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NANOWIRES ASSEMBLY USING MICROFLUIDIC: AN EXPERIMENTAL INVESTIGATION

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Summary Nanowires are common building blocks for the bottom-up assembly of electronic and photonic devices. A significant challenge is to introduce the individual building block in an oriented assembly in order to express its unique anisotropic properties or to create a nano-device. In this work we focus on fluidic alignment of nanowires suspended in an incompressible liquid. The approach is based on manipulation of a micro droplet with suspended nanowires in a confined shape, such as a micro-channel. These nanowires are eventually deposited on patterned surfaces forming parallel arrays. We report on alignment results of nanowires using Poiseuille flow and also report on the motion of the nanowires, in the vicinity of the dynamic contact lines, which follow non-closed spirally shaped streamlines and in certain case, the streamlines of sink- or source-like flows.

Nanowires (NWs) and carbon nanotubes are common building blocks for the bottom-up assembly of electronic and photonic devices. A significant challenge is to introduce the individual building block in an oriented assembly in order to express its unique anisotropic properties or to create a nano-device. Electric[1] and magnetic[2] fields have been used to manipulate dielectric nanowires that are suspended in liquid media. These methods require extensive lithography to fabricate the micro-electrodes. Fluidics-based methods[3] for aligning NWs have also been reported but mainly for assembly of individual or small numbers of devices.

Here we report on an experimental investigation of a fluidic-based approach. The approach is based on a manipulation of a micro droplet with suspended NWs in a confined shape, such as a micro-channel. Controlling the capillary flow inside the micro-channel results in well oriented NWs. These NWs are eventually deposited on patterned surfaces forming parallel arrays of controllable dimension that facilitate mass assembly of nanostructures.

Our assembly approach uses the flow inside micro-channel that is induced by thermocapillary motion. Since the surface tension of a liquid usually decreases with the rise of its temperature, a liquid index (droplet) can flow away from the heated end of a capillary channel. The motion of the droplet results in transferring, extension and compression flow leading to oriented NWs. In the system investigated, the micro-channel cross-section is $w \times h$ $(w>>h)$ (see Fig. 1a). A thermocapillary motion is achieved by creating a temperature gradient T1-T2, which results in pressure difference P1-P2. The wetting liquid was Hexadecane:Octadecane 1:1 solution with 1% of Mercaptoethanol thiol to avoid aggregation of the NWs. The NWs used were made of gold and were produced through an electrodeposition process using templates with a typical diameter of 200 nm and a length of 5um. The NWs (0.2% wt.) were dispersed in the above solution forming a dilute suspension. The micro-channel was made of glass and has a typical rectangular cross-section dimensions of $w \times h=400 \times 40\mu m$. The droplet was heated using *5W* thermal head. The motion of the NWs was observed using optical microscope (X1000) and a video camera (50fps).

In Fig. 2 (a) we see aligned NWs by means of a steady Poiseuille flow created at the droplet far from the menisci. Aligned NWs that were deposited after the movement of the droplet can be seen in Fig. 2 (b). In Fig. 3 we can see NWs behind the moving contact line (air-liquid-solid) of the front meniscus. The NWs are moving along non-closed spirally shaped streamlines. Most likely, we observed combination of the rotation generated by the corner eddies[4] and the corner flow (see Fig. 1a). Apparently, this complicated behavior is caused by the three-dimensional nature of the flow; however the type of imaging used provides us only with two dimensional pictures. It is also possible that the inertia of the nanowires, which in some cases may aggregate, is not neglected; hence the observed spiral motion is a result of bouncing between the corner-like flow streamlines. In Fig. 4 we can see a case where a pre-wetting condition exists formed by a capillary flow in the rectangular shaped channel. This situation especially occurs at the corner of the micro channel (see Fig. 1b). We can see that the NWs are moving along sink-like streamlines. However, this depends on the corner location; namely in the front or the rear meniscus we can observe sink- or source-like flow respectively.

In summary, we observed that the majority of the NWs were aligned with the flow direction using a Poiseuille flow. However, due to the complicated shape of the streamlines in the vicinity of the dynamic contact line, the alignment of numerous NWs is affected. Therefore, it is of great importance to analyze and control these types of flow close to the moving contact line.

References

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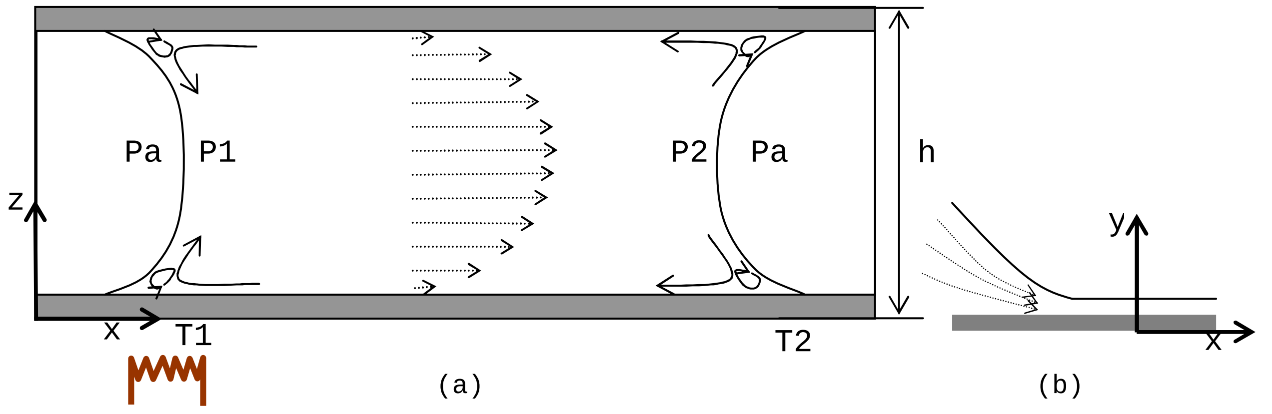

