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Fabrication of pedestal high-contrast grating for biosensing applications

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Many different approaches and detection principles are used for optical biosensing [1-5]. One example is refractometric sensing, where the analyte is detected because its presence causes changes in the local refractive index, which in turn leads to a shift of the resonance position. High-contrast grating (HCG) structures can be employed in refractometric sensing due to their narrow resonance and high sensitivity [6,7].

Here, we present the fabrication and characterization of pedestal-HCG structures, which were chosen as promising candidates for improved biosensing based on theoretical calculations [7]. Moreover, we show an experimental comparison of their performance with conventional HCG. The structures were optically characterized in terms of both bulk and surface sensing.

The fabrication process comprises deep UV lithography for defining the pattern and dry etching for generating the final structures. All fabrication steps are depicted in Fig. 1(a). First, the home-made silicon-on-insulator (SOI) substrates were prepared by a wet oxidation process based on H_2O at 1100 ˚C, resulting in a 1.1 μm SiO_2 layer on Si, and a low pressure chemical vapor deposition (LPCVD) step based on SiH_4 at 560 ˚C, to grow 500 nm of amorphous Si (aSi) on top of the SiO_2 layer. The next step involved a conventional deep-UV lithography process where a one-dimensional periodic lattice of bars (lattice period $\Lambda = 810$ nm and bars width $w = 340$ nm) was introduced onto the aSi surface. Deep reactive ion etching was used afterwards to etch down bars through the aSi layer. For the last step, the HF vapor phase was used for the controllable etching of the SiO_2 layer underneath the aSi grating bars.

To characterize the potential of the structures for biosensing applications, their surface sensitivity and bulk refractive index sensitivity (BRIS) were evaluated from reflection spectra as shown in Fig.2. We deposited on the surface of our structures 2-5 nm thick layers of Al_2O_3 (refractive index (RI) = 1.6) using atomic layer deposition. The resonance position shift, which is determined by the deposited oxide thickness, is 10.5% more apparent for pedestal-HCG than for conventional HCG. In terms of BRIS, the performance of pedestal HCG is 11.2% higher that of the conventional HCG (536 nm/RIU (refractive index unit) as opposed to 482 nm/RIU). This experimental performance increase confirms the theoretical predictions from [7].

To sum up, the performance of pedestal-HCG in terms of surface and bulk sensitivity surpasses that of conventional HCG, suggesting that the pedestal-HCG are good candidates for biosensing applications.

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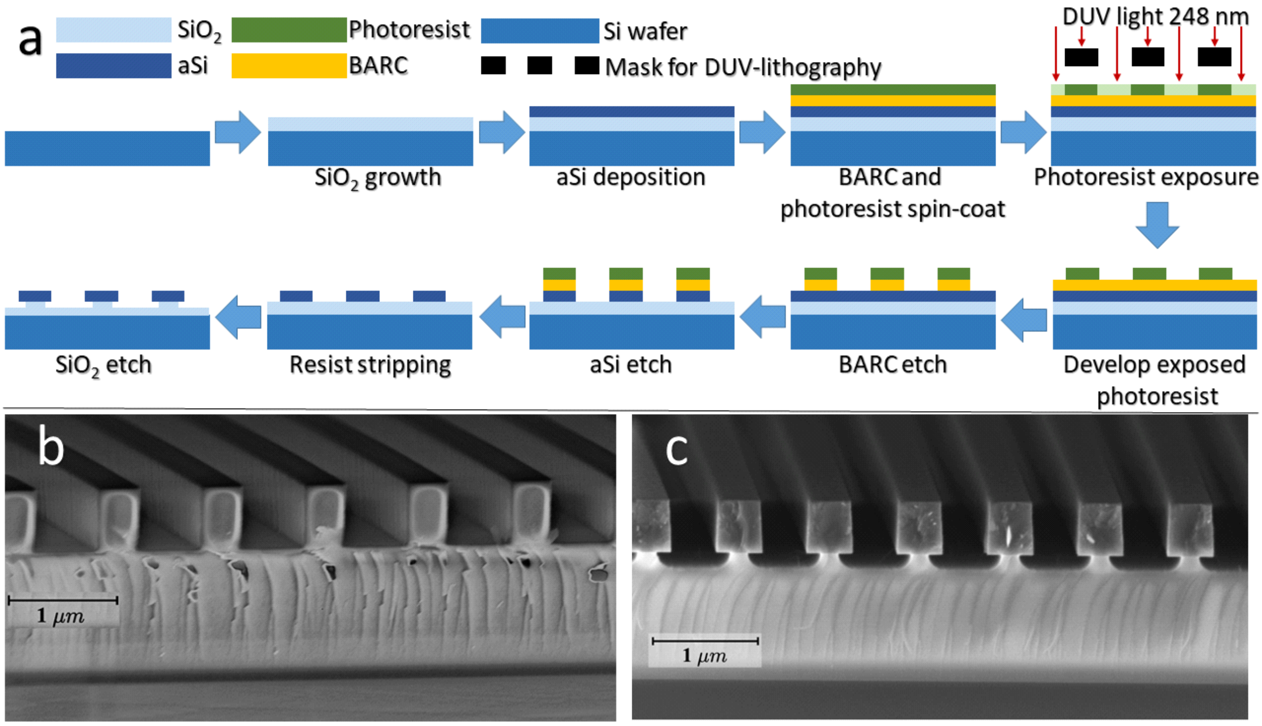

