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XPS analysis of the dose-dependent interaction of UV radiation with a silicon surface

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Abstract

UV radiation is already routinely applied to the cleaning of semiconductor wafers, where the main effect is the chemical removal of surface contaminants by the action of activated oxygen atoms. UV treatment of wafers prior to fusion bonding has shown a dose-dependent effect [1], where an improvement in bond strength is obtained after short exposure to radiation from a low-pressure Hg discharge. Further exposure results in a diminished benefit. It has been suggested that prolonged exposure cause dehydration of the surface and a reduced surface reactivity. Alternatively, there may be a surface roughening effect, but no mechanism for this has been proposed.
Samples of semiconductor standard <100> p-type silicon were subjected to radiation (mainly at 254 nm, with a lower peak at 185 nm) from a low-pressure Hg source placed inside the vacuum chamber of a Kratos XPS system. Exposure to the shorter wavelength was prevented for some samples by means of a filter. Spectra of the abundances of surface species were obtained, without breaking vacuum, as a function both of total radiation dose and spectral composition. These surface chemistry data are compared with bond strengths obtained for whole wafer samples subjected to equal exposures of UV radiation.

Discussion

Formation of a fusion bond between silicon wafers is a thermally activated process that normally requires a temperature in excess of 1300 K for at least one hour. Many groups have shown that this temperature can be substantially reduced without great loss of bond strength. All of the methods used must work by lowering the energy barrier for formation of bonds across the space between wafer surfaces. One way of doing this is to attach reactive groups to the surface, for instance by exposure to a plasma (wherein the energy needed to create and attach these groups is supplied by electrically exciting the gas). Ultra-violet light has also been shown to activate the surfaces for bonding. Experiments with a UV source whose spectral characteristics allow it to create ozone molecules in an oxygen-containing atmosphere appear to show that the atmospheric ozone is not essential to this process, and may be detrimental. However, even in the absence of gaseous oxygen, a significant quantity is present on wafer surfaces in the form of adsorbed water and oxides of silicon. An aim of the experiments reported here is to discover what role is played by adsorbed oxygen in UV-activated silicon. This is done by exposing the wafers to the radiation, but under ultra-high vacuum. X-ray photoelectron and Auger electron spectroscopy of the surface so treated, without breaking vacuum, reveals the chemical changes caused on the surface by the UV radiation alone. One of the interesting observations made in past experiments is that there is an optimum radiation dose. This suggests that two processes are at work, one that enhances the surface activity of the silicon, and one that diminishes it. By analysing the surfaces after a range of exposure times, we will see the evolution over time of the surface chemistry and correlate this with bond strength. It is also possible that a physical effect is at work, for example, roughening of the surface. However, results reported in the literature so far do not indicate roughness increased beyond a level normally considered acceptable for fusion bonding

Results

The results will be presented during the talk.

References:

[1] K.D. Hobart, F.J. Kub, C.A. Colinge, G.Ayele Proceedings (2003) of the 203rd Meeting of the Electrochemical Society, Paris