

Letter to the Editors

A Wafer-to-wafer Alignment Technique

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Abstract

A simple, inexpensive and reliable wafer-to-wafer alignment technique is presented for use in the fabrication of microsensors and microactuators. The technique provides $\pm 5 \mu\text{m}$ alignment precision and requires no special optical or mechanical fixtures.

Introduction

In the logistics of microfabrication, it is frequently advantageous, and often mandatory, to separate sensor fabrication into two or more independent processes, each process being restricted to a different wafer. Later, the final sensor package is completed by bonding the individual wafers together. This technique has been successfully employed to produce a number of complicated sensor designs. However, separating the sensor components onto two different wafers introduces the problem of accurate wafer-to-wafer alignment if the registration of the sensor components is to be maintained [1]. Although today's planar photolithography provides accurate ($< 2 \mu\text{m}$) alignment and/or registration of individual sensor components on a single wafer of either single or double-sided design, wafer-to-wafer alignment is not at present a routine process. Double-sided mechanical aligners can be used to register wafer-to-wafer sensor components if the wafers are to be bonded 'back-to-back', i.e., the patterns are clearly visible on the top and bottom of the completed sensor. However, for encapsulation and environmental isolation, it is more common to 'sandwich' the sensor components between the wafers, i.e., 'face-to-face'. When wafers are combined in the latter fashion, visualization of the sensor components is accomplished only by means of infrared optical aligners. Unfortunately, both double and infrared aligners are

expensive and not readily available in the small research laboratory. In response to these requirements and constraints, we have developed a quick, simple and reliable mechanical alignment technique that provides for high-accuracy ($5 \mu\text{m}$) wafer-to-wafer alignment of sensor components without the need for expensive or bulky equipment. The technique uses standard anisotropic etchants and can, if necessary, be performed without the aid of optical or mechanical fixtures.

Wafer alignment technique

The wafer-to-wafer alignment technique described here relies on the high-precision, three-dimensional 'micromachining' of silicon and planar photolithography to produce accurately positioned grooves in both silicon wafers. The grooves act as alignment 'keys' to position the wafers, as shown in Fig. 1 for two (100) silicon wafers. Alignment of the two wafers is accomplished by placing an alignment 'pin' or cylinder in the appropriate groove of one wafer. The other wafer is then rotated over the first until the grooves in the second wafer match the pins. Mechanical 'jigs' can be machined to facilitate the alignment. However, the entire process is easily accomplished by hand. Alignment is achieved when rotation of the second wafer is restricted. A minimum of two orthogonal grooves (preferably 90 degrees) is required for proper alignment. However, at least two

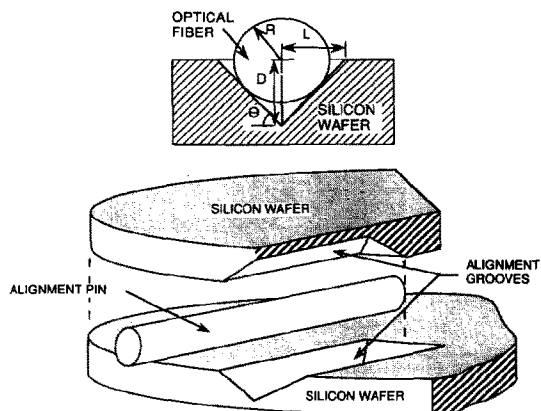


Fig. 1. Diagrammatic representation of the wafer-to-wafer alignment in partial cross-section. A cross-section of the important dimensions of the alignment groove geometry for a {100} silicon wafer (see eqn. (1)) is shown at the top of the Figure.

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additional alignment grooves, making a total of four, are preferred. The grooves can be located anywhere on the wafer that available 'real estate' occurs, but grooves located on the exterior edges of the wafers are preferred for minimal photolithography perturbation. In addition, edge alignment provides for easy removal of the alignment pins if they are incompatible with subsequent processing steps. If the sensor construction provides for inherent mesa structures, the pins can be eliminated and the mesas used as keys to register the wafers.

The composition of the alignment pins can vary depending on the sensor processing needs, sensor design, etc. We have found the use of standard glass optical fibers to be quite satisfactory. Optical fibers are readily available in 125 μm diameters, and can be etched in HF to control diameter variations carefully. The width of the etch groove needed to accommodate a 125 μm optical fiber is 154 μm for a (100) silicon wafer ($\theta = 54.7$ degrees) as shown in Fig. 1 and from

$$\text{width} = 2L = 2R/\sin\theta \quad (1)$$

If the groove is etched to termination, its depth, D , is 109 μm . However, only about 65 μm is actually needed. The optical fibers can be pulled to a diameter of <10 μm , and will consequently require smaller alignment grooves if desired. However, smaller diameter fibers are more difficult to handle and also increase alignment difficulties. Optical fibers sometimes contain contaminants, and if subsequent high-temperature processing is required, it is advisable to remove the pins. If the alignment pins must remain in place during high-temperature processing, quartz fibers can be pulled and substituted for the commercial optical fibers.

References

- 1 R. M. White and S. W. Wenzel, Inexpensive and accurate two-sided semiconductor wafer alignment, *Sensors and Actuators*, 13 (1988) 391.