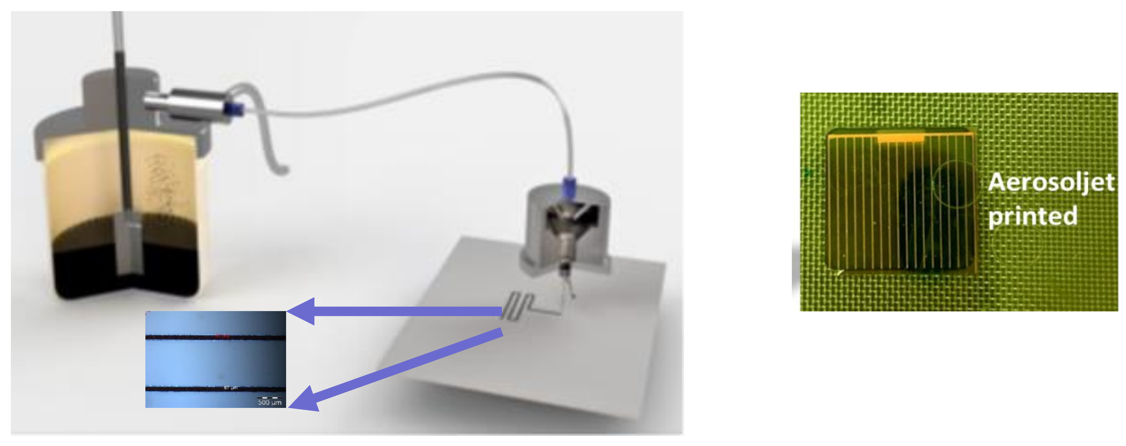


Figure 2- Aerosoljet printing process (left), Aerosoljet printed cell (right)

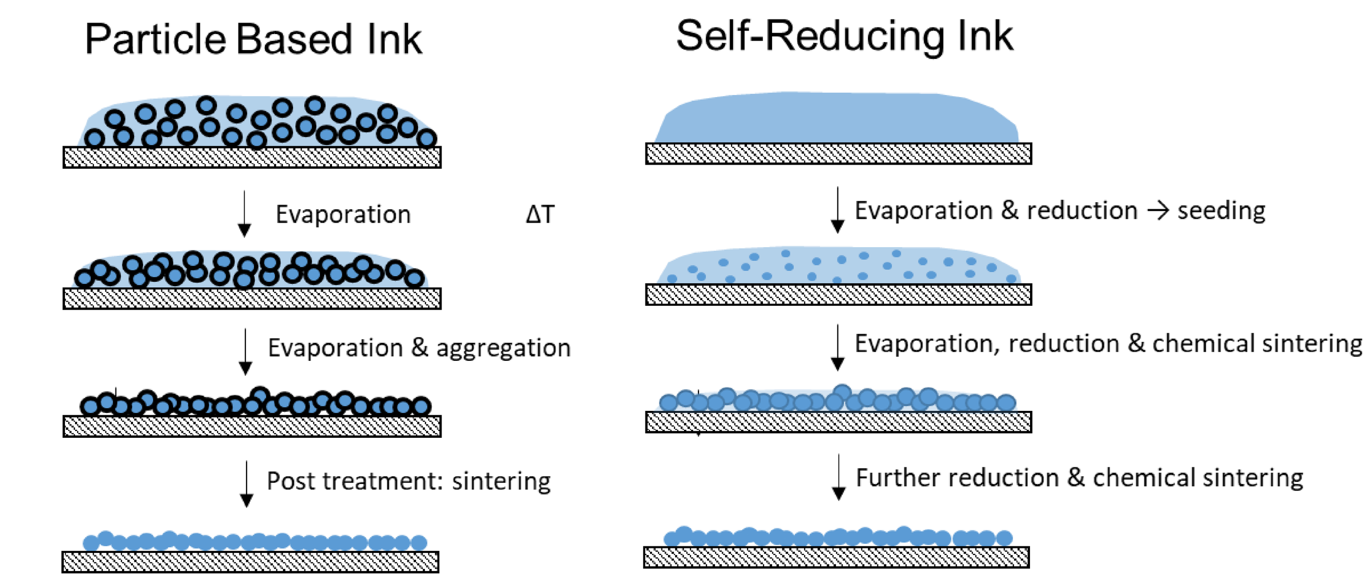


Figure 3- Comparison of the curing process for particle containing(left) and self-reducing (tight) inks.

