Hot-wire based thermal waves technique - A novel biosensing platform

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This work reports on the first proof-of-concept for hot-wire based biosensing technique. Therefore, the effects of different coatings such as ssDNA and dsDNA on a thin Al wire on 3ω voltage were monitored. The results indicate a significant stepwise change of 3ω voltage amplitude after adding each coating step (silanes, ss- and dsDNA) in different media (air, deionized water, and PBS buffer).

Introduction

It is already known that molecular brushes of single and double-stranded DNA (ssDNA, and dsDNA) on a chip have a different heat-transfer resistance R_{th} [1]. The heat-transfer method HTM, utilizes this effect to determine the melting temperature of DNA and to detect this way the presence of single nucleotide polymorphisms (SNPs). In the present work, we aim at combining the different elements of HTM (power source, receptor chip, temperature sensors) in a single element, the "hot-wire", which is able to serve as heater and thermometer together. This brings us to the 3ω-technique [2, 3]. In this technique, an alternating current (frequency ω) along the wire produces a thermal wave and the amplitude and phase angle, measured at the frequency 3ω, reflects the efficiency of heat transfer from the wire to the surrounding medium.

Results and discussion

In this work, we use aluminum (Al) wires (diameter 50 µm) and their native oxide layer serves to immobilize silanes as linker molecules and to functionalize the wire with ss- and dsDNA. Before functionalization process, all Al wires were cleaned in acetone, and isopropanol for 15 min using a sonicating bath. Then, dried with nitrogen gas. During the silanization process, cleaned Al wires were incubated in 150 µl of N-(3-trimethox-ysilyl) propyl ethylenediamine triacetic acid trisodium salt as a -COOH terminated silane, and 10 µl of pure acetic acid as catalyst. Afterwards, a -NH2 terminated ssDNA probe was attached to the silane layer using EDC coupling. Finally, a complementary and fluorescently labelled ssDNA strand was hybridized to the probe DNA at 35°C. All the coated Al wires were mounted in the hot-wire flow cell, which is shown in Figure 1. To measure the 3ω voltage, a Keithley 6221 current source sent sine wave currents of 100 mA with different frequencies (1 Hz to 5000 Hz) to the wire and a lock-in amplifier (Stanford Research Systems, SR850 DSP) registered the 3ω voltage amplitudes and phases. All the 3ω experiments were done in 3 different mediums including air, deionized water, and 1× phosphate-buffered saline (PBS), pH 7.4. The results indicate significant, stepwise changes of the voltage amplitude and phase angle after adding each coating step in different media.

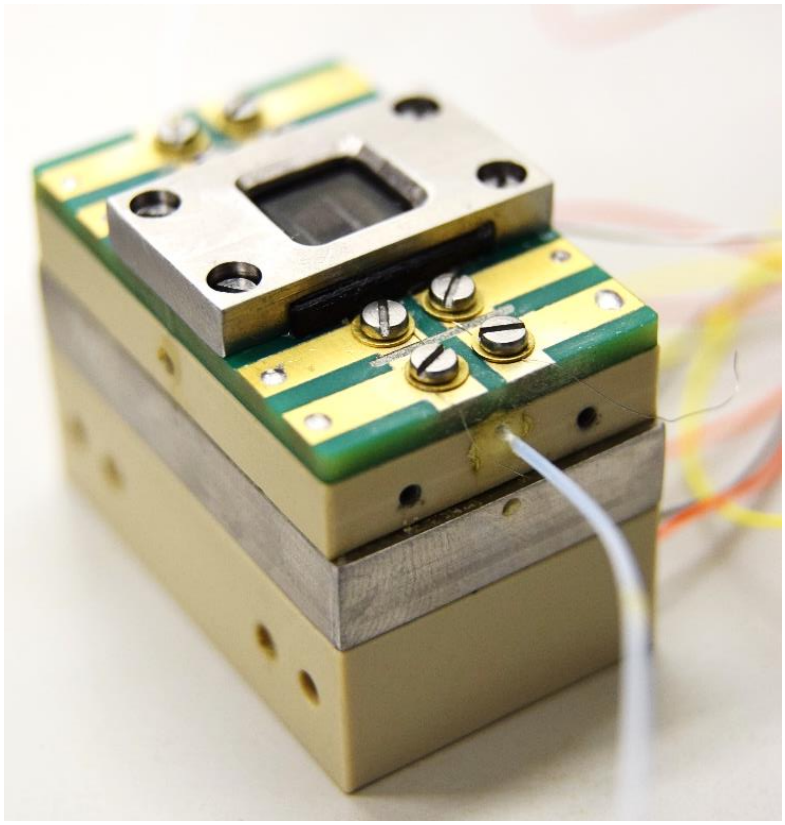

Figure 1: The novel hot-wire flow cell, hosting two different micro-wires that generate thermal waves through the wire coatings.

Conclusions

The 3ω voltage amplitude and phase angle show indeed a systematic dependence on the type of coating of the wire and the surrounding medium. We see a potential advantage of the hot-wire technique in the fact that 100% of the generated heat flow passes the bio-functionalized solid-liquid interface and that is suitable for parallelization.

References

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