Training, workshop, conference, and unintentional doping!

Hi everyone,

It has been a while since my last blog post, so I thought I would give you a quick update on my PhD progress. Since then, I have been attending one Quantimony event and two conferences. In Lancaster, we had our 2nd AAB Meeting & Transferable Skills Training, the 21st European Workshop on Molecular Beam Epitaxy (EuroMBE 2023) took place in Madrid and I attended the 14th Spanish Conference on Electron Devices (CDE 2023) in Valencia. So, let us jump right into it so you can find out more about all this. 😊

Quantimony Events

Our 2nd AAB Meeting & Transferable Skills Training in Lancaster was split into two parts. During the first half, we, the ESRs, had workshops on career choices and writing research grants. In the second half, all ESRs presented their progress together with some invited talks. For me personally, the presentations by Prof. Dr. Jaime Gómez Rivas from Eindhoven University of Technology on *THz time-domain spectroscopy and microscopy of semiconductors and resonant structures* and Dr. Manoj Kesaria from Cardiff University on *Advances in an artificial III-V semiconductor superlattice* were of particular interest.

SL – transport, carrier extraction, and material imperfections

In the last blog post, I wrote about superlattices (SL) and how the movement of electrons is affected by the period thickness. With the analogy of Super Mario we have seen that electron movement is eased by minibands, present in thin period super lattices.

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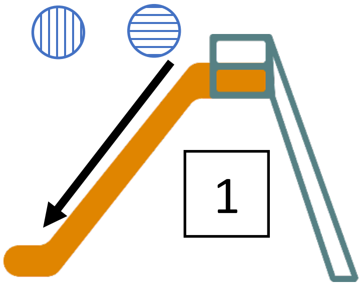
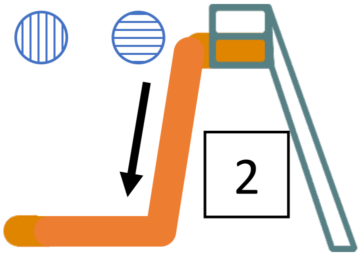
By now it should be clear to you that our goal is the separation of electrons from holes. We want to get both charge carriers out of the solar cell. To achieve this, we do not only optimise the material with superlattices. In addition to that, we facilitate the charge carrier movement (transport) with an electric field. To speak again in terms of Super Mario, we could regard the electric field like a boost pad, giving the extra boost to separate the charge carriers.

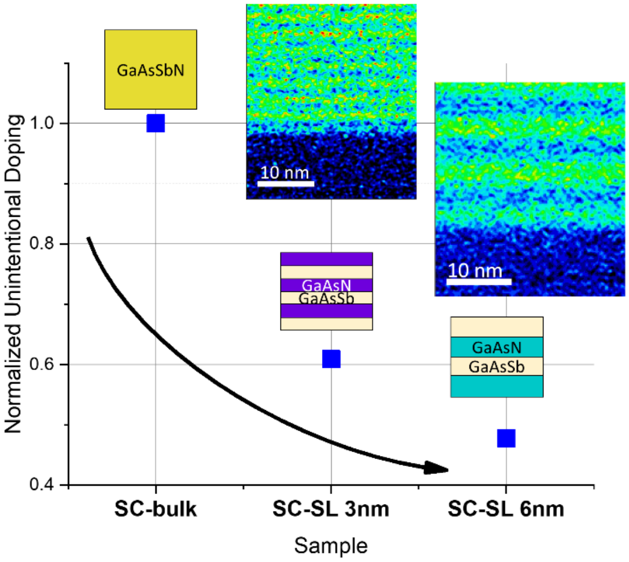


The effect of the electric field can be understood by looking at the slide sketch labelled "1" on the right. If we drop the horizontally and vertically striped balls onto the slide, both will roll down the slide. In case of slide labelled "2", the situation is different: The height difference of this slide is the same, but there is a small area of steep slope and a huge flat area. Consequently, only the horizontally striped ball will see a slope and will be accelerated to the left. The vertically striped ball, on the other hand, might bounce up and down without leaving the slide.



The situation described here with the example of the slides is quite comparable to what happens in our solar cell: The absorbed light creates free electrons (balls) across the whole depth (slide width) of the solar cell. With an electric field (slope area of the slide), those electrons (balls) are swiped across the cell and thereby separated from the holes. But if free electrons (balls) are generated in areas without an electric field (flat slide area), they are not separated from the holes, and their energy cannot be extracted from the cell (slide).

You might wonder why I am stressing the importance and functionality of the electric field so much. It seems obvious that an electric field is beneficial, so why not just make use of it and move on? The reason is twofold: First, it must be said that our solar cells, based on GaAs(Sb)(N) alloy nanostructures, need electric field assistance more than for example a solar cell based on pure GaAs. Although the GaAs crystal matrix can be grown in high quality, mixing nitrogen into the GaAs matrix produces substantial defects. When an electron comes across such a defect, chances are high that it recombines with a hole and its energy is lost. The electric field helps the electrons to move faster across the solar cell. The defect is only briefly noticed by the electron passing by, but there is no time for recombination. The second reason why I am particularly interested in the electric field is that our GaAs(Sb)(N) alloys not only need the electric field but unfortunately counteract the electric field: The nitrogen-induced defects act not only like unwanted recombination centres but also provoke *unintentional doping* that leads to some weak-field areas, where field-assistance is diminished. In other words: Our materials “require a slide” like type “1” but lead to slide type “2”.



As my motivation is to improve the performance of our solar cells, I need to look at performance-limiting factors such as the absence of the electrical field, and therefore, I probed our solar cells for the concentration of the *unintentional doping.* The plot on the right side shows the results of this study that I presented at the 14th Spanish Conference on Electron Devices (CDE 2023) in Valencia. We can see how unintentional doping is highest in the GaAs(Sb)(N) bulk solar cell (SC-bulk). Comparing this to what has been measured for our SL-structures, we see that unintentional doping is roughly 50% lower. In the SL approach, Sb and N are separated in different layers and we see that this not only improves the material quality. In addition to that, there is markedly lower *unintentional doping* in the SL structures, improving the field-assisted carrier collection. By comparing both SL structures with each other, we see that less *unintentional doping* is present in the thick-period SL than in the thin-period SL. This can be explained by the fact that each layer in the SC-SL 3nm only consists of few atomic layers, leading to intermixing between the GaAsSb and the GaAsN layers. The result is a more bulk-like material, with consequently higher *unintentional doping.* However, we know from the last blog post that transport is better in the thin-period SLs compared to the thick-period SLs. Therefore, we need to find the sweet spot between thick and thin periods, where transport is best.

Conclusions

This blog post is a bit shorter than the ones I have uploaded so far. However, I think it is quite densely packed with some new concepts, which is why I would rather stop at this point and sum it up: This time we have learnt that the electric fields in solar cells help separate the charge carriers. This is of particular importance for our GaAs(Sb)(N) materials, where electrons need field assistance to not recombine at the crystal imperfections. Then we have learnt that the field is reduced by unintentional doping. Finally, we have seen that unintentional doping is again lower in the SL structures, which is in agreement with their superior performance with respect to the bulk material.

Let’s see what I have for you after the summer, see you soon!