Thermal tuning of Brillouin resonance in free standing silicon nanowire

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Abstract: We demonstrate thermal tuning of the Brillouin resonance in silicon nanowire waveguides using cross phase modulation detection. We also investigate possible use of this effect for locally mapping the width of an extended waveguide.
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1. Introduction

Stimulated Brillouin scattering (SBS) is a nonlinear process coupling an optical and a mechanical field [1]. The Brillouin resonance has been demonstrated in different silicon waveguide (WG) geometries [2][3]. As demonstrated in [4], even a small SBS gain can be used for realizing tunable and narrow band RF filters. The strong dependency of the mechanical resonance frequency, Ω, to the waveguide width allows tailoring of Ω but is also responsible for the decrease in mechanical quality factor, Q, due to inhomogeous broadening associated with fabrication imperfections. We demonstrate the possibility of thermally tune Ω and investigate the use of such tuning mechanism for compensating for this inhomogeneous broadening.

2. Findings

We have studied the effect of temperature change on the Brillouin resonance of 750 nm wide and 220 nm thick free standing waveguides. They have been fabricated by 193 nm deep-ultraviolet lithography in a 200 mm wafer CMOS pilot line at IMEC and were then under etched in our clean room facility using buffered HF. Using a cross phase modulation (XPM) technic [2] we have investigated how the mechanical resonance frequency *Ω* depends on the temperature (see Fig. 1). The temperature was tuned from 25°C to 80°C by changing the chip holding stage temperature .

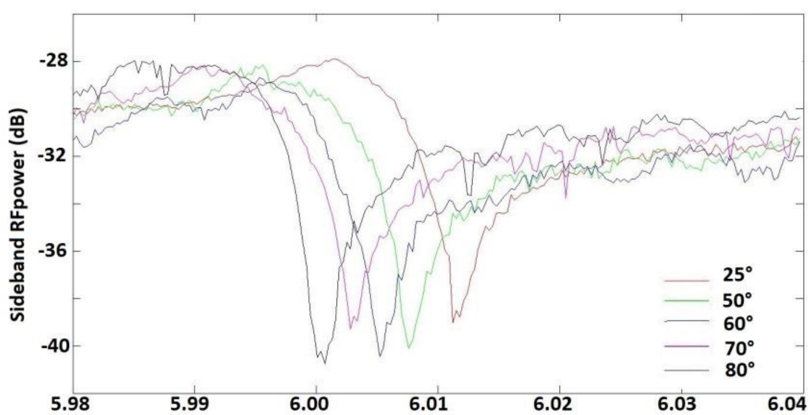

Fig. 1 Fano resonance obtained using XPM experiment for 25°, 50°, 60°, 70° and 80 °

The frequency shift per degree is 0.24 MHz.K^{-1} or $\Omega.4.10^{-5}$ K^{-1} is in agreement with a simple Fabry-Perrot model $\Omega = v/2w$ with v, the sound velocity, and w, the waveguide width, for the phonon resonance. Thereby we take into account the thermal dependency of the sound velocity $\Delta v / \Delta T = v .5.10^{-5}$ as found in literature [5].

3. Perspectives

Using heaters integrated next to the waveguide anchoring points (see Fig. 2b), it is possible to set different temperatures for different part of the free-standing waveguide.

Individual tuning will allow us to measure the resonance frequency, Ω_n, of each individual subsection n of the waveguide. In Fig. 2a we consider a waveguide divided in 8 subsections, 7 of which are heated at the temperature T indicated in the legend. We can see that if T > 80°C we can clearly distinguish the resonance associated with the subsection left at room temperature and determine its resonance frequency.

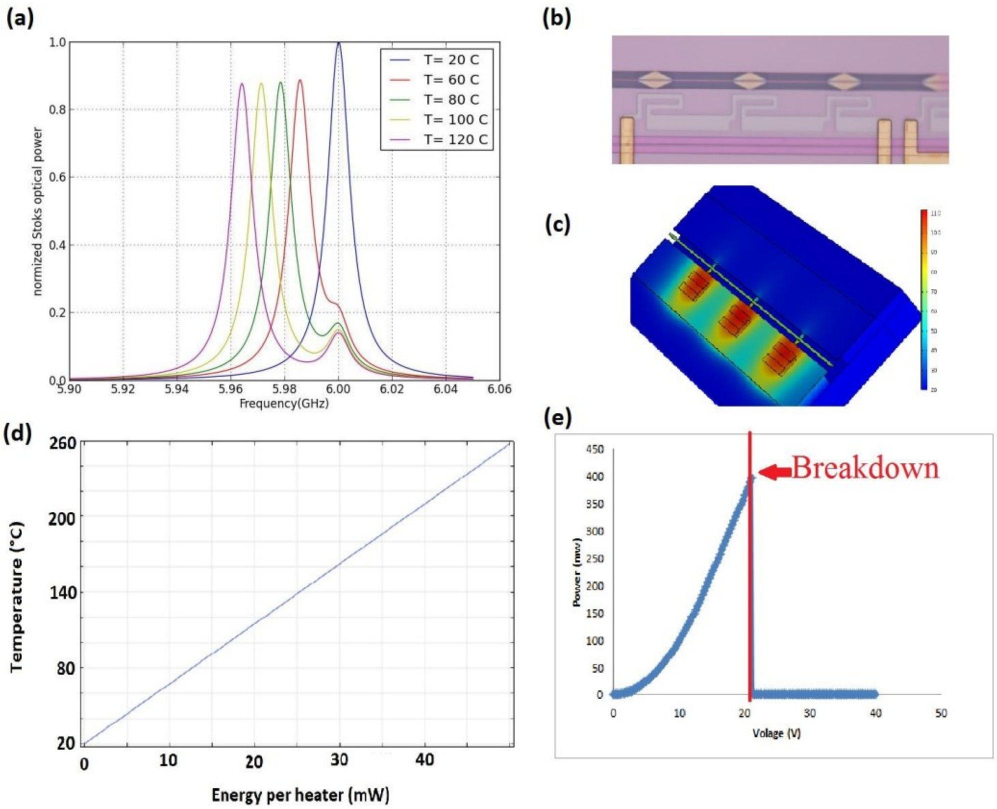

Figure 2 **(a)** Free standing WG width mapping: Stokes power vs. heater power **(b)** Chromium heaters next to the WG anchoring points **(c)** FEM simulation of thermal transport **(d)** Free standing WG : temperature vs. heating power per heater **(f)** under etched Chromium heater characterization

Using a finite element simulation, we can evaluate the electrical power needed to reach this temperature. Fig. 2d shows less than 15 mW per heater is required. We also showed this power is compatible with the maximum power that can be handled by our deposited chromium heater after under etching (see Fig. 2e) before breakdown, i.e. 400 mW for 3 connected heaters or more than 130 mW per heater.

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4. References

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