Quartz-based Vibrating MEMS on Structured Silicon Using Wafer Bonding Technology

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The integration of piezoelectric materials on silicon via wafer bonding technology appears as a promising approach for mass production and offers many opportunities for the development of highly integrated quartz devices on Si-based circuits. In this study, we partially use strategies developed for Si-based MEMS device fabrication and in the meantime, we adjust some parameters to the specifications of single-crystal quartz material.

We will present the results of our wafer-level approach that allows the collective fabrication of gyroscope sensors based on quartz vibrating MEMS. More specifically, we focus on suspended quartz tuning fork microstructures of a desired thickness over controlled depth cavities which integration is based on the bonding and thinning of 4-inch z-cut quartz wafer on pre-structured silicon wafer.

The Quartz-On-Silicon (QOS) hybrid wafer was inspected, after annealing, for the presence of unbonded area. Fig. 1 shows a Scanning Acoustic Microscope (SAM) image of the bonded wafers, it reveals an excellent bonding quality, implying an adequate surface preparation before the bonding. The quartz layer was then patterned by conventional photolithography and Deep Reactive Ion Etching (DRIE) of quartz. Fig. 2 presents a part of a Coriolis Vibrating Gyroscope (CVG) named VIG (Vibrating Integrated Gyro) developed at ONERA[1] obtained by the basic silicon/quartz approach followed by a XeF_2 release. Under vacuum, the resonator exhibits a quality factor (Q) around 12300 at 86.6 kHz, very close to the theoretical thermoelastic limit of 13000, yielding a Q×f product of $1{,}0\times10^9$. This relatively high Q-factor attests the preservation of the single-crystal quartz bulk material properties throughout all the steps of the developed process. More details about electrical measurements and characterizations of the gyroscope sensors will be presented.

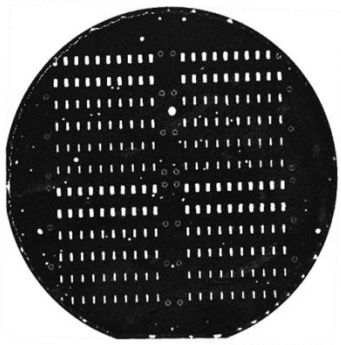

Fig. 1: SAM image of the 4-inch Quartz-On-Silicon hybrid wafer.

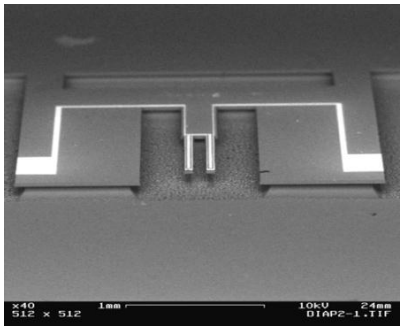

Fig. 2: Quartz tuning fork gyroscope obtained by DRIE of the 30 µm thick quartz membrane.

This very promising QOS technology open the way to a new generation of highly integrated quartz devices.

[1] D. Janiaud, O. Le Traon, B. Lecorre, S. Muller "Quartz vibrating gyro" US patent n° 6,386,035, mai 2002.