

Growth and Integration of Organic Nanofibers in Devices

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Abstract

The PhD thesis focuses on transfer of larger areas of mutually aligned organic *para*-hexaphenylene (p6P) nanofibers from their growth substrate muscovite mica onto pre-structured device platforms. In order to fulfill functionality of the devices, the morphology of the nanofibers has to fulfill specific requirements, e.g. certain width to length ratios. Thus nanofiber growth on larger muscovite mica substrates is an important issue, which is also covered in the presented work. The three main topics of the PhD thesis are:

1. Large scale growth of p6P nanofibers.
2. Transfer of p6P nanofibers.
3. Device integration of p6P nanofibers, exemplified by *field effect transistor* (FET), plasmon polariton coupling and security marker substrates.

The morphologies (lengths, heights and widths) of p6P nanofibers grown on a muscovite mica substrate depend strongly on the muscovite mica substrate temperature during growth. Especially, growing p6P nanofibers on large muscovite mica substrates complicates the heating procedure of the mica substrate due to the poor thermal conductivity of muscovite mica. A homogeneous muscovite mica surface temperature has been achieved by adding a thermally conductive layer between the mica and a hotplate. Together with a precise measurement of the mica surface temperature, resulting in a critical nanofiber growth temperature of 453 K, a quantitative control of the mica surface temperature has been achieved, which in turn led to growth of homogeneously distributed p6P nanofibers on 75x25mm² muscovite mica substrates. In addition to that, *atomic force microscope* (AFM) images have revealed that a p6P nanofiber grown at the critical temperature not only originates from 3-dimensional p6P crystallites forming a 1-dimensional crystallite chain, but also from 1-dimensional crystallite chains adding to the already existing p6P nanofiber.

Transfer of p6P nanofibers from their growth substrate is inevitable in order to implement p6P nanofibers in devices. Controlled transfer of 200x200µm² nanofiber areas from the growth substrate to prefabricated silicon substrates has been achieved with an orientation control of ±5° by a novel stamping technique in an air atmosphere with defined temperature and humidity. *Atomic force microscopy* (AFM) images reveal a distortion of transferred p6P nanofibers in terms of height and width: the nanofiber height is reduced by a factor two and the width is correspondingly increased by a factor two. This distortion is inevitable using mechanical stamping techniques.

Subsequently, arrays of mutually aligned p6P nanofibers have been implemented in devices. Firstly, as simple ordered arrays on holograms, serving as a new generation of anti-counterfeit markers. Secondly, into a prefabricated, Silicon based FET device using the novel stamping technique. Electrical contact to transferred nanofibers has been achieved for both top and bottom configurations of the FET device. Finally, nanofibers have been integrated on a prefabricated structured gold-on-silicon sample, serving as *surface plasmon polariton* (SSP) active substrate. *Photoemission electron microscopy* (PEEM) images of transferred p6P nanofibers on such substrates have been obtained. These include images where *surface plasmon polaritons* (SPPs) are excited in the gold/vacuum interface by a pulsed laser beam, resulting in nanofiber localized beating patterns in the PEEM images.