Development of Microfabricated Total Internal Reflection (TIR)-based Devices for Fluorescence Imaging

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This dissertation reports the development of miniaturized and high-performance Total Internal Reflection (TIR)-based devices, which can be integrated into Micro-Total Analysis Systems (μ-TAS) as a fluorescence detection module, utilizing Micro Electro Mechanical Systems (MEMS) technology.

For the fabrication of the TIR-based devices, using anisotropic etching, Deep-Reactive Ion Etching (D-RIE), and Poly (dimethylsiloxane) (PDMS) casting, we could integrate several optical components onto the same substrate, thus alignment and assembly are unnecessary. The fabricated devices can be used with both upright and inverted microscope with flexible sample delivery platforms.

To reduce the roughness of the Si molds, an approach for smoothing Si surfaces has been proposed. Combining proper choice of masking materials and design patterns with an optimal D-RIE and oxidations and BHF etchings, we could achieve surface roughness on the order of 25nm on the lens of the PDMS TIR-based devices, fulfilling the scattering criterion.

The first device is a single-color TIR-based chip (10mm × 15mm × 1mm in size) which generates a single wavelength evanescent field for excitation of one type of fluorophores. The device has been demonstrated in measurement of the average velocities of fluorescent beads and in detecting of single fluorescent DNA molecules.

The second device is a dual-color TIR-based chip (10mm × 20mm × 1mm in size) which generates two overlapped evanescent fields for excitation of two types of fluorophores. We demonstrated the chip by simultaneously imaging mixture of green and red fluorescent dyes and then mixture of green and red fluorescent beads.

Our proposed devices are smaller and simpler comparing to current TIR optical systems (minimum 50mm 50mm 30mm in size). At this moment, our devices could provide low-cost evanescent excitations in conventional fluorescence microscopes. In the future, they might be integrated into μ-TAS where highly-sensitivity and high-resolution fluorescence imaging capability is necessary.