Popular Science Summary

In recent decades, the average global surface temperature has increased—an effect that is known as global warming. We have already reached a point of no return at which the melting of glaciers cannot be prevented. The main reason for global warming is the human-induced high emission of greenhouse gases since the industrial revolution. In order to mitigate the effect of global warming, sustainable energy sources need to replace fossil fuels, which are limited but still the primary global energy source.

Solar power is—besides wind and hydropower—one of the most promising ways to generate sustainable energy. Within one hour, the sun supplies the earth with more energy than the global population consumes in an entire year. Solar cells are used to harvest this energy by directly converting sunlight to electricity. Standard solar cells that can be found on rooftops are made from silicon. However, silicon solar cells do not have the highest efficiency of all available solar cell technologies. There are more efficient solar cells based on so-called III–V semiconductors, but they are too expensive to be commonly used terrestrially. Instead, they are mainly used in space applications.

Therefore, there are two factors that need to be considered: the efficiency of a solar cell as well as the cost. Nanowire solar cells promise to reach the high efficiencies of world record solar cells based on III–V semiconductors at a low cost. Nanowires are tiny, elongated structures with a high aspect ratio. Typically, they have a diameter smaller than a few 100 nanometers and a length of a few micrometers. That is roughly a thousand times thinner than a human hair. Thus, nanowires are thinner than the wavelength of visible light, and that causes interesting interactions. For example, nanowires can absorb light from a larger area than their own cross-section. Consequently, an array of nanowires absorbs as much light as a continuous film, even though only 10 % of the area is covered, saving 90 % of the expensive semiconducting materials. In such an array, millions of nanowires are aligned in a periodic pattern and each nanowire acts as a tiny solar cell. Since nanowire solar cells consist of millions of such tiny solar cells, the samples are more forgiving towards defects and it is possible to fabricate flexible devices.

The experimental part of this thesis focuses on the fabrication of such nanowire arrays, as well as on their characterization. First, the pattern of the array is copied from a pre-defined mask or stamp and transferred to a growth substrate using lithography. Then, gold is deposited onto the substrate, following the defined pattern. In a chemical

reactor, molecules containing elements of group III and V are used as precursors and supplied via the gas phase. The gold seeds form an alloy, melt, and then the nanowires start to grow underneath the liquid seed particle. The composition and electric properties of the nanowires can be controlled by using different precursors and adjusting their concentration in the gas phase.

Because nanowires are so small, scanning electron microscopes are often used to investigate them instead of light microscopes. A focused electron beam is scanned over the sample and interacts with the nanowires. One possible interaction is that the focused electron beam kicks out secondary electrons that come from the sample. Those secondary electrons are typically used to image the topography of nanosized samples. Another interaction is the electron-beam-induced current. This effect is similar to the current that is generated by a solar cell upon light illumination but allows for studying solar cells with the spatial resolution of an electron microscope—ideal for photovoltaic nanowires. First, the electron-beam-induced current was used to study single-junction nanowires. Then, guided by electron-beam-induced measurements, nanowires with more than one junction were developed. This lays the foundation for multi-junction—the technology yielding world record solar cell efficiencies—nanowire solar cells.