Microfluidic MDM Structure as a Tunable Optical Filter

Huifeng Li, Hyunsoo Park and Xing Cheng
Solid-State Electronics, Photonics and Nano-Engineering Laboratory
Department of Electrical and Computer Engineering
Texas A&M University, College Station, TX 77843-3128

Metal-dielectric-metal (MDM) structures can provide resonant enhancement of performance for optoelectronic devices such as light-emitting diodes, photodetectors and filters [1]. The resonant frequency is determined by both the thickness of the dielectric layer and its refractive index. Tunability of the resonant frequency has attracted a lot of research interests due to many important applications such as fluorescent detection of biomaterials. Traditionally, frequency tunability can be realized by changing the dielectric layer thickness using complex microelectromechanical actuators [2]. In this work, we present a novel tuning scheme based on changing the refractive index of the dielectric layer in an MDM structure. The proposed filter device combines microfluidic channel with an MDM structure to allow fluids of different refractive indexes to be transported into and out of the middle section of the MDM structure through the fluidic channel to achieve frequency tunability. The large index modulation by fluids enables a wide tuning range in resonant frequency.

However, fabricating the MDM structure with a microfluidic middle layer is a challenge because the top metal layer cannot be directly deposited by evaporation. Recently, a fabrication scheme based on nanoimprint and transfer-bonding is developed to create three-dimensional multilayer structures [3]. By using polymer and metal thin films, such method can be adopted to fabricate the desired microfluidic MDM structure. The proposed process to fabricate the optical filter is shown in Figure 1. Figure 2(a) shows the SEM image of the fabricated device. The tuning of the resonance frequency is demonstrated by changing fluids inside the microfluidic channel. The performance of the filter device is compared with numerical simulations, which calculates the field confinement and transmission spectrum of the MDM structure based on the finite-difference-time-domain algorithm. Figure 2(b) shows the calculated transmissions with air or water inside the microfluidic channels. Simulation is also used to optimize device parameters in designing the MDM structures.

The fabrication scheme we developed also allows advanced multilayer microfluidic systems to be built. Other components, such as layers containing organic light-emitting devices and organic photoconductors can be integrated into the microfluidic system. The tunable optical filter allows simple tuning of excitation wavelength to selectively excite certain biomolecules, or blocks certain wavelengths from reaching photodetector when detecting a specific molecule in a mixture. Future multilayer integration of light sources, tunable MDM filters and optical detectors can yield ultra-compact lab-on-a-chip systems, which are convenient for numerous point-of-care bioanalysis.

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2. C. Pinheiro, J. G. Rocha, L. M. Goncalves, S. Lanceros-Mendez, and G. Minas, *Industrial Electronics, 2006 IEEE International Symposium on,* 2006. **4**: p. 2778.
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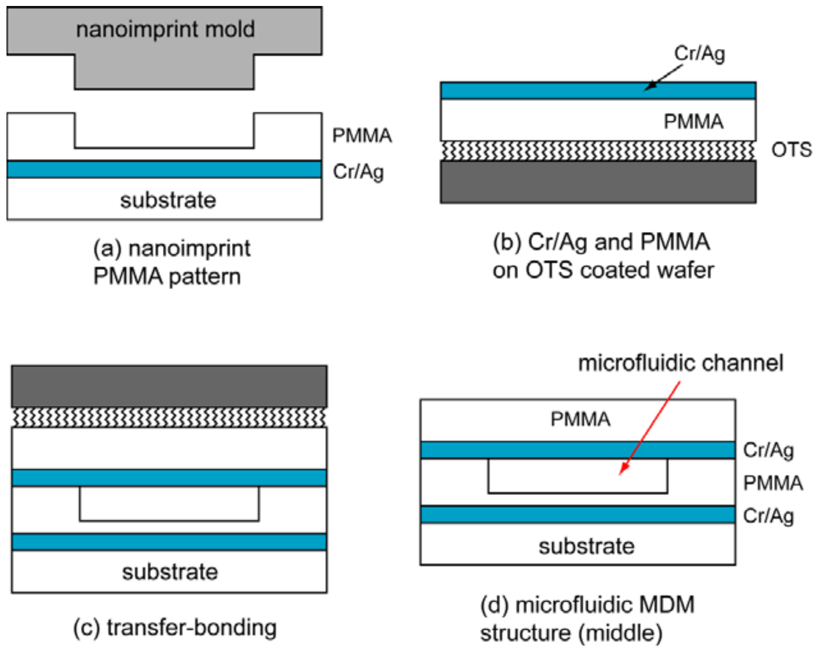
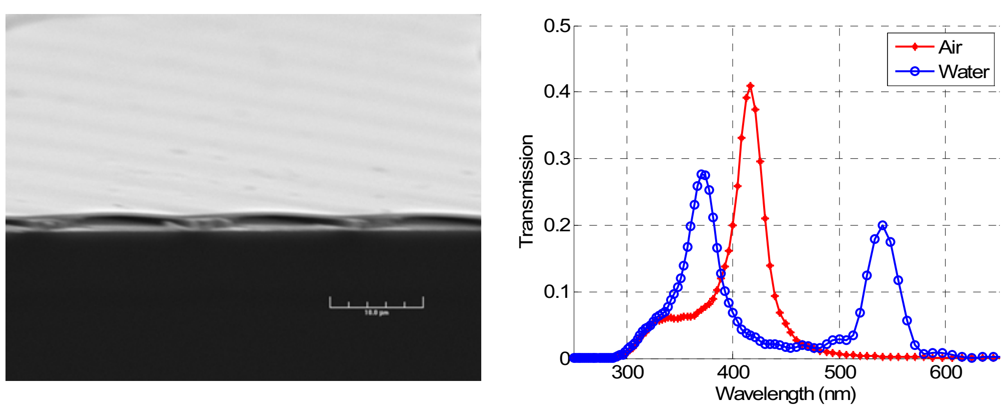


Figure 1. Schematics of the fabrication of the microfluidic MDM structure by nanoimprint and transfer-bonding. (a) Chromium and silver are deposited onto the substrate by thermal evaporation, followed by spin-coating a thin layer of poly (methyl methacrylate) (PMMA). Micropattern is created in the PMMA layer by nanoimprint; (b) A separate wafer is coated with octadodecyltrichlorosilane (OTS) to reduce the polymer-substrate adhesion. Then a thin layer of PMMA is spin-coated on the substrate before evaporating nickel and silver; (c) The metal layer along with the thin PMMA layer is transferred onto the PMMA patterns on the first substrate by transfer-bonding; (d) Removing the OTS-coated wafer completes the whole MDM structure.



(a) (b)

Figure 2. (a) An SEM picture of the microfluidic MDM structure; (b) Calculated transmission spectra of a microfluidic MDM structure with and without water in the channel.