Wafer Bonding for Optical Microsystems

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There is a wide range of applications for micro optomechanical systems (MOEMS). Such systems combine different optical, electrical, and mechanical functions in the same system. Therefore, different material combinations are required which can be effectively realized by semiconductor wafer direct bonding. Important heterogeneous material combinations can be III-V compounds on silicon (e.g. GaAs/Si), or Si/Ge. Methods for bonding these materials were already reported [1,2]. Furthermore, also Si/Si combinations are of interest for near-infrared applications. The present paper deals with the analysis of different Si/Si combinations used as the basic material for optical distance sensors (ODS).

The ODS is designed as an on-chip solution integrating the light source (e.g. a LED, incorporateted into the silicon basis), the detecting elements, and the logic circuits. The emitted and reflected light is detected by photodiode arrays (pin diodes) surrounding the LED on the silicon surface. Different Si/Si combinations have been prepared by semiconductor wafer direct bonding: i.) SOI wafer prepared by high-temperature and low-temperature wafer bonding and ii.) bonded hydrophobic wafer pairs. Hydrophobic surfaces were prepared by SF_6/O_2 plasma treatments. The top wafers were thinned down to thicknesses between 5 and 100 µm by grinding and subsequent polishing (CMP). A high-resistivity FZ-grown material (n-type, ρ = 3 – 5 kΩcm) was used for the top wafer while the handle wafer was of a higher doping level (n-type, ρ = 10 – 20 Ωcm). For bonded hydrophobic wafer pairs, this combination is equivalent to epitaxial material.

The ODS were prepared into the bonded material by a standard CMOS process. An example of a test pattern containing photodiodes of different sizes is shown in Fig. 1. In order to characterize the different materials, especially the properties of the photodiodes were analyzed as a function of the wafer bonding parameters. For SOI wafers, also the basic properties (quality of the buried oxide, etc.) were recorded.

Measurements of pin-diodes prepared on bonded hydrophobic wafer pairs proved analogous low values of the dark current as obtained for diodes on epitaxial material (I_d ~ 1 nA). On the other hand, the photocurrent is larger for diodes on bonded hydrophobic wafers. Larger photocurrents are also observed for diodes prepared on SOI wafers. This indicates that bonded wafer pairs can be applied for MOEMS preparation. In additon, wafer bonding and subsequent thinning makes it also possible to prepare designed substrates for these devices. For instance, hydrophobic wafer bonding and subsequent thinning allows the preparation of top layers having higher resistivities and larger thicknesses as by epitaxy.

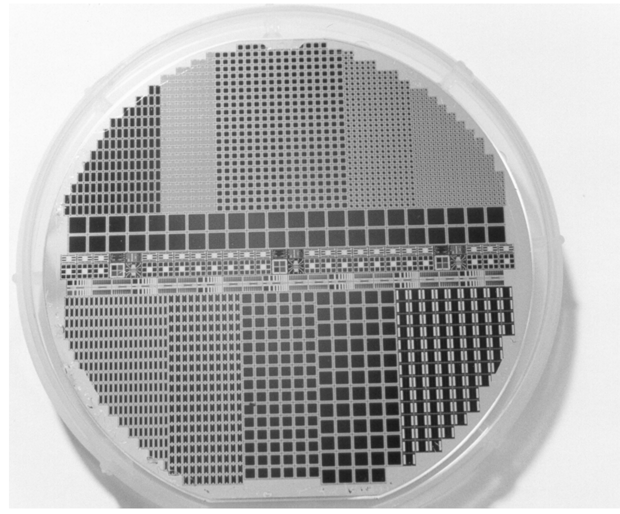

Figure 1: Photo diode arrays of different size prepared on a BESOI wafer.
Wafer diameter: 4 in.
Buried oxide: 200 nm
Device layer: 10 µm