Inspection of Bonded Interfaces using Scanning Infrared Interferometry

N. Podjue[a], W. Kerr[a], and K.T. Turner[b]

[a] Evergreen Instruments, Inc. Canton, MA 02021
[b] Dept. of Mechanical Engineering, University of Wisconsin, Madison, WI 53706, USA

Detecting voids in bonded wafer pairs is critical for ensuring robust bonding processes and managing yield. Here, a new measurement technique to detect voids in bonded using scanning infrared (IR) interferometry is described and used to detect voids in direct-bonded silicon wafer pairs. The void measurements obtained with the scanning IR interferometry technique are compared to measurements made on the same wafers using IR transmission imaging and scanning acoustic microscopy.

Introduction

Nondestructive characterization of wafer bonded interfaces is essential for process monitoring and control. The dominant methods that are currently used to evaluate bonded interfaces and identify voids include infrared (IR) transmission imaging and scanning acoustic microscopy. IR transmission imaging is a non-contact technique that allows for rapid assessment of the bonded interface, but has limited spatial resolution and ability to detect thin voids. Scanning acoustic microscopy provides considerably higher resolution that IR transmission imaging, but typically requires the use of a coupling fluid between the bonded wafer pair and transducer. In this paper, we present a new non-contact method for the inspection of wafer bonded interfaces based on IR Interferometry Scanning (IRISCN). This paper describes the instrument and compares measurements made using IRISCN, IR transmission imaging, and scanning acoustic microscopy.

Instrument and Experimental Method

The scanning IR interferometry tool for bond inspection that we have developed raster scans a low coherence IR interferometer across a wafer. Specifically, the tool uses a fiber-based interferometer made by Lumetrics Inc. (West Henrietta, NY) that is similar to the instrument described in (1). The instrument allows optical path differences between reflections from different interfaces to be measured and has conventionally been used for dimensional measurements of various materials.

The basic concept of void detection with a low coherence interferometer is illustrated in Fig. 1. The presence of a void at the interface creates an additional reflection in the measurement. The interferometer allows the optical path difference between the different interfaces to be measured. The optical path difference that is measured is a function of the thicknesses of the two wafers, t_1 and t_2, and the index of refraction of the material, n, as shown in Figure 1. When a measurement is performed on a bonded wafer pair with voids at specific locations, multiple interfaces are detected at each location. By examining the optical path difference between the layers, one can determine which measured layers correspond to a void at the interface.

