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In-situ surface modification of microfluidic channels by integrated plasma source

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Abstract

In-situ modification of originally hydrophobic polymer surfaces by local plasma enhanced oxidation and its application in electrically controlled fluid capillary systems are demonstrated. A microfabricated coplanar dielectric barrier discharge (DBD) plasma source was developed [1, 2], integrated and applied to modify *in-situ* the surface properties of polydimethylsiloxane (PDMS) capillary channels. The local, immediate and successful setting of the wettability of the polymer microchannels is proved by development of effective water transport in the system subsequently the plasma treatment. The use of microfluidically integrated DBD microplasma system as switchable capillary pump is also presented.

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Keywords: microplasma; surface modification; microfluidic capillary pump;

1. Introduction

The precise and effective sample transport is a substantial task of the microfluidic systems in chemical and biomedical applications, ensuring controlled flow through the sample preparation system. Passive pumping systems are promising candidates considering the price and complexity of the microfluidic cartridges. From economic aspects the application of polymers as structural materials in the fluidic systems is also advantageous however the mainly hydrophobic behavior of these materials is a critical point. In our approach an electrically controlled, local and in-situ surface modification method was developed and proved in polymer based microstructures.

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2. Experimental

2.1. Coplanar dielectric barrier discharge plasma source

A micromachined coplanar dielectric barrier discharge plasma system was constructed as integrable plasma sources for Lab-on-a-Chip applications. Main advantages of the atmospheric pressure DBD plasma sources are the simple and downscalable geometric structure as the schematic drawing of the generator cross-section presents in Fig. 1.

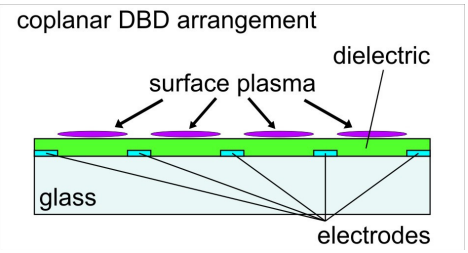

Fig. 1. Schematic structure of the coplanar DBD arrangement.

Due to the high voltage controlled plasma generator system excellent insulator had to be chosen as basic substrate of the device. Therefore microplasma generator structure was manufactured on Borofloat®33 glass substrate. The comb like electrode system was formed from 1µm thick vacuum evaporated Aluminium layer. The Al electrode system was patterned by photolithography, where the active area is 4×4mm and the distances between individual electrodes are 30µm. The whole structure was covered by adequate dielectric multilayer of 200nm SiO_2, 1600nm PSG (phosphorous glass) and 200nm SiO_2 layers deposited subsequently by APCVD (Atmospheric Pressure Chemical Vapour Deposition). This top covering Silicon-Oxide layer ensures excellent bonding capability with the fabricated Silicon based organic polymer microfluidic system as the integrated system presents in Fig. 2.

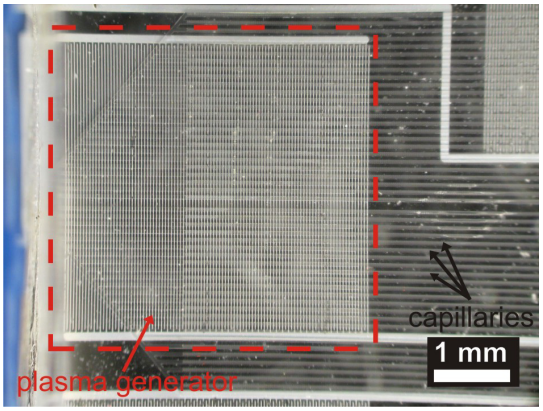

Fig. 2. The comb layout (electrode distance 30µm; electrode width 10µm; 16mm^2 area) covered with PDMS layer containing the capillary system.

2.2. Microfluidic capillary pump system

Polymer based microfluidic capillary pump structure was fabricated by PDMS soft lithography technique applying SU-8 epoxy based negative photoresist as moulding replica [3]. The multi-layered SU-8 structure was

patterned by subsequent spin-coatings and lithographic exposures followed by a final development step. Fig. 3. shows the secondary pillar structure of the SU-8 master replica (forming high aspect ratio wells on the bottom of the final PDMS channels).

