

## **Application specific CVD growth of carbon nanotubes**

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There are various methods to produce carbon nanotubes (CNTs) in more or less bulk fashion. The fabrication of well defined CNT-based structures for specific applications, however, still involves in most cases coating of surfaces with diluted suspensions of CNTs and then selecting tubes which have been arranged by chance in a suitable way, using some type of microscopy. Chemical Vapor Deposition (CVD) offers the opportunity to grow CNTs on surfaces directly where they are needed by exploiting the fact that catalysts are required for CNT growth.

In order to control the position of a CNT the catalyst is positioned by patterning it lithographically. From sufficiently small catalyst dots, a high yield of single CNTs per dot can be achieved. The orientation of the as grown CNTs can be controlled by different methods: vertical alignment can be achieved via a dense growth of CNTs (c.f. fig. 1) or orientation in an electric field, e.g. in a plasma (c.f. fig. 2). Horizontal alignment can be achieved by a directed flow of the process gas or by applying a suitable horizontal electric field during growth (c.f. fig. 3). Optimized process parameters for these different modes will be presented along with results from specific applications.

Since CNT-CVD typically is performed at temperatures around 800°C, where thin catalyst layers decompose into small islands, there is a whole class of substrates which cannot be used, namely flexible polymers such as polyimide. As known from the deposition of dielectric layers on semiconductors, plasma-enhanced CVD offers the opportunity to operate at reduced substrate temperature while supplying part of the net reaction energy via the plasma. Optimization of catalyst material and layer thickness, of processing pressure and gas precursor mixture enabled CNT growth at temperature as low as 350°C. This enables, among others, coating of electrodes in neural implants for enhanced biocompatibility and charge transfer capability.

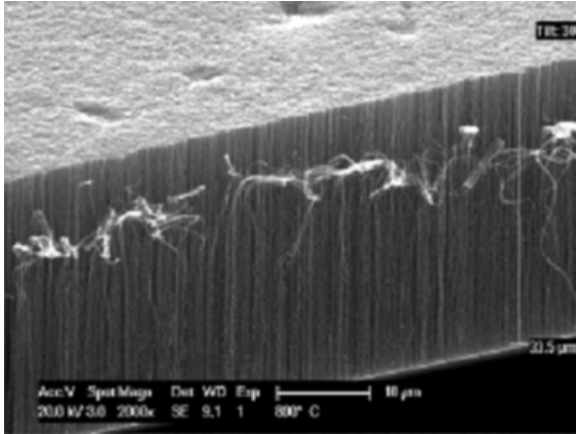


Fig. 1: Thermal CVD grown vertically aligned dense CNTs

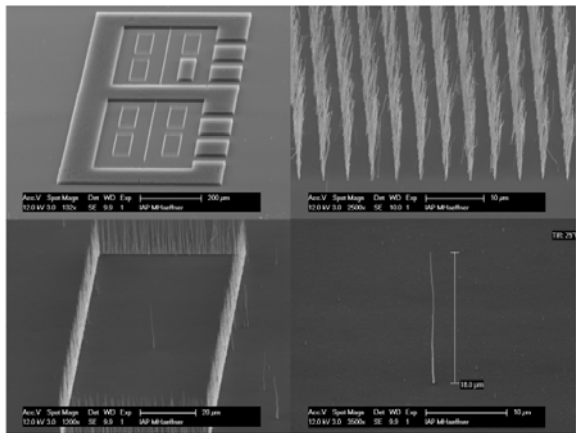


Fig. 2: PECVD grown CNTs from patterned catalyst

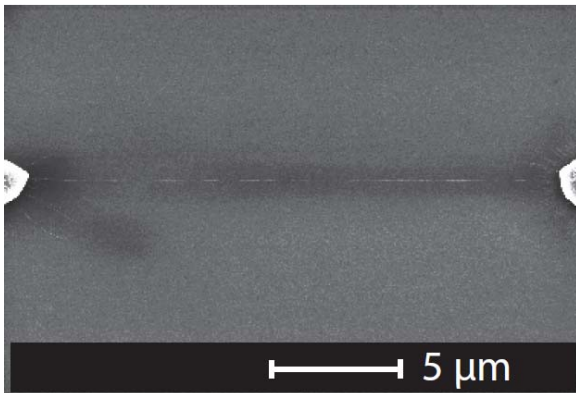


Fig. 3: Horizontally aligned CNT grown in an electric field