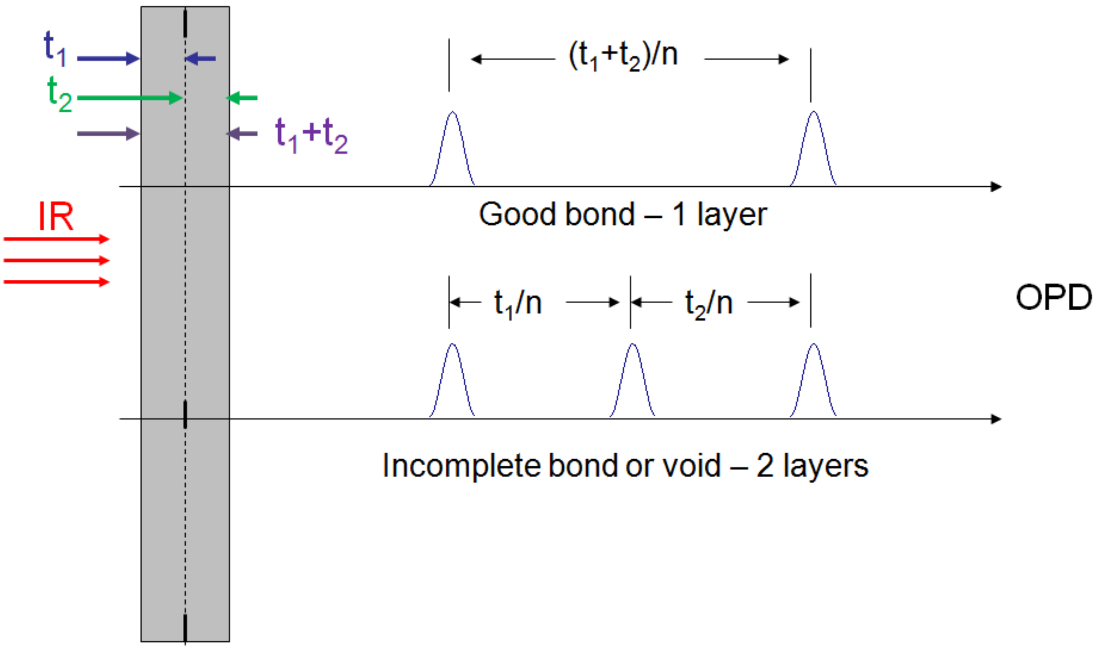

Figure 1. Illustration of void detection in wafer bond interfaces using low coherence interferometry. Several voids are indicated in the schematic wafer pair shown on the left. A void at the interface creates an additional interface from which light can reflect. Thus, when a measurement is performed at a location that is void free (top), only two reflections are seen in the measurement. When there is void at the interface, three reflections are observed (bottom).

In the system used in the current study, the IR interferometer is focused to a spot size with a diameter of approximately 50 µm on the wafer. This spot is raster scanned across the wafer. The density of the scans is easily adjusted as it is simply a function of the motion control system used to raster the probe, but affects the total time required to scan a wafer. In the present study, the probe was scanned on an x-y grid that was 0.25 by 0.6 mm, resulting in approximately 20,000 data points across 100 mm diameter silicon wafer.

To examine the capabilities of the technique, multiple silicon-silicon direct bonded wafer pairs were fabricated. Specifically, standard thickness (525 µm), single side polished 100 mm dia. Si (100) wafers were bonded at room temperature. Prior to bonding, the wafers were cleaned using a 'piranha' clean (5:1 H_2SO_4:H_2O_2). The wafers were bonded at room temperature by pressing the wafers together at a single point and allowing the bond front to spread across the wafer. The wafer pairs were not annealed. This fabrication process results in a bonded wafer pair with only a native oxide at the interface. Two wafer pairs that had random process voids were inspected in the current study.

The two wafer pairs were inspected using the IRISCN technique with the parameters described above, IR transmission imaging, and scanning acoustic microscopy. IR transmission imaging was performed on a custom built system that consisted of halogen light source and monochrome CCD camera (Sony EI-50) with an appropriate lens and filter. The scanning acoustic microscopy images were acquired by Sonoscan, Inc, (Elk Grove, IL).

Results and Discussion

Figure 2 shows the multiple interfaces detected by the IRISCN instrument on wafer 1. Four interfaces are detected; however one of the interfaces (Fig. 2(c)) only contains a relatively small number of points located exclusively at the edge of the wafer. This layer and the outer ring that appear in Fig. 2(d) are measurement artifacts that result from the geometry of the wafer edge and the fact that the wafers may not be perfectly aligned. With the exception of these artifacts, the interfaces shown in Fig. 2 match with the void detection scheme presented in Fig. 1. Interface 1 (Fig. 2(a)) is the reflection from the bottom surface of the wafer pair, interface 2 (Fig. 2(b)) is the reflection from void at the bonded interface, thus data points are only present where there are voids. Interface 4 (Fig. 2(d)) is the reflection from the top surface of the wafer. Void information for the interface is determined from the layer that corresponds to the light reflected from the interface.

