Bulk Micromachined Ultrasonic Transducers

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1 Introduction

Ultrasonic transducer has extensive applications in non-destructive evaluation (NDE), medical imaging and so on. In order to improve the impedance matching property of airborne transducer, and introduce such transducers into scanning application, a bulk micromachined ultrasonic transducer is designed and fabricated. Initial investigation results showed that, this newly developed transducer has the advantages of uniform cavity, consistent elements, and reliable vibration membrane. It is expected that this innovative invention will surpass most traditional cMUTs design, and win wide acceptance in air-coupled ultrasonic application.

2 Fabrication Process

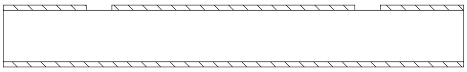
Fabrication of the proposed transducer involves the individual preparation of membrane and cavity wafer, as well as the bonding of these two components. This will be illustrated in detail in following sections.

2.1 Membrane Wafer Fabrication

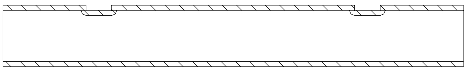
Fabrication procedure of membrane wafer is depicted in Fig. 1. First, 300 nm LP-CVD nitride is deposited and patterned. Next, 100 nm LOCOS oxide is grown on some local regions of the wafer, with nitride as mask. Following thermal oxidation, 800 nm Al is sputtered. This Al layer acts as the top electrode of the proposed transducer. When the metal electrode is made ready, 5 µm PE-CVD oxide is deposited on it. This oxide layer has two functions: first, it provides enough buffering for future CMP polishing; second, it protects the Al layer from damaging and establishes a good insulation.

Before further processing, mask windows are etched in the nitride layer on the backside of the wafer. This step is necessary for future perforation etching, because at the end of the process flow, the membrane will be released from backside.

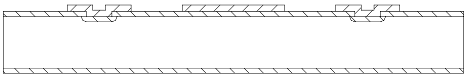
When the window etching is successfully transferred, a CMP process is employed to planarize the unevenness of the front side and to improve the surface smoothness. Such smoothness and flatness are very important for future wafer bonding.



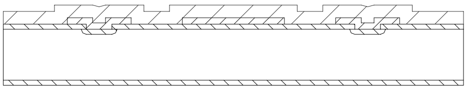
a). LP-CVD Nitrid/patterning, 0.3 µm



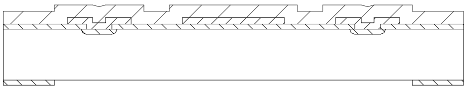
b). thermal oxidation (LOCOS), 100 nm



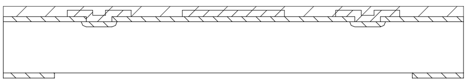
c). Al sputtering/patterning, ~800 nm



d). PE-CVD oxide, ~5 µm



e). backside nitrid processing, 0.3 µm



f). frontside CMP, 4 µm removal

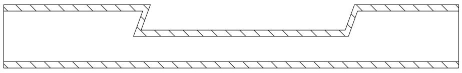
Fig. 1: Membrane wafer fabrication.

2.2 Cavity Wafer Preparation

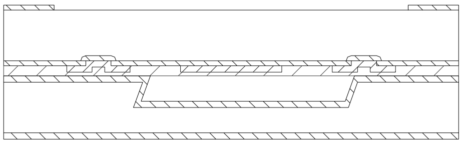
Preparation of cavity wafer is relative simple: patterns are transferred into bulk silicon and cavities are etched in it. Depending on the desired cavity geometry, wet or dry etching process can be utilized. For our application, hexagonal structures are preferred, hence, a combined dry and wet etching is adopted.

2.3 Wafer Bonding

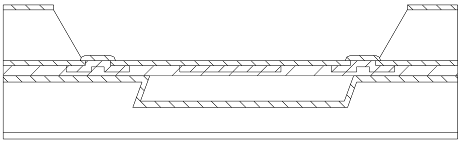
When both wafer components are ready, they are joined together by silicon direct bonding (Fig. 2). The bonding is carried out in a wafer bonder under vacuum, because lower pressure in the sealed cavity is preferable to the normal operation of the transducers.