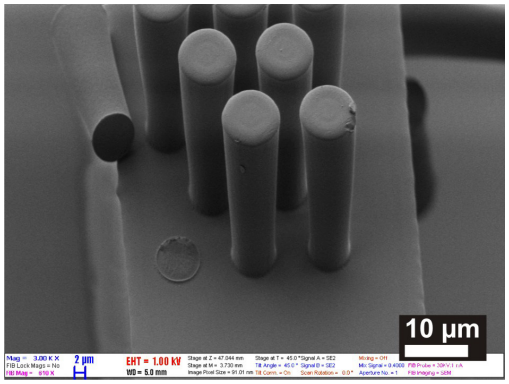

Fig. 3. Multi-layered SU-8 moulding replica of the microfluidic system.

3. Results and discussion

The successful local plasma assisted surface modification was verified by in-situ experiments. For characterizing the surface modification effect of the local plasma, the capillary system was integrated onto the plasma generator surface as presented in Fig. 2. Due to the excellent sealing between the plasma source and the microfluidic structure local plasma was formed inside the microchannels as presented in Fig. 4.

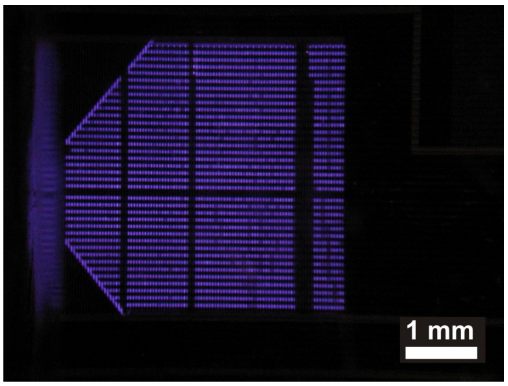

Fig. 4. The generated atmospheric surface air plasma formed locally in the PDMS channels.

The electrical performance of the RF micro-plasma source was monitored by recording the voltage and current values in time (Fig. 5) where is the time averaged electric power consumption is 2.4W.

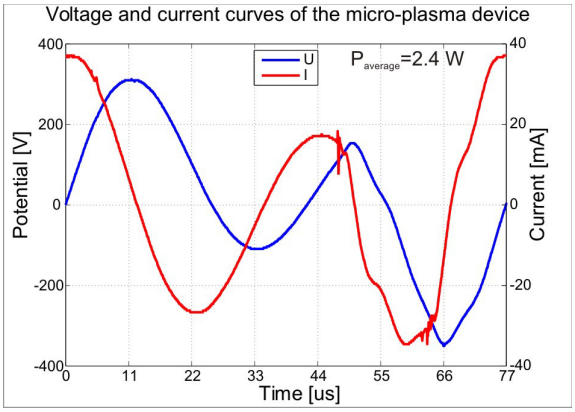

Fig. 5. Time dependent voltage and current curves of the driving signal of the plasma source.

PDMS channel surfaces completely change their surface characteristics from hydrophobic to hydrophilic within 60s during exposure of the generated atmospheric air plasma. The modification of the local surface was demonstrated by enhanced water transport in the treated capillary system as presented in Fig. 6. The effective region of the surface modification is expanded by 100-200µm compared to the area of the plasma source, according to the diffusion length of the active chemical species along the channels before recombination. We can conclude that our experiments demonstrate the performance of the plasma induced local surface modification in electrically controlled capillary pump systems.

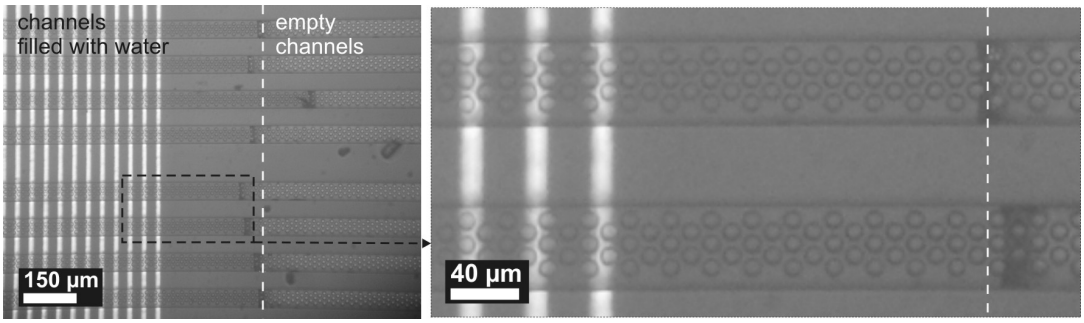

Fig. 6. Filled capillary channels over the plasma source.

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