The Monolithic Integration of 6H-SiC Electronics with 6H-SiC MEMS for Harsh Environment Applications

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ABSTRACT

We report the development of a design and fabrication methodology for the first monolithic integration of silicon carbide (SiC) MEMS sensors with SiC-based electronic amplification and control circuitry.

Using this process we have been able to demonstrate functioning electronic devices that can operate at 280^{0}C. The feasibility of the monolithic fabrication and integration of SiC electronics with SiC MEMS devices for harsh environment applications is demonstrated.

Keywords: smart MEMS, sensor systems

1 DISCUSSION

We report the development of a design and fabrication methodology for the first monolithic integration of silicon carbide (SiC) MEMS sensors with SiC-based electronic amplification and control circuitry. MEMS and circuit integration on silicon has been successfully implemented over the past several years [1,2] and bulk micromachined SiC MEMS pressure sensors and accelerometers have been demonstrated in [3,4]. The major challenge for integration of SiC-based MEMS and electrical circuitry involves the fabrication process. Due to the inertness of SiC to wet etch chemistry, deep reactive ion plasma etching is necessary to form the bulk micromachined MEMS structure. This provides a unique challenge during device and circuit integration. We have developed a novel design and process methodology to achieve this goal. Once this process is optimized, it will allow for temperature compensated sensing, amplification, control and filtering circuitry to be integrated with the MEMS sensing devices to reduce the signal-to-noise ratio and to condition the signal to reduce offsets and non-linearities before it passes off chip.

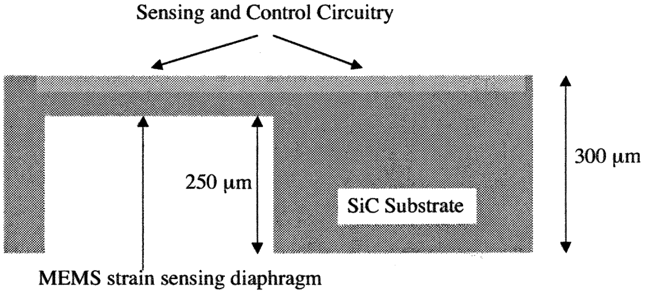
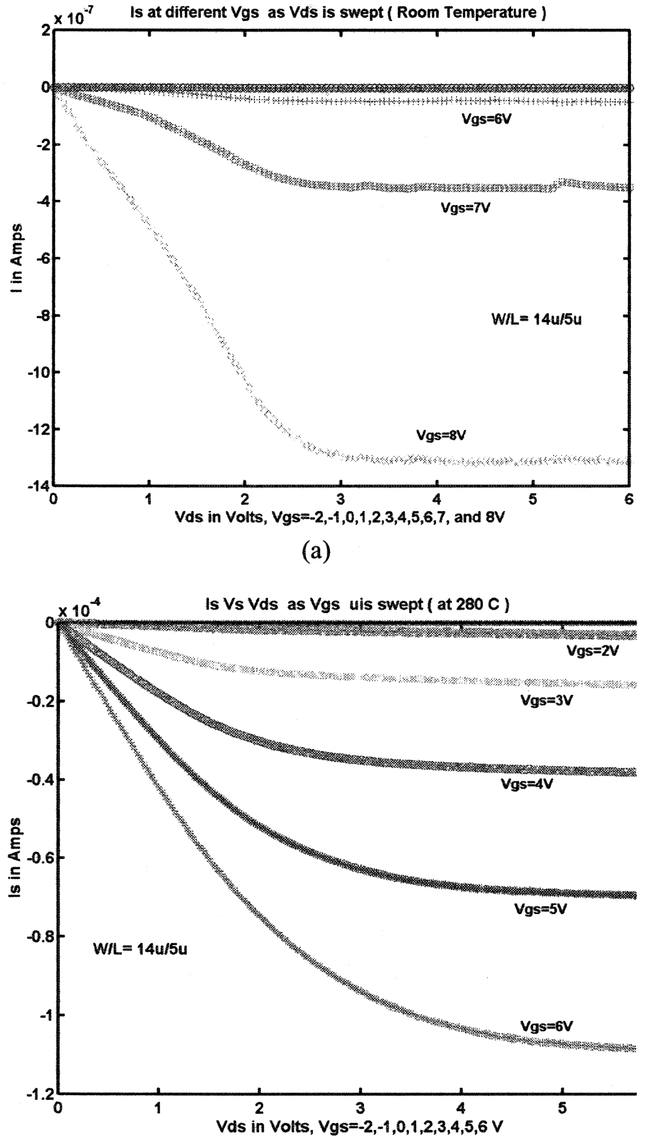


Fig. 1: Cross section of integrated SiC MEMS devices and SiC electronics.

This process is fully CMOS compatible with an additional mask step to realize normally-on depletion mode N-MOSFETs, used in place of P-MOSFETs as loads in circuits. The depletion mode N-MOSFETs have a lower thermal budget and do not require high anneal temperatures. Using 16 mask steps with two levels of high temperature interconnect metallization, the process provides the flexibility of fabricating the MEMS structure at the beginning, intermediate or final stage of the process run (Fig. 1). The MEMS devices consist of pressure sensors or accelerometers that may be bossed implemented with piezoresistive strain sensing mesas in a Wheatstone bridge configuration. The electronic devices consist of resistors, enhancement- and depletion-mode N-MOSFETs, P-MOSFETs, Schottky and P-N diodes and signal conditioning circuitry.



(a)

(b)

Fig. 2: I-V Characteristics of an enhancement NMOSFET at (a) room temperature and (b) 280^0C.

2 CONCLUSIONS

Using this process we have been able to demonstrate functioning electronic devices that can operate at 280^0C (Fig. 2a and b). Along with the results from [3,4], the feasibility of the monolithic fabrication and integration of SiC electronics with SiC MEMS devices for harsh environment applications is demonstrated.

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