Chapter 7

Conclusions

A monolithically integrated Fabry-Perot cavity pressure sensor has been developed using a combination of surface and bulk micromachining. Surface micromachining provided accurate dimensional control of the device, such as for the cavity gap, leading to high performace of the device. On the other hand, bulk micromachining produced a self-guiding structure and mechanical stop for the optical fiber interconnect, which would be very useful in practical applications. The two greatest advantages of this fabrication technique are compatibility with standard VLSI technology and formation of a cavity with an air gap without using a wafer bonding process. Compatibility with well-established VLSI technology makes it possible to manufacture the sensor in high volume and reduces the cost of the sensor. Also, high manufacturing yield can be achieved by using surface micromachining techniques, which allow a high quality cavity to be constructed monolithically.

Micromachined diaphragms, consisting of silicon dioxide and silicon nitride, have been observed to suffer from residual stress inside the layers. The stress of the film is believed to be even bigger in localized areas where either etch windows are patterned in the film or bubbles are generated during the etch process of the thin sacrificial layer underneath the film [1]. This residual stress can prevent the fabrication of large micromachined diaphragms free from buckling or cracks. Use of a composite film stack has been found to help reduce the unwanted effects of residual stress. Relatively large size composite diaphragms consisting of silicon dioxide and silicon nitride were sucessfully fabricated without buckling or cracks.

Remote pressure sensing has also been demonstrated by using the micro pressure-sensitive cavity and a multimode optical fiber as an interconnect. The small cavity gap should allow the microcavity to produce an interferometric effect with even a low coherence length light source, e.g., an LED, and a multimode fiber which could not be used in conventional interferometric devices. Use of LEDs and multimode fibers may make it possible to build a high performance sensor at low cost. One drawback of the micromachined cavity observed is the averaging effect of the optical response caused by variation in the amount of deflection over the optically sampled area. The averaging effect results in smaller dynamic range of the sensing system. The easiest method to reduce the averaging effect is to decrease the optically sampled area, i.e. using a smaller core, but also leading to weaker reflected signal due to low coupling efficiency. Another possiblity is to use a modified diaphragm, e.g., one with corrugated structures or with different boundary conditions [2] , that can produce uniform deflection of the diaphragm.

In this dissertation the design of a Fabry-Perot cavity pressure sensor to enhance manufacturing yield has also been studied. Uncertainty in cavity gap induced by process variations was calculated using an analytic method. The analytic method makes it simpler to calculate variations of optical response due to thickness variations of the cavity structure. The uncertainty would bound the accuracy of a sensor. In this study it was found that there exists an optimum design, a combination of initial cavity gap and mechanical travel of the mirror, which gives high yield with a specific level of performance. This design methodology could be applied to other interference-based optical devices, such as an optical modulator [3] .

Among future work to be done is the development of deposition processes which produce low residual stress in the deposited films. For silicon nitride prepared using LPCVD it has been observed that high deposition temperature and high silicon concentration tend to reduce residual stress in the silicon nitride [4] . Small residual stress would greatly help to improve the mechanical reliability of micromachined structures released from a substrate. For micro Fabry-Perot cavity based devices, it will also give more choices in the design of the optical response of the cavity. Other work to be done is to find possible applications of the micromachined Fabry-Perot cavity sensor. For example, the micromachined Fabry-Perot cavity could be used as a gas sensor, an optical modulator, or a tunable optical filter. If the cavity gap were coated or filled with a material of which refractive index changes as the material is exposed to a certain gas, the optical response of the cavity becomes sensitive to the presence of the gas. The gas sensor could be more sensitive to the gas due to the resonance effect of the cavity. As an active device, the micromachined cavity can be actuated by either electrostatic or piezoelectric forces. Such a structure would allow the cavity to be integrated with other material-based photodetectors, such as III-V materials for optical communication, by removing the silicon substrate.