MANIPULATION OF BIOLOGICAL FILAMENTS WITH ELECTRIC FIELDS

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The induced alignment of biological filaments on surfaces has the potential to provide controllable geometries for lab-on-a-chip structures. Microtubules as well as actin filaments show polarity and can therefore be manipulated by electric fields. In this work, actin filaments of about 1 µm in length are manipulated with an electric field and stretched between two gold electrodes. Depending on the concentration, the stretching was performed on single actin fibers, as seen in Scanning Electron Micrographs. These filaments can function as tracks for molecular motors in the so called "bead geometry", while most other groups work with the gliding geometry, where microtubules or actin filaments move on top of a layer of motor proteins.

This work is motivated by the various applications of a manipulation of beads in nanobiotechnology or medicine. Up to now, the standard procedure for a manipulation of actin filaments or microtubules is the coating of a substrate with motor proteins and the application of an electric or magnetic field [1,2]. With the use of a special channel geometry or a hydrophobic/hydrophilic surface functionalization, it was then possible to track the filaments into circular structures [3]. Although these experiments work reproducibly and can be externally controlled, the cargos for the transport need to be bound to the moving filaments, rather than transported directly and the filaments can move freely within special limits of the structure. These disadvantages can be overcome by the use of the bead geometry, which transports cargos on fixed filaments. Arsenault et al. [4] demonstrated that actin filaments align along the electric field lines, although the nature of the strong dipole moment of the filaments is not known.

For these kinds of experiments, the electrodes need to be optimized to achieve the highest possible force acting on the actin filaments. The best geometry for two opposite electrode was found for an opening angle of 60° in simulations of finite element methods by the program Comsol. This angle was used for all experiments. An overview image of the set-up is shown in Fig. 1. The stretching of the actin filaments was performed in a 2.4 nmol/ml solution of G-actin in an actin polymerization buffer. This solution was incubated on the chip for 2 minutes, while an AC voltage of 2 $V_{p\text{-}p}$ was applied, leading to an electric field from 2.5 to 7 V/µm for electrode distances ranging from 300 nm to 800 nm. After the incubation time, the solution was thoroughly washed with distilled water to remove any solutes for the observation in a Field Emission Scanning Electron Microscope Jeol 1530.

Fig. 2 demonstrates that a single actin fiber can be placed between two nanostructured gold electrodes. However, for a controlled alignment and stretching of the fibers, the fibers need to be of approximately the same length. In order to control the length of the actin filaments, 0.024 or 0,006 nmol/ml of gelsolin was added to the solution during polymerization giving filaments of about 1 µm in length [5]. Fig. 3 shows an actin filament bundle of controlled length between two electrodes of 600 nm distance, which is still curled. However, several actin fibers of about the same length were successfully stretched and located between two sharp gold electrodes of a bigger distance (Fig. 4). This is in contrast to other experiments, where the actin filaments were only manipulated but not exactly located and stretched [4].

It can be concluded that this method is a valuable tool for the controlled handling of actin filaments for further applications in nanoparticle based sensors and actors. We demonstrated an accurate location of the filaments, which were additionally stretched between two electrodes.

Acknowledgement
This work was supported by the University Bielefeld

References:

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Figures:

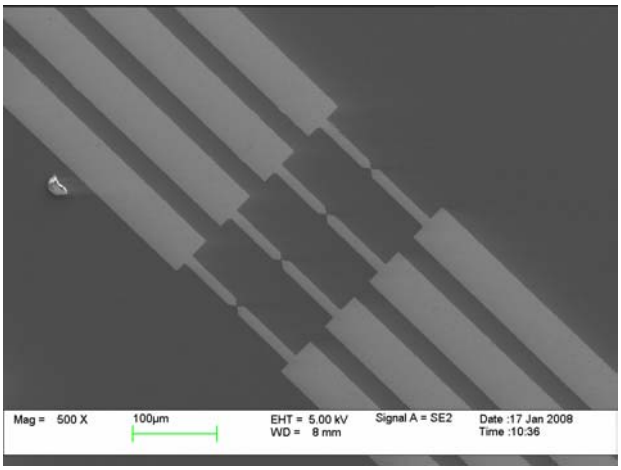

Fig. 1: *Scanning Electron Micrograph of the gold electrode set-up*

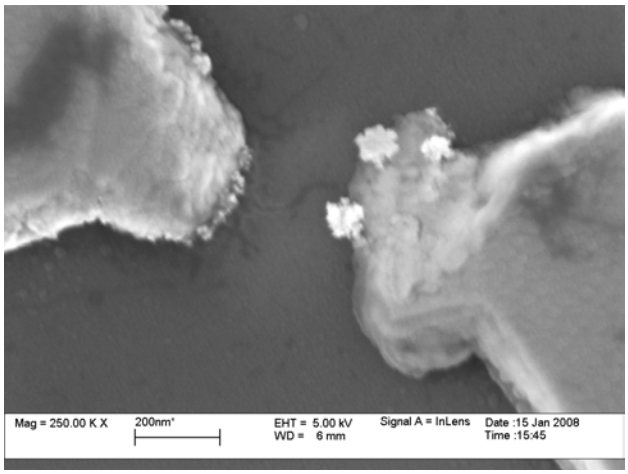

Fig. 2: *Scanning Electron Micrograph with back scattered electrons of a single actin fiber between two gold electrodes*

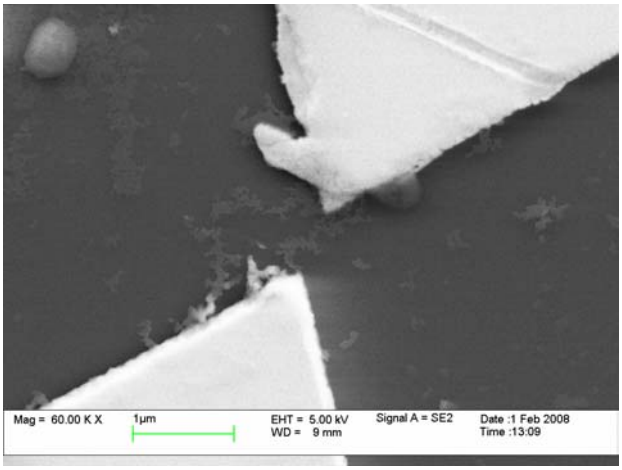

Fig. 3: *Scanning Electron Micrograph of an actin bundle between two gold electrodes with 1:100 m/m gelsolin.*

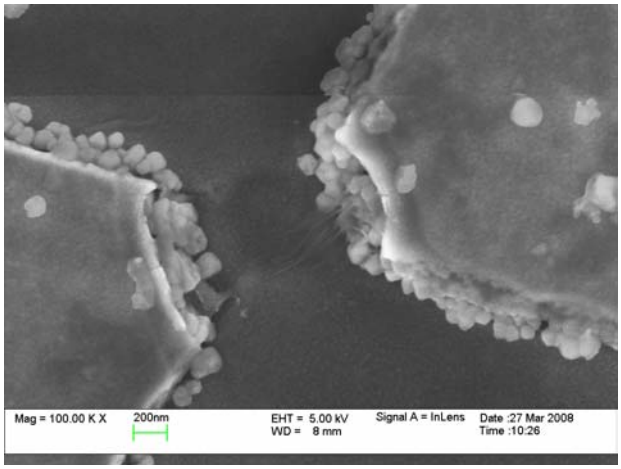

Fig. 4: *Scanning Electron Micrograph with back scattered electrons of several stretched single actin fibers between two gold electrodes with 1:400 gelsolin.*