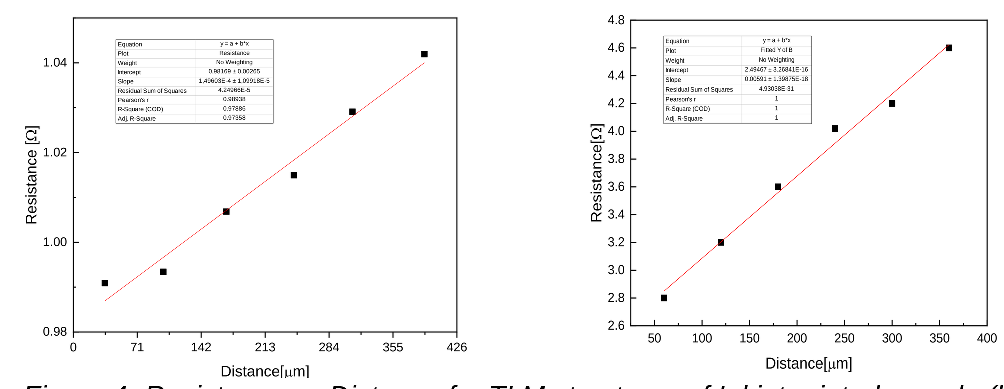


Figure 4- Resistance vs Distance for TLM structures of Inkjet printed sample (left) and Aerosoljet printed cell (right)

Conclusion

In conclusion, two well-known BEOL methods Aerosoljet printing, and inkjet printing were successfully applied for the deposition of conductive metallic inks as front contact electrodes on III-V semiconductors.

As a result a low contact resistivity of <10 mΩ cm2 between metal and semiconductor was achieved. In addition, by minimizing the lateral dimensions of electrodes less than 2% of the front side surface are shaded.

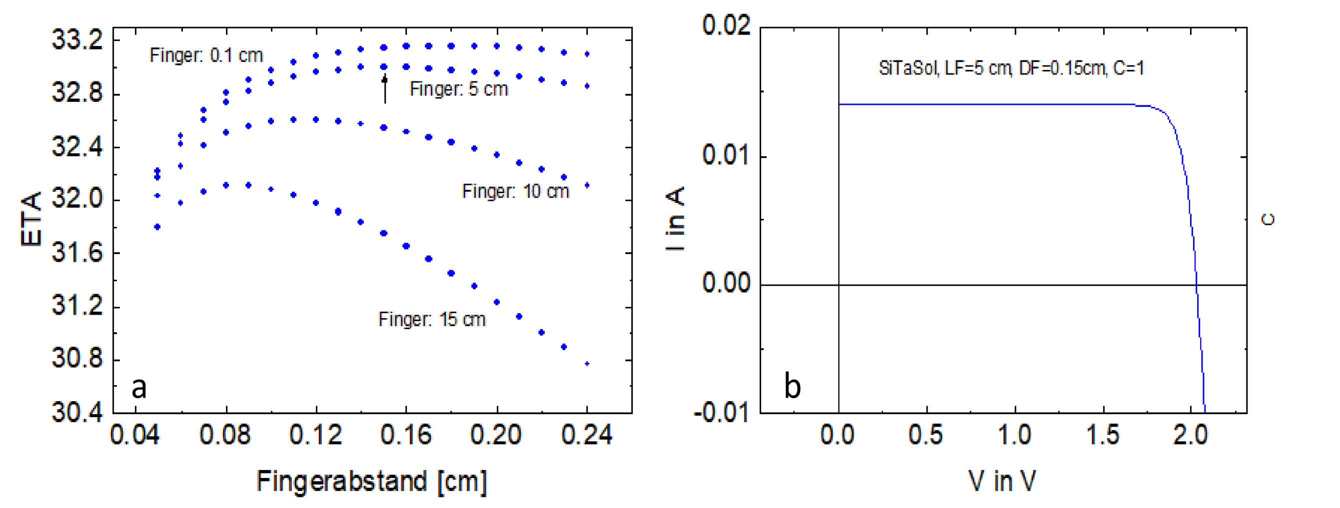


Figure5- Simulated Efficiency of solar cells vs finger distances (left) and IV simulation of a cell with finger length of 5 cm and a finger distance of 1.5 mm

Acknowledgement

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