Comparison of dry etch release processes for micromachining applications

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Micromachining techniques involving etch release processes have been developed and used widely for microelectromechanical systems (MEMS) in recent years [1-8]. When fabricating three-dimensional microstructures, "release" etch is the key process to removing sacrificial material, leaving the mechanical structure free from underlying support. Various sacrificial materials have been employed for the release process. For example, using polysilicon as the structural layer, silicon dioxide or organic material could be used as sacrificial layers. For SiO_2 sacrificial layer release, hydrofluoric acid (HF) wet etching, followed by supercritical drying process [2] or vapor phase HF etching have been employed [3], while for organic sacrificial layers release, oxygen plasma is used [4]. However, the wet release processes for SiO_2 can suffer from inherent problems such as stiction [5], difficulty in releasing narrow gaps [6] and in the dry etch release case, particularly for organic sacrificial layers, very low etching rates. On the other hand, other materials could be used as the structural layer while using polysilicon as the sacrificial layer. Thus far, there have been few reports on the development of fluorine based dry etch release processes for polysilicon [7-8], and to our knowledge, no comparison studies have been performed.

In this paper, we report on the systematic comparative study of dry release processes, by characterising the release etching of polysilicon sacrificial layer in micromachining using vapor phase XeF_2 (Xenon Difluoride) continuous etching and inductively coupled plasma etching with SF_6 gas. Test structures of 0.5µm thick LPCVD polysilicon with varying widths (1 - 500µm) and therefore, side etch openings have been fabricated successfully, see figure 1. Details of the test structure fabrication process will be described. XeF_2 and SF_6 release etch processes have been studied as a function of etch time, pressure and the size of openings. Measurements have been carried out by optical microscopy and scanning electron microscopy. It has been observed that for XeF_2 etch release, lateral etch rates of up to 12µm/min under a pressure of 3Torr can be achieved, when the etch opening size is comparable to the mean free path of XeF_2 (~ 60µm), see figure2a. Limitation of the diffusion of etch species, pressure effects, loading effects, aperture effects have been observed (figure 2) and will be discussed in detail. In addition, the comparison of etch release characteristics for XeF_2 and SF_6 etching will be presented. Moreover, the optimized process has been employed for the fabrication of silicon carbide resonators.

References

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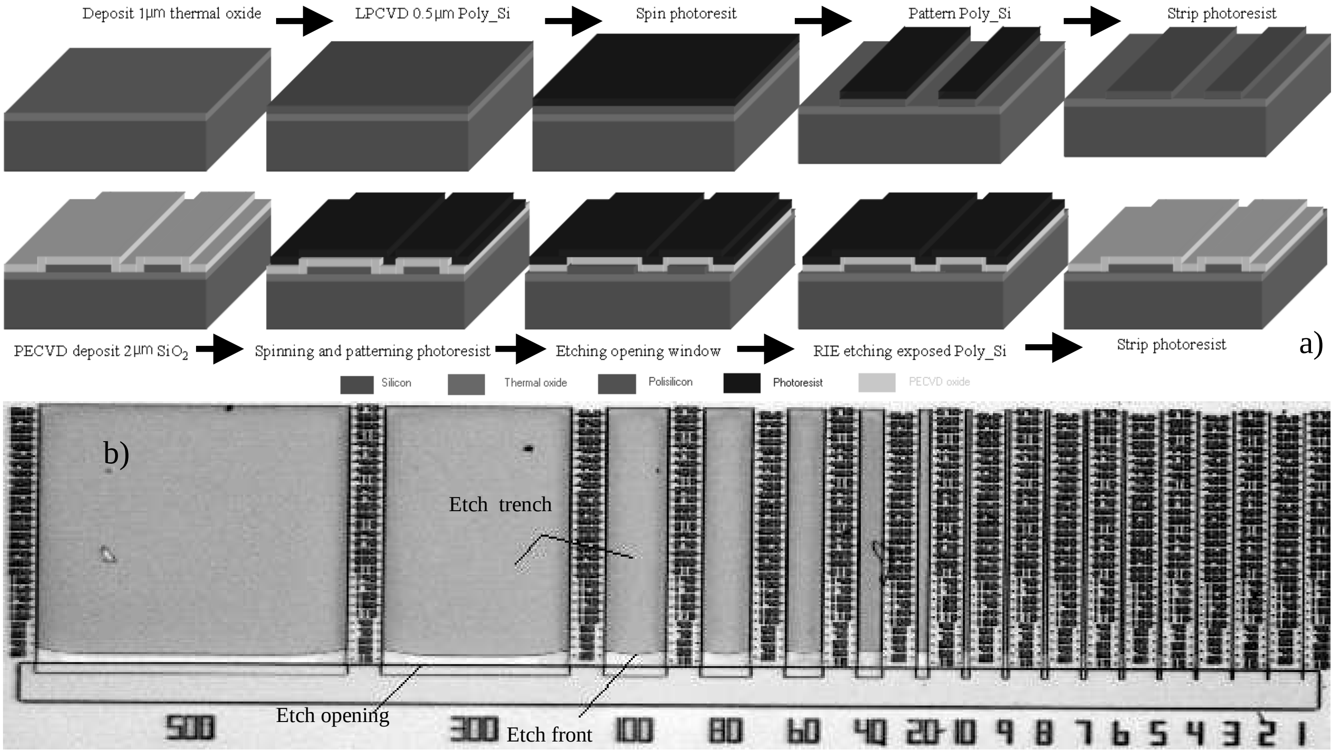