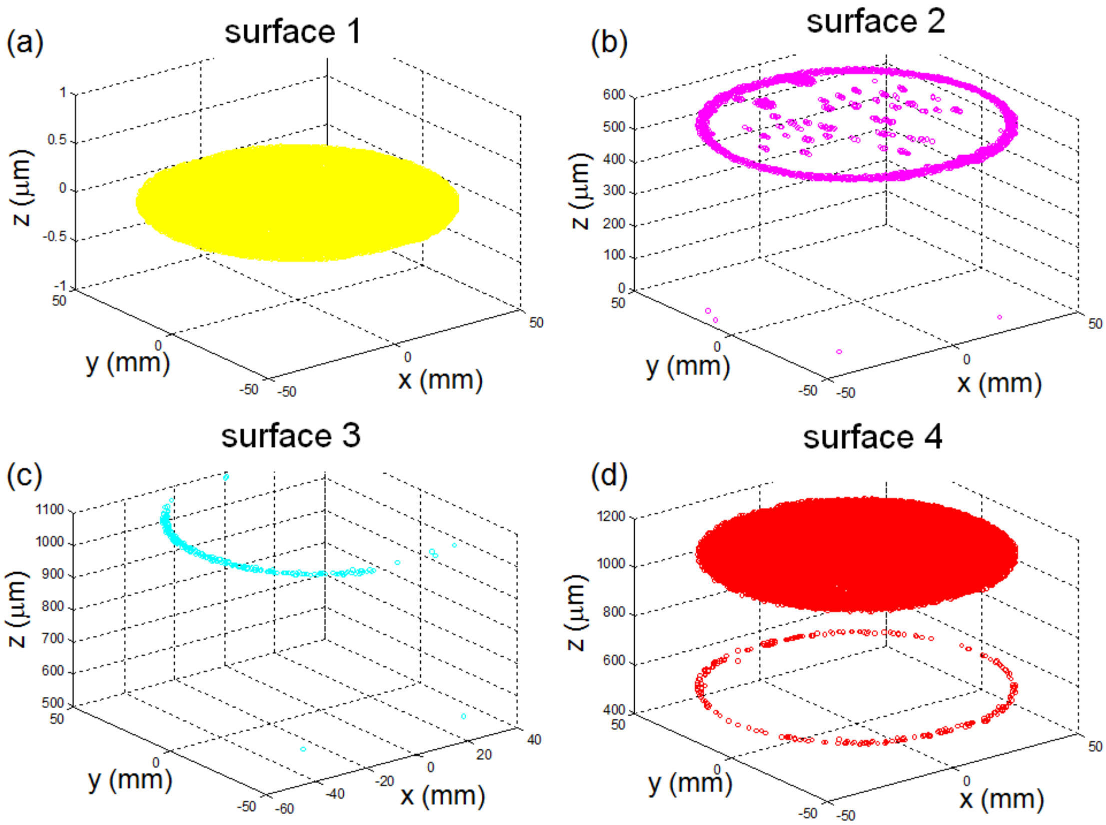

Figure 2. Data obtained from wafer 1 separated by interface. The following interfaces are shown: (a) reflection from bottom surface of bonded wafer pair, (b) reflection from voids at the interface, (c) a measurement artifact from the wafer edge, (d) reflection from top surface of wafer pair.

A comparison of the IRISCN, IR transmission, and scanning acoustic microscopy measurements are shown in Figures 3 and 4 for wafers 1 and 2, respectively. As seen in the figures, the IRISCN detects numerous voids that are not observed in the IR transmission mages for both wafer pairs. In general, all voids that are detected in the IR transmission image appear up as multiple clustered points in the IRISCN measurements. The voids that are detected in IRISCN measurements, but not in the IR transmission images, do appear in the scanning acoustic microscope (SAM) images. This suggests that these voids are real and thus the IRISCN technique has the potential to detect voids not observed in IR transmission imaging. There are several small voids, detected in the SAM image of wafer 1 that are not seen in the IRISCN measurement (Fig. 3). This may be a result of the resolution of the raster scan (x-y grid is 0.25 by 0.6 mm) or these may be below the resolution of the IRISCN measurement. Currently, an estimate of the smallest void that can be detected by the IRISCN technique is not known.