Figure 1. (a) Schematic of the fabrication process for the pedestal high-contrast grating. (b) SEM image of the HCG in cross-section, (c) SEM image of the pedestal-HCG in cross-section.

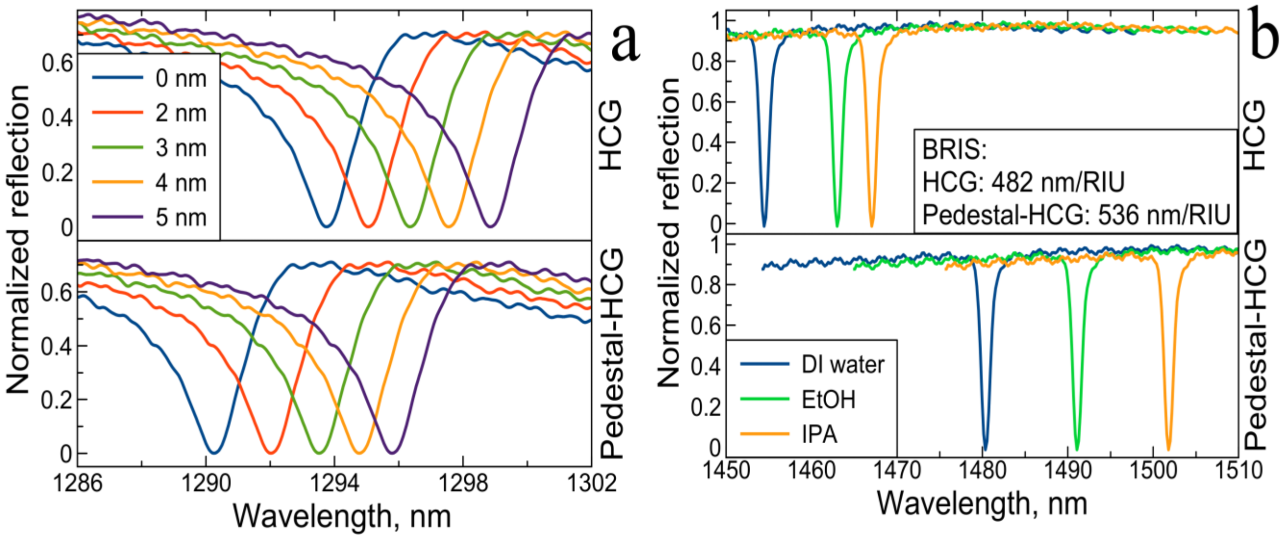

Figure 2. (a) Reflection spectra of conventional and pedestal high contrast gratings measured with different deposited thicknesses of Al_2O_3. (b) Reflection spectra of conventional and pedestal high contrast gratings in deionized water, ethanol and isopropanol media, which have a refractive index of 1.33, 1.35 and 1.37, respectively.