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Optical Waveguide Tools for Microsystems

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Planar optical waveguides are well established components for the interrogation of chemical processes at surfaces with, for example, total internal reflection fluorescence (TIRF) elements having a long pedigree [1] and surface plasmon resonance (SPR) sensors finding widespread use in biomolecular research [2]. The most important attributes of these devices are that the optical fields are confined to a submicrometer region above the solid surface of the transducer and that the light is delivered to the surface in a well-controlled way without passing through the bulk of the sample.

Integrated optics aims to exploit the technological approaches of microelectronics and guided-wave optics to realize miniature versions of such components within circuits on a chip, with immense potential for integration of sensing functions in "lab-on-a-chip" systems [3]. Several individual integrated optical devices have seen great success in telecommunications systems and this has led to a sophisticated "toolkit" of integrated components for building planar lightwave circuits (PLC's). Planar lightwave circuits are realized by combining photolithographic patterning and etching with the deposition of dielectric films onto surfaces or the diffusion of dopants into surfaces, and are thus inherently complementary to microfluidic systems. The use of the mass-production techniques developed for microelectronics in the production of integrated optical devices brings low cost, and the micron-scale replication technology allows miniaturization and dense integration. Integrated optical waveguides provide a strong and well-controlled evanescent interaction of light with chemical species at a surface in a very small sample volume, allow integration of reference sensors and arrays of sensors measuring different parameters on the same chip [4], can integrate metallic or transparent electrodes for electrochemical monitoring or reaction control [5], may probe a wide range of optical phenomena, and are compatible with optical fiber for "solid-state" connection to instrumentation [6].

While optical techniques have many advantages for chemical sensing, they are also increasingly useful for manipulation of chemical and biological species [7]. Optical tweezers are well-established as a tool for non-contact, non-destructive handling of biological materials and of inorganic nanospheres attached to biological molecules [8]. Recently, interest has grown in optical manipulation at surfaces as a potential part of the toolbox of the "lab-on-a-chip" to complement sensing and detection [9-11]. In particular, advances have been made in trapping and propulsion of metallic and dielectric micro- and nano-particles in the evanescent fields of optical waveguides, which may form part of a planar microsystem into which optical detection and spectroscopy of separated species could also be integrated. Optical waveguides embedded in surfaces represent a powerful means of controlling the distribution of optical intensity and intensity gradient at such surfaces for particle control.

In this paper, optical waveguides and waveguide devices for chemical sensing and for trapping, propulsion and sorting of nano- and micro-spheres will be described and recent experimental results presented and compared with theoretical models. The potential future application of integrated optical techniques in microsystems will be discussed.

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