UV/Ozone Activation Treatment for Wafer Bonding

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Abstract

Chemical activation of semiconductor wafers prior to bonding can greatly affect the resulting surface energy. Wafers can be activated by wet chemical cleaning [1], oxygen plasma[2,3], and argon sputtering/oxidation [4]. The mechanism that causes the bonding is thought to vary for each of the processes. SC1 renders the silicon surface hydrophilic and bond strength is due to the reaction of the hydroxyl groups at the surface. Oxygen plasma creates a highly reactive nonstoichiometric oxide that can react at the bond interface at room temperature. Sputtering creates a reactive silicon surface. The bond strengths of each of these methods vary greatly, *e.g.* plasma treated wafers achieve full bond strength without a final high temperature anneal while SC1 treatment requires a final anneal. Recently uv/ozone has been used to achieve bond strengths greater than those of SC1 treated wafers [5]. The advantages of using uv/ozone are: 1. it can be used for materials other than silicon, 2. wet chemistry is eliminated, 3. the radiation effects of an intense plasma exposure are reduced.

Experimental

The chamber used was a Samco International Model UV-1 with 200 mm chuck capable of heating from room temperature to 300°C. The uv lamp produces 85% in the 254 nm wavelength and 15% in the 185 nm wavelength at 15 mW/cm^2. The chamber has the capability of exposing wafers to uv only, ozone only, and a combination of uv/ozone together. In addition, a nitrogen purge can be incorporated into the activation treatment.

Three inch silicon wafers were used in the experiments. Wafers were treated in a number of different ways and bond strengths were measured using the crack propagation technique for wafers annealed at 23°C, 100°C, and 200°C. UV/ozone treated wafers were measured for bond strength as a function of exposure time and a function of chuck temperature. UV only with nitrogen purge treated wafers were measured for bond strength as a function of exposure time. Ozone only treated wafers were also measured for bond strength as a function of exposure time. Finally, the bonding wave velocity of these varying treatments was measured and compared to the resulting bond strength.

Resutls

The results of bond strength testing for wafers exposed to uv/ozone, show that a maximum is reached after exposures in the range of five to ten minutes when the chamber temperature is at 23°C and 50°C. After ten minutes the bond strength decreases for each case. This effect could be due to surface roughning of the grown oxide, removal/evaporation of water necessary for initial bonding, or incomplete removal of hydrocarbons. However, there is a trade off between chuck temperature and exposure time. Wafers exposed for one minute show high bond strength at chuck temperatures of 100°C. There appears to be an optimum process which removes some, but not all, of the surface water while creating a smooth hydrocarbon-free reactive silicon surface. It has been reported that exposure to uv/ozone at room temperature results in the slow desorption of carbon contaminants while a resulting thin, low-density oxide film is grown [6]. The oxide film has considerable OH incorporation. This earlier report on uv/ozone may explain the increased bond strength at higher chuck temperatures for shorter exposure time; hydrocarbon by-products are removed while a reactive oxide is formed. In oxygen plasma bonding a similar low-density, highly reactive oxide is formed [3].

A uv only exposure produced similar results to uv/ozone, *i.e.* bond strength was maximized for exposures between five to ten minutes. However, bond strength was enhanced for uv only. The uv can react with water on the surface creating hydroxyl groups. The hydroxyl groups then form strong bonds across the interface.

The ozone only experiments resulted in the lowest bond strength regardless of chuck temperature. These results are consistent with dehydration of the silicon surface. Reacting water and hydroxyl groups are both removed in the ozone environment.

In this talk, the mechanisms for uv/ozone, uv only, and ozone only will be discussed. The resulting bond strength versus initial bond wave velocity will be correlated.

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