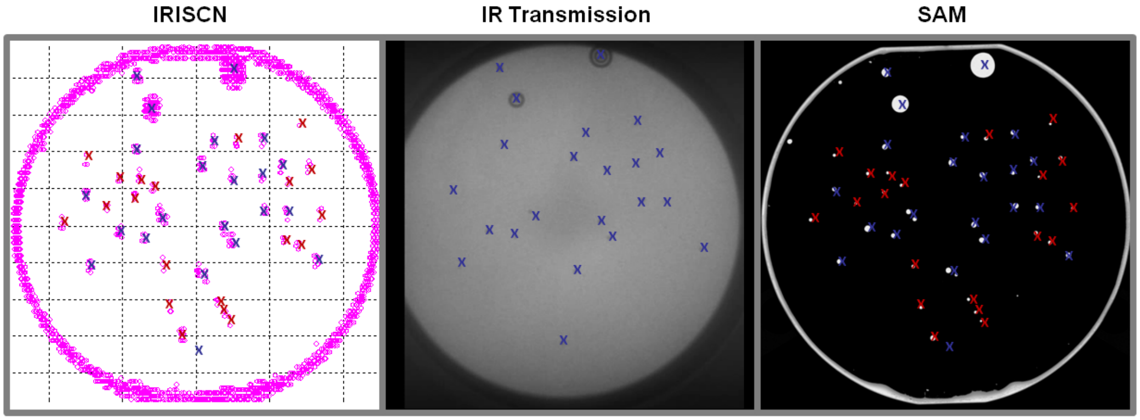

Figure 3. Comparison of IRISCN, IR transmission imaging, and scanning acoustic microscopy (SAM) measurements for wafer 1. In the IRISCN map, the pink data points indicate locations of voids detected. The blue X's indicate defects detected by standard IR transmission imaging and are also detected by IRISCN. The red X's indicate defects detected by IRISCN, but not seen by IR transmissions imaging. The defects marked in red are detected by scanning acoustic microscopy as well.

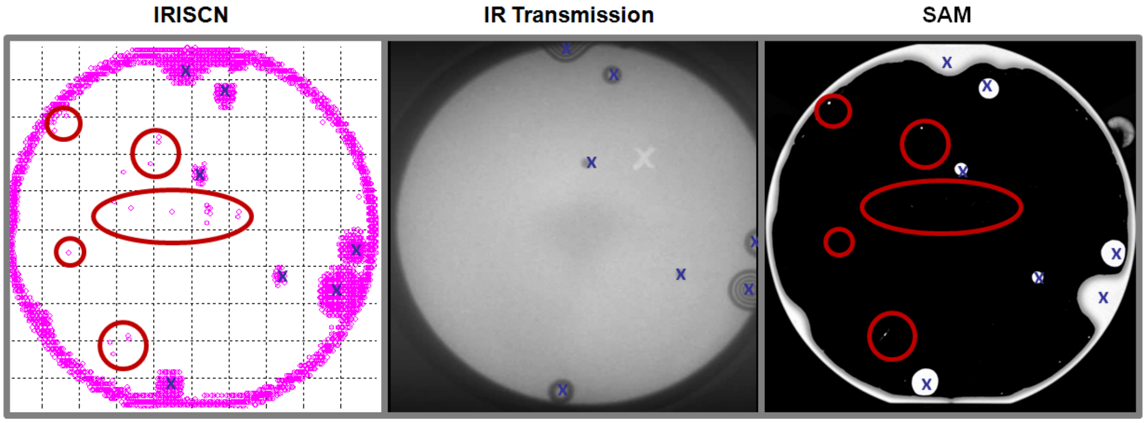

Figure 4. Comparison of IRISCN, IR transmission imaging, and scanning acoustic microscopy (SAM) measurements for wafer 2. The blue X's indicate defects detected by standard IR transmission imaging and are also detected by IRISCN. The areas circled in red show defects detected by IRISCN, but not seen by IR transmissions imaging.

Summary and Conclusions

We have described a new technique to detect voids in direct bonded wafer pairs using a scanning low coherence infrared interferometer. The technique is non-contact and does not require a coupling medium. The experimental results demonstrate that the technique has better resolution than IR transmission imaging as a number of small voids show up in both the IRISCN images and scanning acoustic microscopy images that do not appear in the IR transmission imaging. Current efforts are directed at establishing the resolution of the technique and applying the method to detect voids at interfaces containing micrometer scale thick IR transparent films.

References

1. V.G. Badami and T. Blalock, *Proc. SPIE*, **5879**, 587903 (2005).