Influence of Process Route on Membrane Profile and Q-Factor of an Acoustic Resonator Sensor

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Abstract

Membranes for acoustic resonator sensors can be fabricated using deep reactive ion etching techniques. To produce the pattern a mask is needed. The most common materials used for the mask are photoresist and silicon dioxide. This paper explores what influence the choice of the mask material and etching parameters has on the profile of the membrane and as such on the Q-factor of the resonator. Results are presented for membranes fabricated using photoresist, silicon dioxide, aluminum, alumina, or combinations of these materials as etch masks. Best results were achieved using very thin (~27nm) alumina films patterned in a lift-off process as a mask and following the Bosch deep reactive ion etch by an isotropic etch to get a smoother surface.

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1. Motivation and results

Electromagnetic excitation of an acoustic resonator as an alternative to piezoelectric or capacitive excitation enables non-contact measurements in liquids ([1], [2]). Using silicon for the acoustic resonator is advantageous as it has low thermal coefficients, favorable elastic properties and there are well-established microfabrication methods for silicon devices [3]. We have developed a process route for an integrated magnetic-acoustic-resonator sensor as shown in Figure 1. To achieve a high Q-factor it is essential to optimize the fabrication process of the membrane to get a uniform membrane profile and a smooth membrane surface. This paper looks into the use of different materials as masks during the etch process and how combining a Bosch etch and isotropic etching can improve the smoothness of the membrane.

Using thick photoresist as an etch mask during the Bosch process is very straightforward but we found that the produced membrane profiles are not very uniform (s. Figure 2, top). We think this is due to redeposition of photoresist on the membrane. The low selectivity of photoresist also limits the etch depth. Thermal SiO2 as a hard
mask does not influence the etch profile (s. Figure 2, bottom) and reaches selectivities of up to 1:150. But etch depth is limited by the thickness of the thermal oxide (standard wafers usually up to 2μm) and patterning the SiO2 requires another etch process. Using aluminum and alumina as mask material we got very high selectivities with the selectivity for alumina being nearly two orders of magnitude higher than the selectivity of SiO2. However, using aluminum we experienced the formation of micrograss. Alumina produced the best results as an etch mask showing high selectivity and well defined edges (s. Figure 3). Good results were achieved with alumina etch masks as thin as 27nm and the alumina is easily patterned using lift-off techniques.

Fig. 1. Sensing system (exploded) based on a silicon membrane oscillating in a shear mode. The coil is driven by an RF signal instigating eddy currents in a thin metal layer on one side of the membrane. Being in a static magnetic field the eddy currents produce periodic radial Lorentz forces on the membrane causing it to oscillate. Changes of the viscosity of the analyte or the mass at the surface of the membrane affect the membrane’s resonant frequency and thus can be measured.

Fig. 2 Profiles over the diameter of the silicon membrane showing the influence of photoresist on the etch depth after the BOSCH process. The first sample (top/blue) was etched in the DRIE system without removing the photoresist on the SiO2 hard mask while the photoresist on the second sample (bottom/red) was stripped before the DRIE process.
Impurities or redeposition of sputtered molecules of the mask can lead to the formation of micrograss or micropillars (s. Figure 4, left). This is undesirable as it is detrimental to the Q-factor of the resonator. The image in Figure 4 on the right shows that a short isotropic etch can remove such micropillars. Accordingly we found using alumina as a hard mask and following the Bosch process by a short isotropic etch to yield the best results to achieve high-Q resonator silicon membranes.
References

