Abstract

With the proliferation of industries world-wide, there is a growing need and interest in sensing and monitoring environmental pollutants and monitoring the concentration of chemicals/gases in industrial process control. There is also an increasing demand for chemical sensors in other applications such as home security, breath analysis and food processing.

Design and development of metal-oxide based gas sensor system is reported in this thesis. The system consists of three components viz. microheater (which aids in heating the sensor film to required temperatures), CMOS ASIC (the sensor interface circuit) and the thin film transducer (a semiconducting metal oxide thin film whose resistance changes with the concentration of the target gas).

Microheaters were realized through PolyMUMPs process. Thermal characterization of surface-micromachined microheaters is carried out from their dynamic response to electrothermal excitations. An electrical equivalent circuit model is developed for the thermo-mechanical system. The mechanical parameters are extracted from the frequency response obtained using a Laser Doppler Vibrometer. The resonant frequencies of the microheaters are measured and compared with FEM simulations. The thermal time constants are obtained from the electrical equivalent model by fitting the model response to the measured frequency response. Microheaters with an active area of $140\mu m \times 140\mu m$ *have been realized on two different layers (poly-1 and poly-2) with two different air-gaps* ($2\mu m$ *and* $2.75\mu m$*). The effective time constants, combining thermal and mechanical*

responses, are in the range of 0.13ms to 0.22ms for heaters on poly-1, and 1.9μs to 0.15ms for microheaters on poly-2 layer. The thermal time constants of the best microheaters are in the range of a few μs, thus making them suitable for sensor applications that need faster thermal response.

The mechanical deformation of the microheaters subjected to an electrothermal excitation, due to thermal stress, is also analyzed using lensless in-line digital holographic microscopy (DHM). The numerically reconstructed holographic images of the microheaters clearly indicate the regions under high stress. Double exposure method has been used to obtain the quantitative measurements of the deformations, from the phase analysis of the hologram fringes. The measured deformations correlate well with the theoretical values predicted by a thermo-mechanical analytical model. The results show that lensless in-line DHM with Fourier analysis is an effective method for evaluating the thermo-mechanical characteristics of MEMS components.

A sensor interface circuit comprising a resistance-to-time period converter as the front-end circuit and a proportional temperature controller to control the microheater temperature is designed and realized in 130nm UMC CMOS technology. The impact of biasing the transistors in subthreshold versus saturation conditions on analog circuit performance is systematically analyzed. A cascode current mirror, designed in 130nm CMOS technology, is biased in subthreshold and saturation regions and its performance has been analyzed through rigorous analytical modeling. The analytical results have been validated with SPICE simulations. It is demonstrated that the subthreshold operation provides better performance in terms of linearity, power, area, output impedance and tolerance to temperature variation, making it a preferable option for applications such as signal conditioning circuitry for environmental sensors. On the other hand, biasing the circuit in saturation is preferable for applications like transceivers and data converters where high bandwidth, SNR and low sensitivity to process variations are the key requirements. Based on this analysis, a sensor interface circuit has been prototyped *for resistance measurement on 130nm CMOS technology, using subthreshold cascode current mirrors as the key building blocks. This current mirror results in 14X lower power compared to above-threshold operation. The interface circuit spans 5 orders of magnitude of resistance, and consumes an ultra low power of 326μW. A proportional temperature controller with an integrated on-chip power MOSFET is also realized on the same chip for heating and temperature control of microheaters. The microheater is reused as temperature sensor. The entire circuit works with 1.2V supply, except the power MOSFET and the heater driver circuit, which operate with 3.3V supply.*

ZnO, a semiconducting metal-oxide, is used as the sensing material. Thin films of ZnO are spin-coated over insulating substrates using sol-gel processing technique. Gold pads deposited over the sensing film act as electrodes. The sensor film is characterized at different temperatures for its sensitivity to ethanol. A peak response of 14% change in resistance is observed for 5ppm ethanol, at a working temperature of 275°C.