SILICON WAFER BONDING FOR ENCAPSULATING SURFACE-MICROMACHINED MEMS USING INTERMEDIATE GLASS LAYERS

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Recently, the importance of surface-micromachined MEMS has considerably increased, when compared to bulk-micromachined devices. The reasons are a smaller chip size, new functions, better chip performance and the layer-related design philosophy as known from CMOS-design. A serious challenge for these devices is the encapsulation of the structures at wafer level using wafer bonding. These surface-micromachined structures are so sensitive and fragile that they require a protection cap in order to survive the dicing and assembly process.

Yet most of the established bonding technologies cannot be used for such systems: (1) Anodic bonding of whole glass wafers is not suitable because the glass wafers cannot be structured as finely as needed and the glass induces a large amount of stress into the bonded systems. Additionally, there is the risk of bonding the fragile structures to the glass cap wafer, which destroys the device. (2) Silicon direct bonding for encapsulation purposes is often not possible due to rough surfaces, small bonding areas and the difficulties when using wet processes for cleaning and surface activation.

An alternative is to bond a silicon cap wafer to the device silicon wafer by using intermediate bonding layers (Fig.1). Glass is well-suited as intermediate joining material, because different glass materials with different properties can be used. The deposition and structuring glass on the wafer surface is possible in various ways. The amorphous character of the glass gives different possibilities in the technological process.

In this paper three bonding technologies using intermediate glass layers are discussed:

1. anodic bonding of cap wafers with sputtered thin-film sodium-borosilicate-glass,
2. anodic bonding of cap wafers with bonded and thinned sodium-borosilicate-glass wafers, and
3. glass frit bonding using low melting point glasses

The fabrication methods of deposition and structuring of the glass layers, such as glass sputtering, bonding, screen printing and etching are described, but also the bonding processes themselves (Fig.2). A special focus is the preconditioning of the bonding glass layer, the surface activation of the micro-machined wafers and the post-condition of the bonded glass by heat treatment (thermal relaxation). The advantages, disadvantages and technological problems are discussed by example of an accelerometer (Fig.3). It was found that glass frit bonding is the most suitable process for a safe production process. But the anodic bonding technologies also show very interesting features, so they are useable for special application.

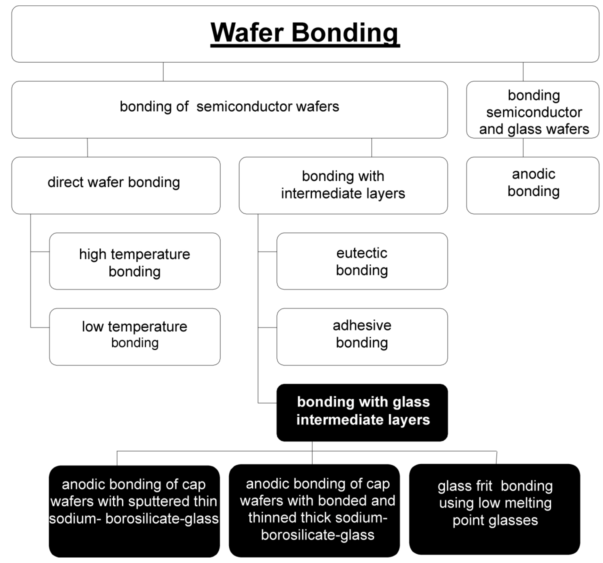

Fig.1. Classification of wafer bonding technologies.

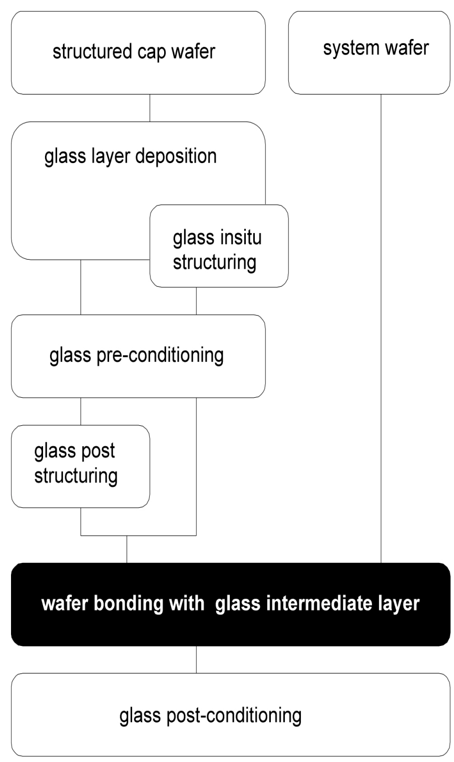

Fig.2. Process flow for wafer bonding with intermediate glass layers.

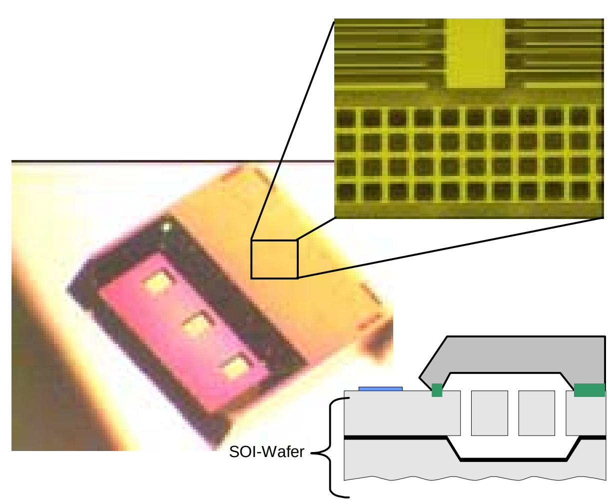

Fig. 3. Example of an encapsulated acceleration sensor in SOI –based surface micro-machining technology.