Figure 1: (a) A Schematic illustration of the studied system of a liquid drop moving in micro-channel with a rectangular cross section. The flow inside the micro-channel is induced by thermocapillary motion. (b) A sink-like flow illustration at the corner of the micro-channel as a result of a pre-wetting condition.

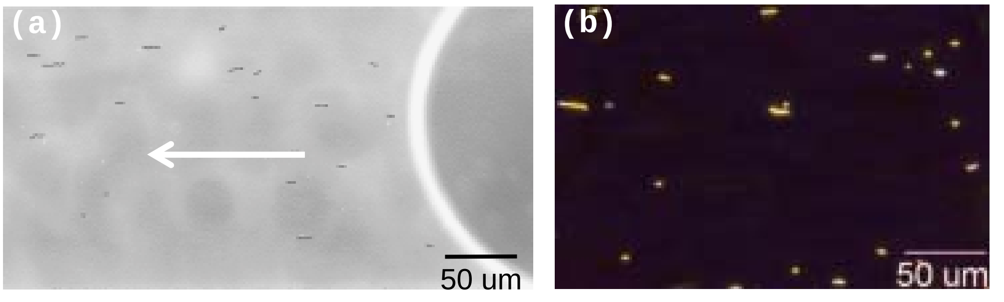

Figure 2: (a) Optical picture of nanowires aligned in a droplet. (b) Deposited NWs after the movement of the droplet.

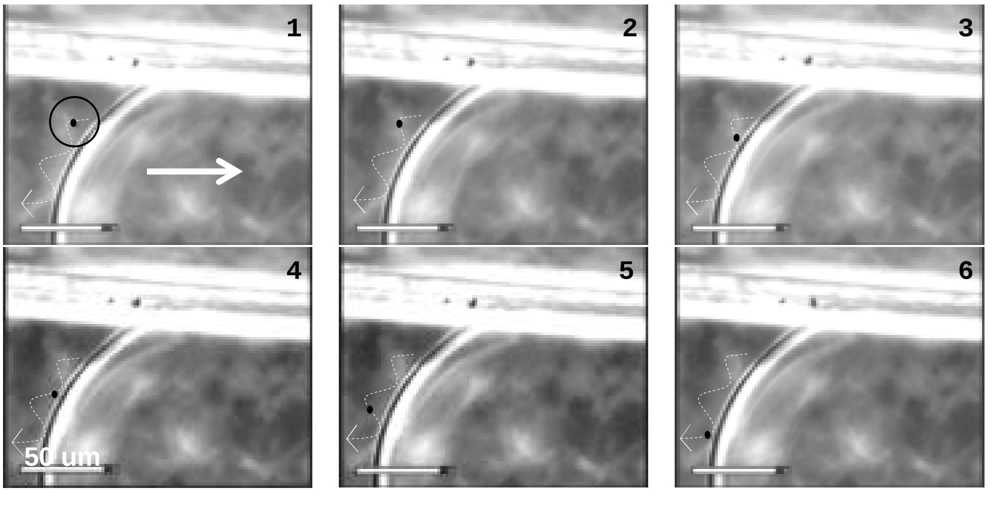

Figure 3: A series of pictures taken in the vicinity of the dynamic contact line during the droplet movement. The center of gravity of a nanowire (marked with a black dot) is moving along a non-closed spirally shaped streamline.

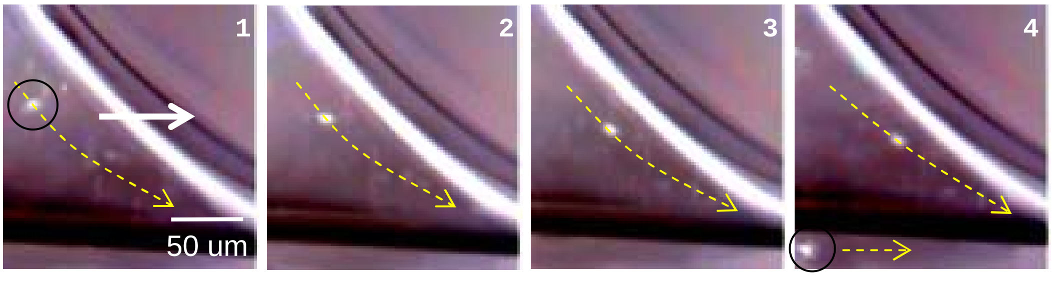

Figure 4: A series of pictures taken in the vicinity of the dynamic contact line during the droplet movement where a pre-wetting condition of the channel exists. The centers of gravity of the nanowires (marked with a white dot) are moving along sink-like flow streamlines.