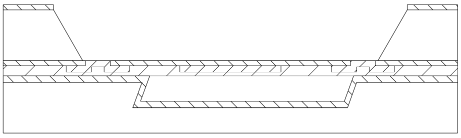
a'). cavity wafer preparation



b'). SFB/360°C annealing, in vacuum



c'). perforation etching



d'). oxide etching (wet or dry), 100 nm

Fig. 2: Cavity wafer preparation.

After bonding, an in-site annealing process is operated. This step is used to increase the strength of the bonding. Following that, the wafer pair is dipped in KOH solution for perforation etching. To expose the Al bonding pads, an additional HF etching is also carried out. A bonded wafer stack is shown in Fig. 3, achieving a yielding rate of almost 100%.

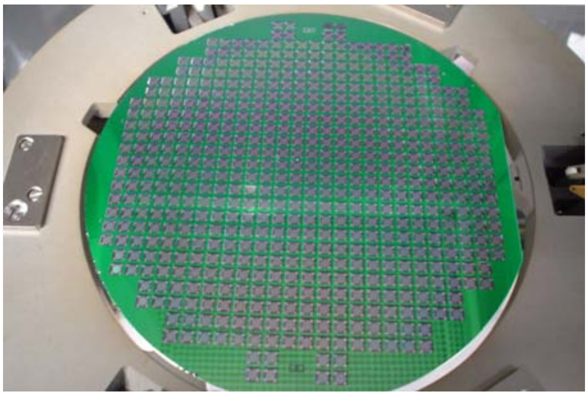


Fig. 3: Ultrasonic transducers fabricated on a 6” wafer.

3 Sample Quality Inspection

To inspect the quality of the fabricated transducer, as well as the appearance of the cell array. SEM is used. Fig. 4 shows a top view of the cleared membrane after perforation etching, presents whose completeness and homogeneity.

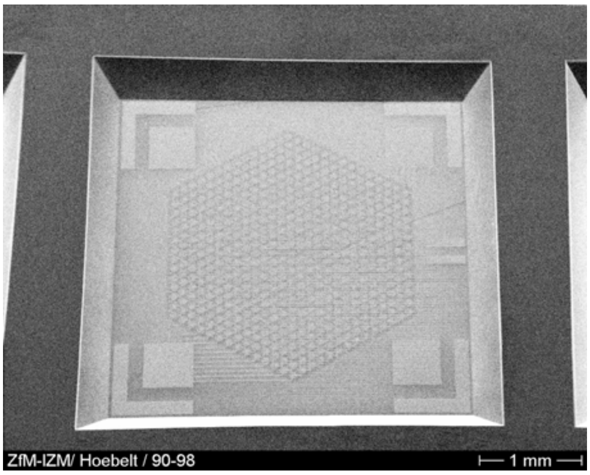


Fig. 4: SEM photo of the honeycomb-like transducer array.

To further evaluate the quality of the metal electrode and the cavity component, some optical photos were taken. Fig. 5 shows one of these photos. With this photo, one can see that both the cavities and the electrodes are tide and regular.

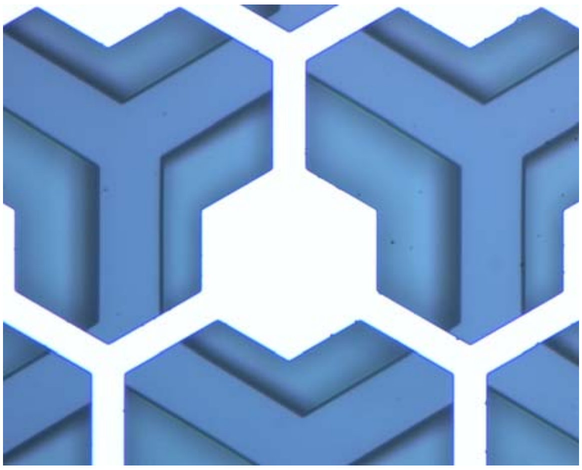


Fig. 5: Detailed image of one transducer element.

4 Discussions

The transducer proposed in this report is fabricated by bulk process, therefore, very uniform vibration membrane and arbitrarily large electrodes gap can be realized. Since such arrangement greatly improves the consistency of the cell elements, and avoids the risk of stiction during membrane releasing, it is expected that this process will win great acceptance in transducer fabrication.