Solar Cells, Semiconductors and MBE

Welcome back! A couple of weeks have passed but today I am thrilled to publish my second blog post. My fellow PhD students and I have met up in Lancaster (UK) for a Transferable Skills Training and to present our progress to the supervisors of the Quantimony ITN. Of course, I want to keep you updated on my progress as well. That's why within this blog post, you will read about solar power, solar cells and we will decipher another acronym: MBE!

The Green Energy of the Sun!

There is a general agreement that climate change is one of the most pressing challenges today. Like so many problems in the world, it can be traced back to the root, that we, as the population of the earth, are living beyond our means. Too much of fossil fuels (coal, oil, and natural gas) are burned to satisfy our thirst for energy.

As it is not an option to just continue as we have in the past, we need to change to renewable energy sources. Besides using kinetic energy sources like wind and water, the motivation is high to exploit the sun as a limitless energy source. According to the Technology Roadmap of the International Energy Agency (IEA) the solar energy reaching the surface of the planet exceeds our current consumption by roughly 3500 times. Of course, this energy has other purposes in our ecosystem than only moving electric cars but still, it is of high interest to benefit from this source of renewable energy!

Using Solar Power

As mentioned before, the sunlight that makes flowers bloom, trees grow, and our skin tanned carries a lot of energy.

On a hot summer day, we can literally feel ourselves heating up when exposed to the sun. This thermal energy can be used in two ways. Firstly, solar water heaters may directly heat up the water we use to shower or clean. In this way, no oil or gas must be burned to heat up water for daily needs.

Another approach is to use concentrated solar power. Using huge parabolic mirrors, the sunlight is concentrated on a small area where it produces heat. The heat then drives a heat (steam) engine to transform the heat into kinetic energy. Then, the kinetic energy is transformed into electrical energy with an electrical power generator.

You may think now that this is a costly way of doing it. And you are right! Obviously, the transformation from radiative energy to kinetic energy to electrical energy is anything but loss-free. In addition to that, it would be more practical to have a system that is less space-consuming. And the answer lies in photovoltaics!

The Sun's Spectrum and Photovoltaics

As said before, it would be better to transform solar energy directly into electric energy. This is done with photovoltaics: according to Wikipedia, *the term "photovoltaic" comes from the Greek φῶς (phōs) meaning "light", and from "volt", the unit of electromotive force.* The most common approach to *"do photovoltaic"* is using semiconductor materials. Without going further into detail now (no worries, we will do that later) let me explain to you what the main considerations are.

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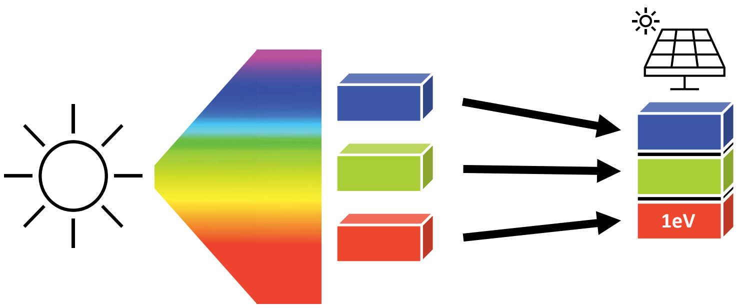

If we look up to the sky the sunlight appears white to us. But in fact, it is composed of different colours, like a rainbow. We can see this in the sketch on left.

All these colours carry energy, and a good solar cell should be able to transform the entire spectrum of colours into electrical energy. As said before, semiconductor materials can be used to absorb the sunlight and deliver electrical energy. The problem is that every material has a preferred colour, for which the energy conversion works best. In the sketch above, three different materials are represented by blocks. Each one individually, only transforms the blue, green, or red part of the spectrum into electrical energy. But if they are combined into one solar cell of multiple material layers (Multi-Junction-Solar-Cell: MJSC), the energy of the entire colour spectrum of the sun can be harvested.

Growing crystals by MBE

We have seen in the paragraph above, that good solar cells can be obtained by stacking several semiconductor materials on top of each other. One could imagine the stacking works like baking a layer cake (pictured on the right), but unfortunately, it is not that simple. The layers we are talking about are far thinner than human hair and the different elements, that form one layer need to be arranged in a crystal structure.

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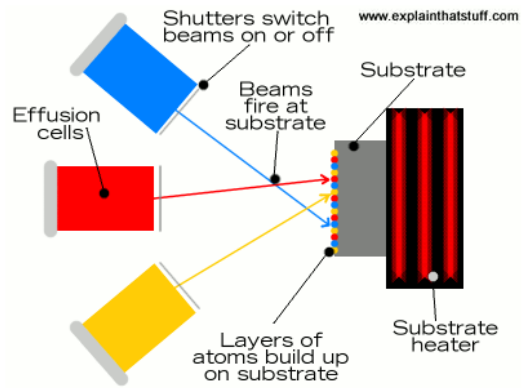
Different techniques have been developed to perform this *material deposition.* One of them is called Molecular-Beam-Epitaxy (MBE) which is the new acronym we learn in this blog post. Epitaxy is a fancy word for the deposition of a new layer of atoms on top of the crystal lattice. An epitaxy becomes a *Molecular-Beam*-Epitaxy if the different elements, that form one layer, reach the crystal separated into different beams. The sketch on the next page illustrates what happens:

Each of the effusion cells is filled with a different element. By heating them up, a *molecular beam* fires at the substrate and a new layer is deposited on the crystal (substrate). Layers can be composed of several elements if the beams of both elements hit the substrate simultaneously. In this way, we grow alloys like GaAs, InAs and GaAsSb.



For those who feel like the transition from a *rainbow layer cake* to *molecular beams* was too quick – I agree. If you are further interested, please have a look here.

Conclusion and Outlook

The important Take-Home-Message(s) for this post are:

- Solar energy is a great renewable energy source.
- Solar energy can be directly transformed into electrical energy using semiconductor materials.
- The sunlight is composed of many colours. We can stack several semiconductor materials on top of each other, to harvest solar energy with maximum efficiency.
- MBE allows the (crystal) growth of semiconductor materials with control down to the individual atomic layers.

MBE is the technique we use to grow nanostructures like quantum dots (QDs) or super lattice (SLs) that we use in our solar cells. But those are acronyms that we are going to decipher in the next blog post 😊
Stay tuned and healthy!