Specific (bio-)chemical sensing with organic microlasers

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Monitoring of environmental pollutants present at low concentrations requires creation of miniature, low-cost, and highly sensitive detectors that are capable to specifically identify target substances. We propose a detection approach based on refractive index sensing with polymer micro-lasers. The sensitivity and specificity of the detection is improved due to a functionalization of the microcavity material which allows specific detection of target molecules (here, heavy metal ions).

We have developed a relatively simple and easily reproducible polymer based fabrication technology of high quality (Q)-factor (Q>6000) laser microcavities. A polymer layer doped with a commercial laser dye (eg. PMMA polymer host and DCM laser dye guest) is spin-coated onto a commercial Si/SiO_2 substrate and micrometric cavities are formed using UV lithography and reactive ion etching [1]. Various porous (polystyrene based) and non-porous

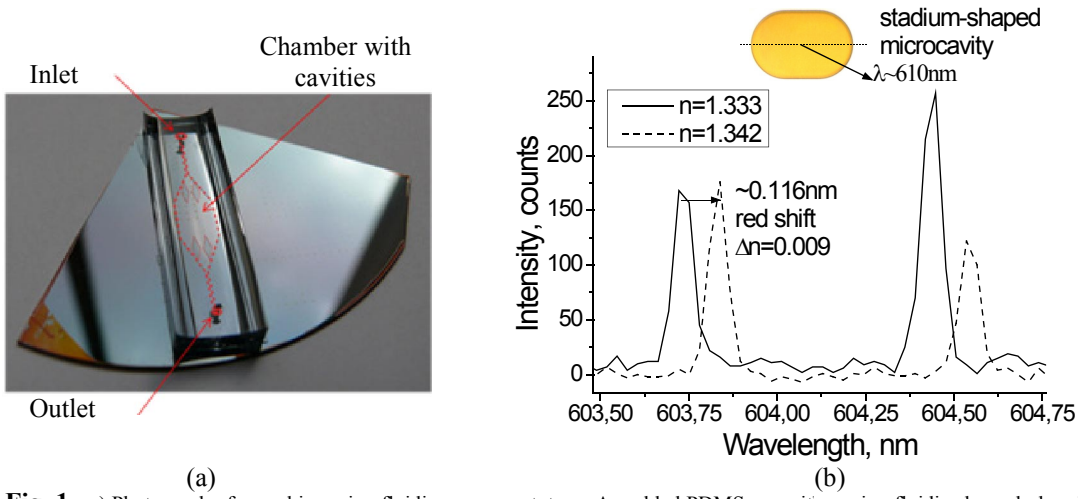

Fig. 1. a) Photograph of a working microfluidic sensor prototype. A molded PDMS cap witn a microfluidic channel placed on top of the Si/SiO_2 substrate with microlaser cavities on it. b) Refractive index sensing with a stadium-shaped PMMA microlaser.

(PMMA) polymers have been investigated and different cavity shapes have been fabricated and their respective sensing efficiencies tested. It was demonstrated, for instance, that directionality and spectral properties of microlaser emission can be controlled by varying the cavity contour [1]. Sensing originates from the influence of the refractive index change of the medium on the lasing spectrum of a cavity, which generally features a comb of almost equally spaced peaks [2]. The specificity of the cavity response to the analyte solution is ensured by functionalizing the cavity by ligands. In that perspective, we have synthesized effective ligands that specifically bind Cd^{2+}, Hg^{2+} and Pb^{2+} ions [3] while being compatible with lasing.

In order to bring laser microcavities in a direct contact with the analyte solution and enable easy spectra recording, they are placed inside a molded polydimethylsiloxane (PDMS) microfluidic chip (Fig. 1a). The molded PDMS chip has transparent sidewalls that enable pumping and easy recording of lasing spectra in lateral directions (in the plane of the cavity).

Validation of our refractive index sensing principle was demonstrated with both traditional PMMA (13 nm/RIU) and porous polystyrene-based (10 nm/RIU) cavities. A clearly identifiable red-shift is seen in the cavity lasing spectra that depend on the refractive index of the cavity surrounding (Fig. 1b). A sensor can be calibrated by precise quantification of the spectral shift, thus allowing for further concentration measurements.

References

[1] M. Lebental, E. Bogomolny, and J. Zyss, in *Practical applications of microresonators in optics and photonics*, A. Matsko, (CRC Press, 2009).
[2] M. Lebental, N. Djellali, C. Arnaud, J-S. Lauret, J. Zyss, R. Dubertrand, C. Schmit, and E. Bogomolny, "Inferring periodic orbits from spectra of simply shaped microlasers", Phys. Rev. A **76**, 023830 (2007).
[3] L. Zhao, T. Wu, J.-P. Lefèvre, I. Leray and J.A. Delaire, "Fluorimetric lead detection in a microfluidic device", Lab on a Chip, **9**, 2818 – 2823 (2009).