Optical characterisation of an HSQ lithography process

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We report on a new linewidth metrology method which makes use of the resonances of optical structures. It has an ultimate accuracy of better than 0.1%, but has the limitation that it cannot be used for arbitrary structures.

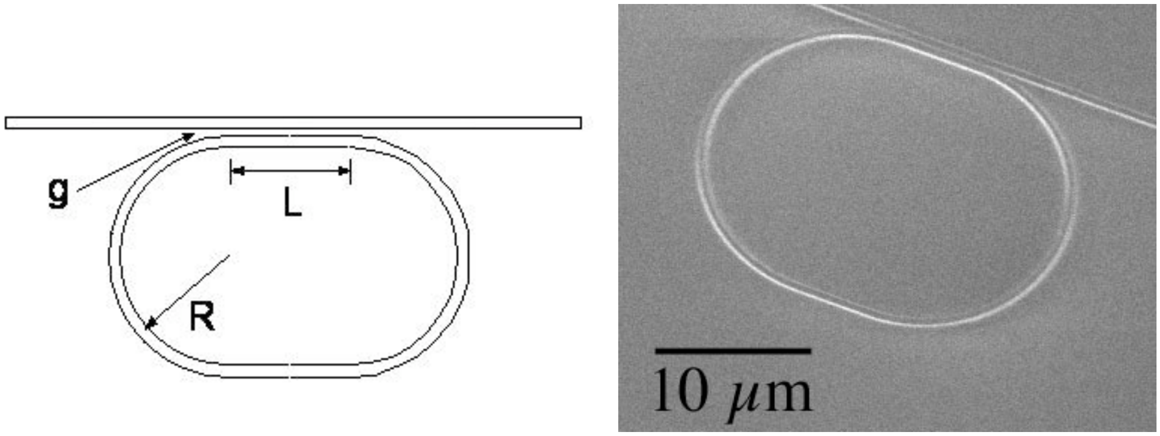
One suitable device is a single ring resonator, side coupled to a bus waveguide, fabricated on an SOI wafer, shown in Fig 1. They were fabricated using electron beam lithography with hydrogen silsesquioxane (HSQ) as the resist. The radius, R, was 20 µm and, to enhance the coupling effect, there is a coupling region formed by a straight waveguide with a length, L, of 10 µm. The gap between the bus waveguide and the coupling region is 150 nm. Light will couple from the bus waveguide to the ring at a resonant frequency λ which varies with both the width, w, and thickness, t, of the waveguide. For 500 nm wide waveguides on 220 nm thick SOI, finite element modelling showed that

$$\Delta\lambda = 0.75\Delta w + 2.0\Delta t$$

where $\Delta\lambda$, Δw and Δt are the changes in λ, w and t respectively; w is the average width around the resonator structure after lithography and etching.

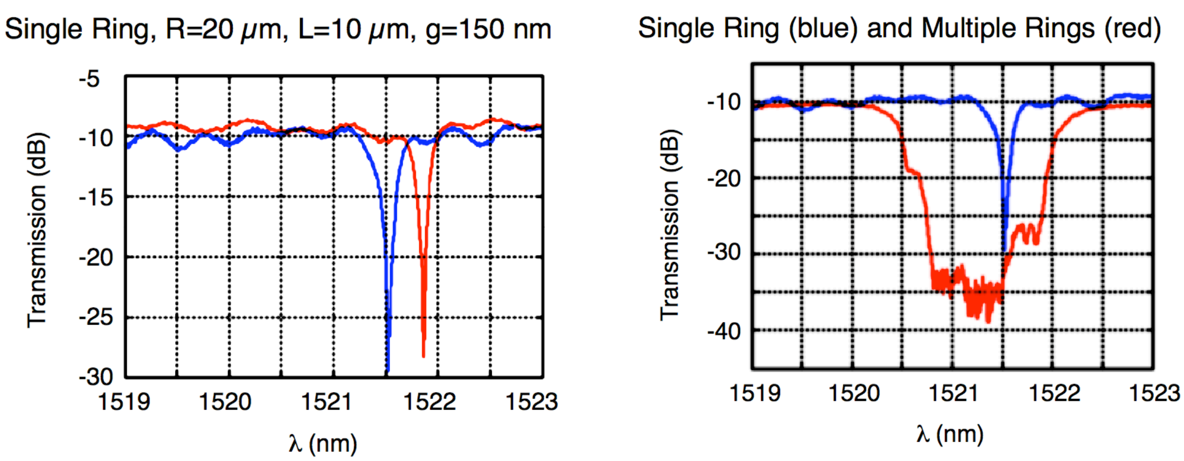
Although the value of the resonance wavelength is in principle more sensitive to variations in the waveguide thickness, the variations observed do at least give an upper bound to the variations in the width of the waveguide. The errors can be reduced by increasing the thickness and decreasing the width of the waveguides.

A number of papers have shown that HSQ suffers from significant delay effects. In particular the dose changes with the age of the dilution, even when kept in a fridge. We used optical resonance techniques to monitor the stability of HSQ processing over many weeks. We diluted small volumes of FOX16 HSQ for immediate use, which gave more consistent results than those obtained by preparing a single dilution of HSQ to be used over the same period. Fig 2 (a) shows resonances obtained from two devices fabricated five days apart. A shift of wavelength of 0.33 nm was observed, corresponding to a change in width of 0.43 nm. The results of a second experiment with 64 ring resonators along the bus waveguide are shown in Fig 2 (b). From the width of the resonance it can be deduced that the variation in width over the 64 rings was about 1.5 nm. This was a test of the fidelity of the proximity effect correction since rings at the ends needed different dose to those in the centre.



(a) (b)

Fig 1 Ring resonator structure used for optical characterisation: (a) schematic; (b) SEM micrograph.



(a) (b)

Fig 2 –Measurements of the resonance for (a) two different single ring devices fabricated on different days on two different substrates (b) a single ring and 64 rings fabricated on the same substrate.