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Microwave chip technology for dielectric characterization of tubulin self-assembly

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Self-assembly of tubulin into microtubules is the core of the life processes of healthy but also cancer cells. The lack of monitoring methods of this phenomena in the microwave band led us to propose a lab-on-chip method to monitor tubulin self-assembly states in the frequency region of the upcoming 5G telecommunication boom.

We developed a chip-based on coplanar waveguide (CPW) on a quartz glass substrate operating in a 1 - 50 GHz band with a PDMS microfluidic channel for label-free sensing of two structural states of tubulin - free tubulin vs. self-assembled tubulin into microtubules. Computational optimization based on full-wave simulation was used for the specimen's complex permittivity extraction from measured S-parameters including CPW, microfluidic channel, and a sample. For extraction of the unknown sample's complex permittivity from the measured scattering matrix, it is essential to have the perfectly characterized model of CPW sensing line with the PDMS microfluidic channel. For this reason, we determined the material properties of the quartz glass substrate, PDMS microfluidic channel as well as a surface impedance of used CPW's conductor. The chip was fabricated with the use of positive resists (LOR 5a and S1818) and laser lithography process.

The chip was mounted on ceramics auxiliary chuck and connected through GSG 50 GHz probes to the vector network analyzer (Rohde & Schwarz ZVA67) during the measurement. The measuring system was calibrated by a NIST Multiline-TRL calibration kit situated on the same quartz substrate. Calibration design incorporated also a shift of the reference planes on the CPW. Four samples were examined; (i) pure water, (ii) buffer, (iii) buffer with free tubulin and (iv) buffer with preassembled and stabilized microtubules. The presence of tubulin and microtubules in the buffer was controlled by a standard optical turbidimetric measurement at 350 nm.

We monitored the tubulin units and its self-assembled structure, and compared solutions complex permittivity. We were able to detect slight differences in the real and imaginary parts of their complex permittivity across the whole frequency band. The design of the chip and also the obtained data can contribute to the monitoring of biological nanoscopic self-assembly processes.

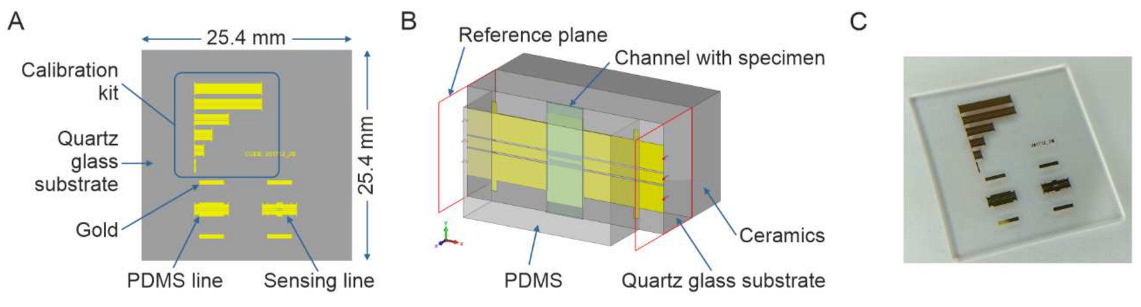

Figure 1. A) The chip includes a multiline TRL calibration kit, the line for the characterization of PDMS (microfluidics material) and the sensing line. B) 3D model of the sensing line with the brick of PDMS with a specimen inside the microfluidic channel. C) Fabricated chip.

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