Tailoring the optical properties of nanoporous anodic alumina with geometry modification for further sensing applications

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Nanoporous anodic alumina (NAA) is one of the smartest materials with considerable interest in recent years [1] due to their physico-chemical properties like thermal stability, environmental toughness or biocompatibility, and also to its easy fabrication to obtain a highly ordered and manageable porous assembly for purposes such as nanomaterials synthesis [2], photonics [3] or sensors [4].

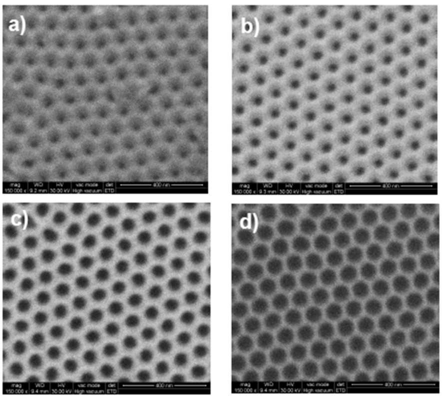

Figure 1: Set of ESEM top view images of the first group of GCA samples, 1.7 µm a) GCA-1 (PW=0 min); b) GCA-2 (PW=6 min); c) GCA-3 (PW=12 min); d) GCA-4 (PW=18 min).

Two batches of NAA samples, the second twice as thick as the first one (1.7 and 3.4 µm), have been prepared. Each set possess four samples with the same pore length but different porosities (figure 1) and have been studied by means of the Fabry-Pérot optical interferences both in reflectance, covering the UV-visible and the near infrared region of the spectrum, and in the UV-visible spectrum of photoluminescence. Changes in the two types of spectra are related to the different pore lengths and pore diameters.

Table 1 summarizes the geometric features of the samples and resumes the fabrication conditions.

Label	L_p (µm)	n	P (%)	D_p (nm)	EOT (µm)
GCA-1 / GCA-5	1.7/3.4	1.65	14.3	38.6	2.8/5.6
GCA-2 / GCA-6	1.7/3.4	1.58	23.1	51.2	2.7/5.4
GCA-3 / GCA-7	1.7/3.4	1.41	44.6	72.3	2.4/4.8
GCA-4 / GCA-8	1.7/3.4	1.20	71.2	90.9	2.0/4.0

Table 1: Optical and geometric characteristics of the eight GCA samples: fabricated in 0.3M oxalic acid at 40V. The interpore distance (D_{int}) was 102 nm for all the samples.

Oscillations appear in the optical spectrum of the nanoporous alumina when the pore geometry (pore length, L_p, and pore diameter, D_p) are suitable for the evidence of the Fabry-Pérot effect [5]. Figure 2a shows the reflectance spectra of the first sample of each group, GCA-1 and GCA-5, as an example. Furthermore, simulations have been also made using the effective medium approximation [6] to corroborate experimental results. We were able to fit pretty well the experimental data with simulations based on the effective medium approximation. Figure 2b depicts the simulation of reflectance compared with the experimental spectrum of sample GCA-1. NAA presents also interesting photoluminescence properties [7]. In figure 3 is represented the emission spectra of the same pair of samples.

We noticed that the capability of nanoporous anodic alumina is promising for being used as an accurate and sensible optical sensor employing either reflectance or fluorescence spectroscopy.

This work was supported by the Spanish Ministry of Science and Innovation (MICINN) under grant nº TEC2009-09551 and TEC2012-34397, CONSOLIDER HOPE project CSD2007-00007and AGAUR 2009 SGR 549.

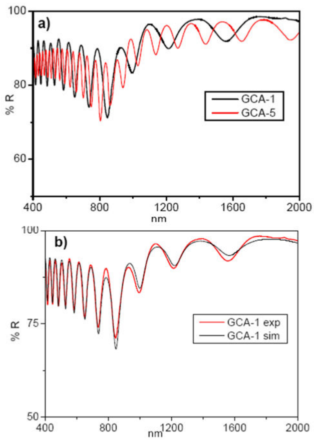

Figure 2: a) Comparison in the reflectance spectra of samples with the same porosity and the two different pore lengths, 1.7 and 3.4 μm, GCA-1 and GCA-5, black and red lines. b) Comparison in the reflectance spectra of the experimental sample, GCA-1, and the corresponding simulation, red and black lines respectively.

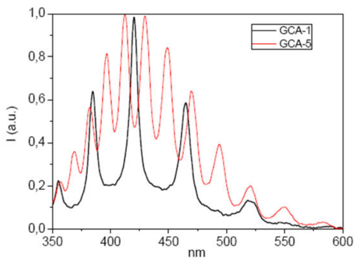

Figure 3: Fluorescence spectra of GCA-1 and GCA-5, black and red lines respectively, in the UV-visible region. The number of oscillations is multiplied by two in the sample with the double pore length.

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