Photoluminescence and Aging Effects in Photonic Microcavities Based on Porous Silicon Microspheres

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Photonic microcavities constitute a field of research that has attracted the attention of many researchers from all over the world.[1] The fact that light can be confined in a very reduced volume of the order of 1 micrometer or even less is very interesting not only from the point of view of basic science but also from the point of view of technological applications. For instance, very sensitive chemical sensors based on the light interaction with matter could be achieved by means of microcavities because the electromagnetic field can be greatly enhanced inside them.[2] So far, planar microcavities based on different materials like silicon, indium gallium arsenide phosphide, silicon nitride, etc. were successfully obtained.[3] However, only a reduced number of materials like for instance silica, poly-styrene, silicon, etc. has been able to be shaped in a spherical geometry and having a surface smooth enough so as to allow them work as optical microresonators.[4,5]

Here, we report on porous silicon particles.[6] They were synthesized by chemical vapour deposition of di-silane gas under controlled conditions of temperature, pressure, and decomposition time. Because the particles are highly spherical and their surface is very smooth (see Fig. 1), and also because of their high refractive index value, they can work as photonic microcavities with well defined resonating modes. These modes were identified in the near infrared range and they experience large (hundreds of nanometers) and fast (nanometers per minute) shifts upon the exposure of the microspheres to the open atmosphere (see Fig. 2). We have attributed this behaviour to a highly porous nature of the microspheres and to an oxidation process. This hypothesis has been confirmed by Transmission Electron Microscopy and by Mid-Infrared Spectroscopy.

The nano-porous nature of the microspheres produces the typical photoluminescence of electrochemically fabricated porous silicon (see Fig. 3). This is a very important characteristic because it may allow light amplification and therefore lasing in a single microsphere by taking advantage of the microcavity light confinement effect.

References

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Figures

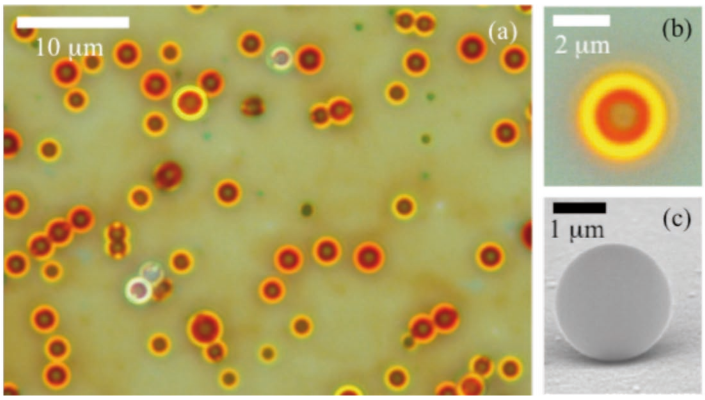

Fig. 1 Optical microscopy images at 1000X magnification showing: (a) Porous silicon microspheres obtained by decomposing disilane at 400 ºC. (b) A zoomed image (at the same magnification) of a single microsphere. (c) Scanning Electron Microscopy image at 45000X magnification of a porous silicon microsphere of about 2 micrometers in diameter illustrating its spherical perfection and smooth surface.

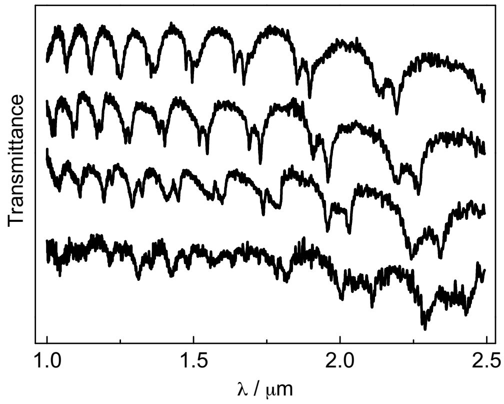

Fig. 2 Optical transmittance spectra of a porous silicon microsphere of about 3 micrometers in diameter. They were measured in vacuum (bottom spectrum) and after different exposure times: 1 hour, 20 hours and 120 hours (2nd, 3rd and 4th spectra from bottom to top respectively). The resonating modes correspond to the dips of the spectra. They blue-shift as the exposure time of the microsphere to the open air increases.

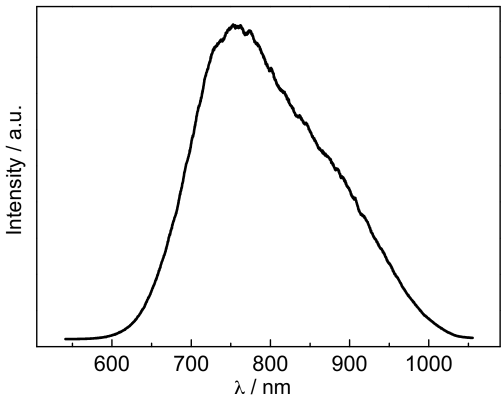

Fig. 3 Photoluminescence signal of a cluster of porous silicon microspheres. The excitation source was the 488 nm line of an Ar laser.