Experimental Procedure for Anodic Bonding

Purpose:

In this experiment students will learn how to bond a silicon wafer to a sodium-rich Pyrex glass wafer by applying high voltage and temperature.

Materials:

Si wafers, 7740 Pyrex glass wafers, Piranha clean

Equipment:

Hot plate with ceramic top, high voltage power supply (0-3.5kv), micro-ammeter (1-10mA), probe stand, aluminum plate, electrical wires, surface thermometer

Theory:

Anodic bonding, also referred to as field assisted glass-silicon sealing, is a process of bonding a silicon wafer to glass under the influence of high temperature and an externally applied electric field. In order for good contact to occur, the two surfaces to be bonded must be quite smooth with roughnesses less than 0.1 μm. In a typical anodic bonding procedure, the wafers to be bonded are assembled together and heated on a hotplate to about 500^0C. A D.C. power supply connected to the assembly such that the positive terminal is connected to the silicon wafer and the negative terminal is connected to the Pyrex glass wafer is then turned on. When an electric field of several hundred to a thousand volts is applied across the assembly, the glass seals to the silicon wafer. The bonded areas initially appear as dark splotches starting in the area where the voltage is directly applied. Eventually these splotches cover the entire surface. The resulting bond is essentially irreversible. Figure 1 gives a schematic drawing of a generic anodic bonding setup.

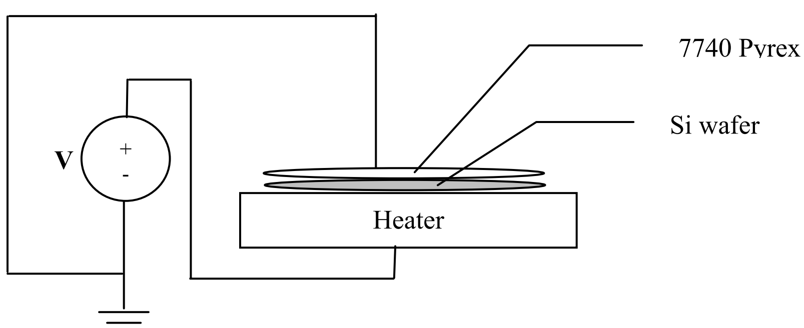

Figure 1: Generic Anodic Bonding Setup

The bonding mechanism itself is not well understood, but it is generally agreed that it is primarily due to the presence of mobile sodium ions in the Pyrex glass. At an elevated temperature the positive sodium ions in the glass have an increased mobility and are attracted to the negative electrode on the glass surface. This leaves behind negatively charged oxygen ions adjacent to the silicon surface. Initially the potential is uniformly distributed across the glass, but with the increased temperature and voltage, a large potential drop develops between the Pyrex glass and the anode. The resulting electric field between the surfaces pulls them into intimate contact, possibly creating covalent bonds. Figure 2 illustrates this process.

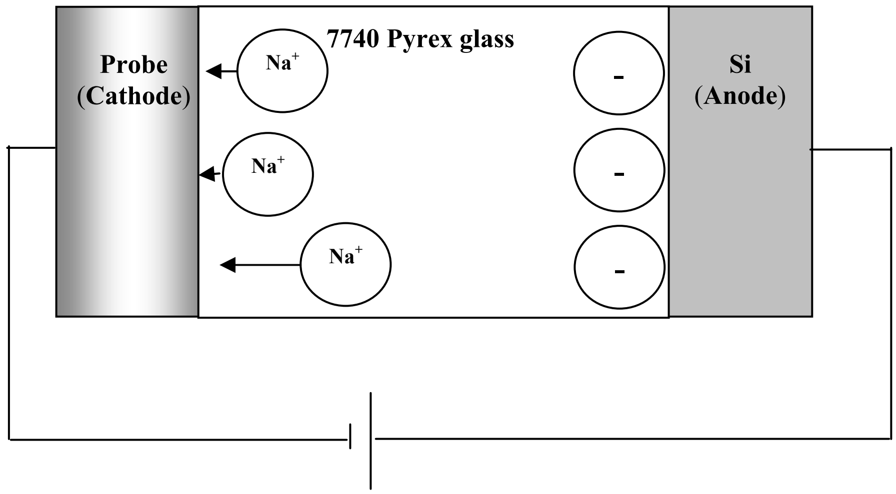

Figure 2: The Anodic Bonding Process between Silicon and Pyrex 7740 glass

Procedure:

1. *Cleaning the wafers*:
   The success of the anodic bonding process depends heavily on the cleanliness of the surfaces involved. Without clean surfaces, adequate contact can not be made. The Si and 7740 Pyrex wafers are cleaned in a solution known as **Piranha clean** consisting of a 3:1 ratio of H_2SO_4: H_2O_2.
   a. Place 30 ml of H_2SO_4 in a Petri dish. Immerse the both the silicon and the Pyrex wafers in the dish. Next add 10 ml of H_2O_2 and allow the wafers to clean for ten minutes.
   b. Rinse the wafers thoroughly with de-ionized (DI) water.
   c. Dry the wafers thoroughly using nitrogen gas.
   d. When disposing of the used Piranha clean, dispose only small portions at a time while continuously flushing with plenty of cold tap water

2. *Bonding the wafers*:
   a. Place the aluminum plate on the hotplate. Place the Si wafer on top of the aluminum and the 7740 Pyrex on top of Si as shown in Figure 3.
   b. Connect the wires as shown in Figure3. The positive voltage should go to the aluminum plate and the negative voltage should go to the probe stand. Lower the probe so that it gently pushes on glass. The application of a little pressure on the wafers aids in the bonding process.
   c. Set the temperature of the hotplate to 500^{o}C. Observe the surface thermometer read out to determine when 500^{o}C has been reached. (Thermometer is not shown in Figure 3.)
   d. When the temperature of the hotplate reaches 500^{o}C, turn on the high voltage power supply and increase the voltage only to 50 V. After 30 seconds, increase the voltage by another 50 V to 100 V. Continue increasing the voltage by 50 V at 30 second intervals until the voltage is 500 V.