Figure 1a) Process flow for the test structures; Figure 1b) The view from top by optical microscope of trench size from 1-500μm, etching under XeF_2 pressure of 1torr and flow rate of 100sccm for 10mins

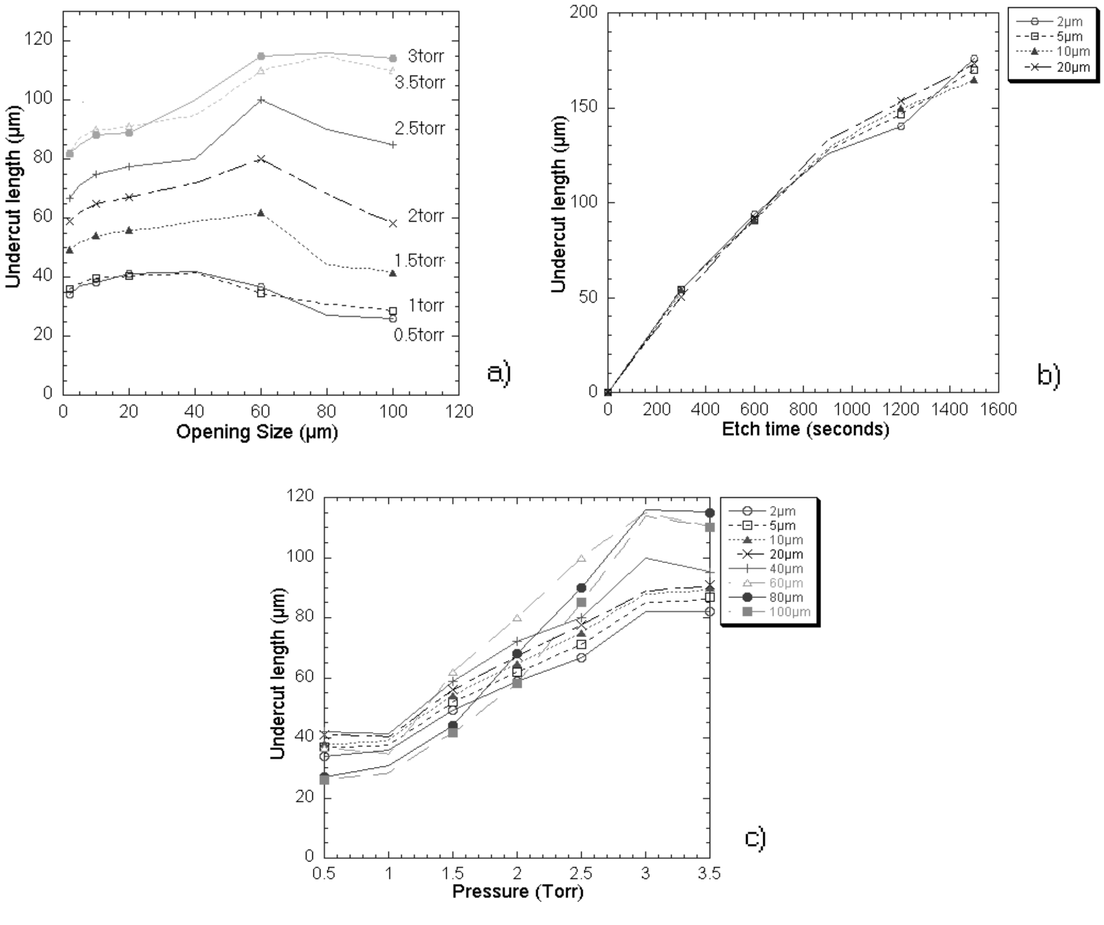

Figure 2 The undercut length as a function of a) etch opening size, b) etch time and c) etch pressure