C.3. BRIEF DESCRIPTION OF THE RESEARCH IN LAYMAN'S TERMS, AIMED AT THE GENERAL PUBLIC.

Single-walled carbon nanotubes (SWCNTs) are constructed by rolling an atomically thin sheet made of carbon atoms arranged in a hexagonal pattern known as “graphene”. SWCNTs come in two varieties with regard to their electrical properties: semiconducting and metallic. Their electrical properties are determined by the angle at which the graphene sheet is rolled, this is, their chirality.

In order to directly implement SWCNTs into any realizable or conceivable technology it is highly desirable to be able to produce them with a high degree of selectivity in terms of their electrical properties. Alternatively, one can simply aim to produce a mixture of semiconducting and metallic SWCNTs and separate them afterwards. However, the addition of a post-synthesis segregation step is time consuming and, since such steps generally rely on chemical modification of the nanotubes damage can occur so that their electrical properties are affected. For this reason it is preferable to develop synthesis techniques that can produce either only metallic or only semiconducting SWCNTs (or at least that yield a much higher proportion of one type of nanotubes over the other). Some methods already exist. Chemical vapor deposition (CVD) is a widespread synthesis technique that has been used to produce a large variety of one-dimensional nanostructures, SWCNTs among them. Recently, the technique has been adapted to produce films of well-aligned semiconducting SWCNTs over large areas of a flat substrate. However, full control over their chirality to tailor the individual bandgaps of the SWCNT is lacking. For this reason, it is advantageous to come up with a synthesis procedure that, besides of conferring chirality control, is also capable of implementing spatial control over the growth location of the nanotubes, as this is also a requirement for large-scale device fabrication. It is also important to understand the fundamental growth mechanisms to grow SWCNT in a controlled manner

The main goal of this research is to develop a novel synthesis technique that can be referred to as “e-beam-driven nanoengineering”. The method aims to grow SWCNTs with well-defined electrical properties and at the same time allow a deep insight in to the growth mechanisms. The synthesis techniques based on electron-beam modification of solid micro-materials are a recent development; therefore, there is still plenty of room for gaining fundamental knowledge about the microscopic processes that lead to the building-up of nanostructures as well as for the development of experimental know-how.

The particular method proposed here is to be carried out inside a Transmission Electron Microscope (TEM), a machine that is capable to observe the atomic structure of a material. The starting material that serves as precursor for the growth of SWCNT inside the TEM is a small mixed particle that contains C, H and O as well as gold nanoparticles within it. The electron beam of the microscope is used to irradiate the particle in order to initiate the growth/synthesis of a carbon nanotube (SWCNT). The irradiation causes the Au nanoparticles to migrate towards the surface of the precursor until they get to the surface. From this point onwards, the growth of the SWCNTs relies on the remarkable catalytic properties of the Au nanoparticles. Volatile hydrocarbon molecules alongside O_2 are desorbed from the precursor as the beam continues to irradiate it and break down the starting material. The Au nanoparticles are then exposed to a cloud made of these vapors. The function of O_2 is to activate the catalytic properties of the Au nanoparticles which are then able to break-down hydrocarbons in order to produce C atoms. The C atoms aggregate in order to produce the seeds that will eventually grow to become SWCNTs.

Through this approach one could directly observe the growth dynamics in real-time, thus, advancing our understanding of the growth of SWCNTs from metallic nanoparticles at an atomic level. The exploration of self-assembly processes instigated by fundamental interactions between an electron beam and a solid precursor is an important step towards extending the sub-field of e-beam-driven chemistry and nanoengineering techniques.