   Important!
   As you increase the applied voltage, regularly observe the ammeter reading. If the current exceeds 1 mA at any time, turn the voltage to zero and turn off the power supply. A current over 1 mA indicates that a short circuit has occurred, current finding its way from anode to cathode through some other means than through the wafers.

e. After 5-10 minutes you will observe a dark color starting at the tip of the probe and then spreading over the wafer surface. The appearance of these dark splotches means the anodic bonding process has begun. Wait until the entire surface has been changed to this dark color. Normally this will take 15-25 minutes
f. Decrease the applied voltage to zero and turn off the power supply.
g. Turn off the hotplate.
h. Wait for 20-30 minutes for the wafers to cool to room temperature.
i. Visually inspect the bonded wafers. If time permits, visually inspect the wafers using the scope on the micromanipulator.

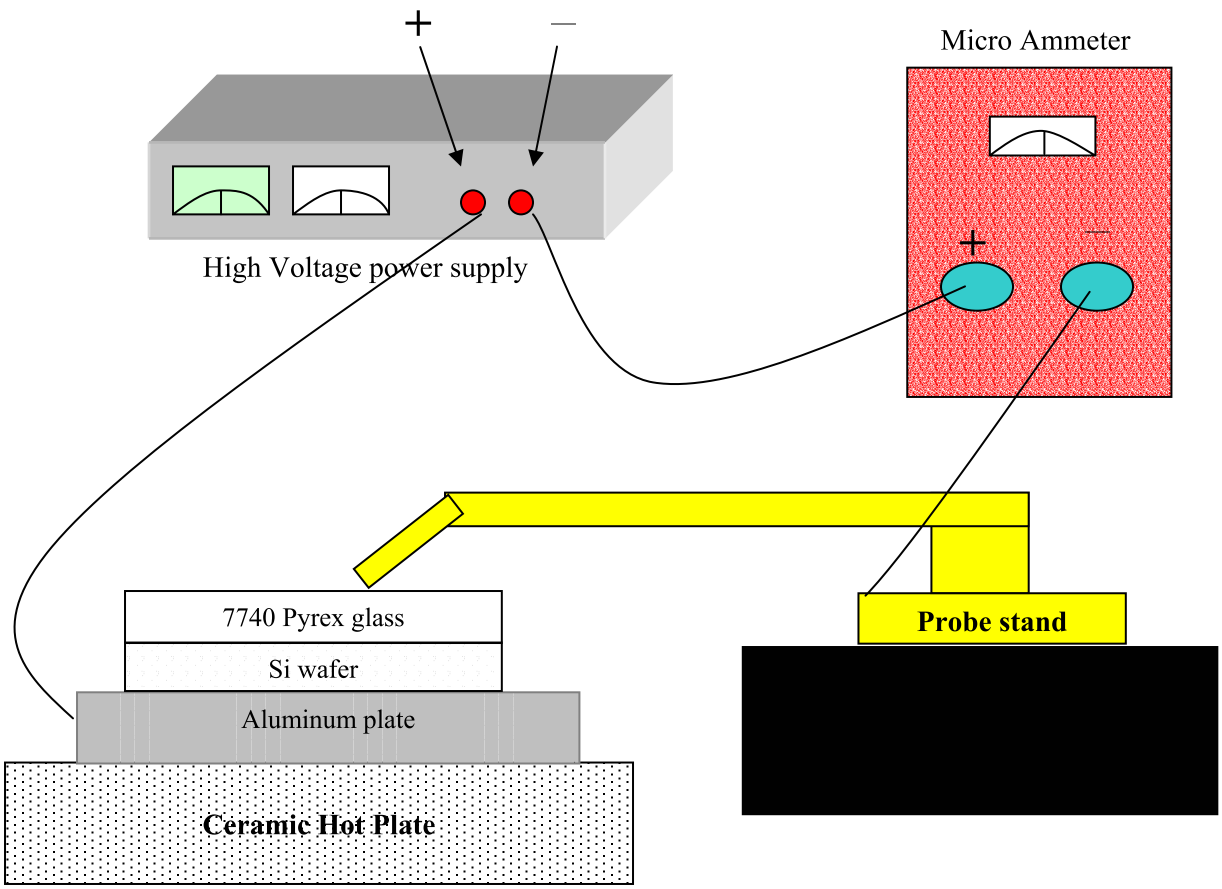

Figure 3: Anodic Bonding Experimental Setup

Precautions:
1. Be sure all circuit connections are made before turning on the power supply.
2. Do not touch any part of the circuit while the power supply is on. The high voltage can result in a violent shock.
3. Do not directly touch the surface of the hotplate.

Analysis and Observation:
Address the following items in your memorandum:
1. Briefly describe the set-up and procedure you used to bond the silicon wafer to the Pyrex glass.
2. Qualitatively describe the bonding process that you visually observed after applying the high voltage.

3. Are there any areas on the wafer that did not bond well? How can you tell? What may have caused this?
4. Why must 7740 Pyrex or some other sodium rich glass be used in anodic bonding?
5. Not all sodium rich glasses are suitable for anodic bonding. For example, microscope slides are made of a sodium rich glass known as soda lime, but are ill suited for anodic bonding. When bonding a microscope slide to a silicon wafer, the slide will shatter before it can return to room temperature. Why do you think this occurs? Why doesn’t it occur when using 7740 Pyrex?