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Towards nanowire sensors on a microfluidic platform: In-situ formation, positioning and sizing of nanowire bundles

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INTRODUCTION: Progress in microelectronics, sensors and optics is strongly dependent on further miniaturization of components. However, the resolution of top-down technologies based on lithography has limits concerning the dimensions and the choice of material. Hence, several bottom-up approaches have been investigated to satisfy the need for structures with large aspect ratios in the nanometer regime [1]. Unfortunately, most of the methods described up to now either use expensive instruments or involve tedious procedures. Previously, it has been shown that microfluidic devices can support the formation of nanometer-sized structures, such as metal wires and hybrid fibers [2]. In these approaches, those nanostructures are formed at the interface of two reagent streams. We have advanced this method by developing a smart chip design that facilitates the *in-situ* formation, as well as the positioning of nanowires with controllable lengths

METHODS: We employ a multilayered microfluidic chip made of PDMS [3], which comprehends a fluid layer and a control layer, filled with nitrogen gas and separated by a thin, flexible PDMS membrane. Application of pressure to the gas inlets actuates the freestanding membrane and results in deflection of the predefined donut-shaped features into the fluid layer, thereby encapsulating a volume inside the fluid channel. The fluid channel is utilized to form nanowires by co-flowing aspartic acid (10 mM) and $CuNO_3 \cdot 6H_2O$ (15 mM) [4].

RESULTS: Nearly immediately, we can observe the formation of metal-organic wires at the interface where both reactants meet. Changing the flow rate of one reactant stream allows to induce the wire formation at different positions in the channel, e.g. directly under a donut structure. Hence, upon pressurization (3 bar) of the donut structure, the wire underneath is encapsulated and simultaneously fixed in position. Due to the continuous flow inside the channel, the nanowire bundles break at the edge of the donut trap so that their length is defined by the size of the donut (Fig. 1). Nanowires of various lengths between 50 and 250 µm have been created within a few minutes.

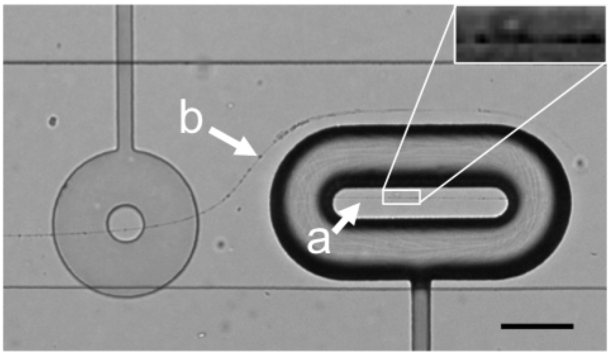

Fig. 1: Optical microscope image showing the encapsulation of a wire bundle by actuation of the right donut (arrow a). Reagent streams are still flowing through the channel, but are now partly deflected by the closed donut feature (arrow b). The black interface due to ongoing nanowire formation can be clearly seen (b). Inset (brightness adjusted) shows a magnification of the trapped wire. Scale bar: 100 µm.

DISCUSSION & CONCLUSIONS: The here-described approach accomplishes different intriguing goals of nanotechnology; it facilitates a defined and reproducible formation pathway, localization and control over the assembly process and capability to decide the length of an anisotropic structure. It is generally applicable, and we envision that the presented method will lead to easier integration of fully functional systems by bridging nano-, micro- and macroscopic dimensions. Our future work focuses on the construction of nanowire-based sensing devices made of conductive metal-organic materials.

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