Sensors Based on SiC-AlN MEMS

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III-V Nitrides (AlN in particular) have excellent piezoelectric properties, and have been successfully used in both polycrystalline [1,2] and single crystalline (epitaxial) forms [3,4] in SAW devices operating to gigahertz frequencies. Integration of III- nitride materials with microelectromechanical systems (MEMS) creates new and exciting opportunities for miniaturizing, reducing power consumption, and improving the performance and functionality of many devices including sensors (chemical, biological, gas and fluid), actuators, RF MEMS and optical arrays. Advances in photo-electrochemical (PEC) micromachining of single crystal SiC [5,6], an excellent substrate for AlN epitaxy, has now enabled the development of piezoelectric MEMS from these high quality, single crystal materials. Such single crystal SiC-AlN devices are more robust, providing improved chemical stability, thermal stability, reproducibility and sensitivity compared to conventional polycrystalline piezoelectric MEMS.

An overview of Boston MicroSystems' SiC -AlN piezoelectric MEMS, and their various applications in chemical, physical, and fluid sensing, will be presented. The design, fabrication and performance of two devices, piezoelectric bimorph microresonators and flexural plate wave (FPW) fluid sensors will be discussed.

Single crystal n-doped 6H-SiC substrates with one or more alternately doped SiC epilayers are PEC micromachined in HF electrolytes to form the desired MEMS structures. The p-doped SiC epilayer functions as an etch stop with an exceptionally high selectivity (~10^7:1), while the n-doped SiC epilayer provides the template for AlN epitaxy as well as the bottom electrode for the piezoelectric film. AlN is epitaxially grown on to the micromachined SiC devices by molecular beam epitaxy using growth parameters optimized to obtain smooth, low stress AlN films. The favorable and closely matched mechanical, thermal and acoustic properties of AlN and SiC lead to low loss, high Q devices. The design and dimensions of the piezoelectric MEMS sensors are optimized for manufacturability, sensitivity and Q factor.

In the case of microresonators, Ti/Au metal layers are deposited to form the top electrode on the AlN film, and the contact to the n-SiC lower electrode (Figures 1&2). The structure is driven to resonance (typically 1 to 20 MHz, depending on the design) by applying an ac bias across the AlN layer. Chemoselective polymer coatings are deposited on the microresonators for chemical sensor applications. When the device is exposed to the chemical, the film adsorbs/absorbs the species, thereby increasing the mass of the microresonator and decreasing the resonant frequency. Since the microresonator has extremely low mass (~ng), exceptionally small (~1 pg) changes in mass are sufficient to produce a measurable (~100 Hz) shift in resonance frequency.

Figure 3 shows an example of a SiC-AlN FPW sensor, consisting of two sets of inter digital electrodes (IDTs) formed on a AlN-SiC bimorph membrane. When an appropriate ac signal is applied to the IDTs, adjacent regions of the plate bend in opposite directions thereby generating a Lamb wave. By monitoring the frequency and attenuation of the wave in a fluid, the density and viscosity are independently determined.

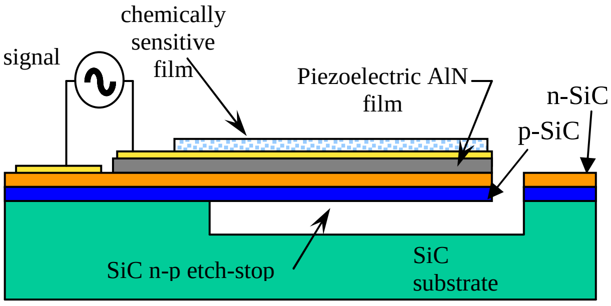

Figure 1. Schematic of microresonator based sensor

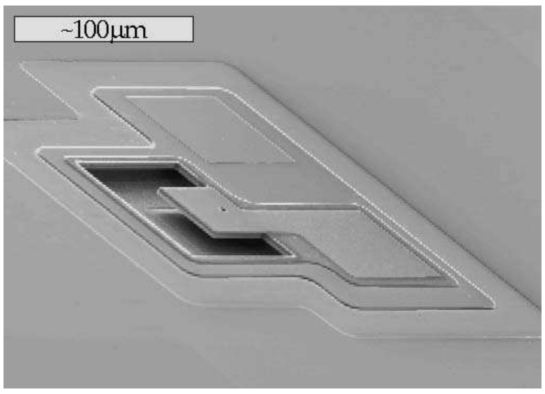

Figure 2. SEM micrograph of a SiC-AlN bimorph piezoelectric microresonator.

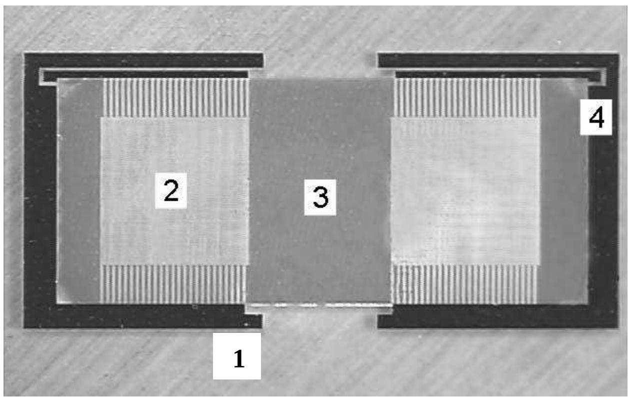

Figure 3: Optical micrograph showing a single crystal SiC-AlN FPW fluid viscosity-density sensor: 1) transparent SiC substrate, 2) IDT electrode (25 finger pairs, □=40□m), 3) SiC-AlN bimorph membrane (3.5mm×1.5mm×1.5□m), 4) metal contact pads.

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