Cleaning of Silicone and Hydrocarbon Contact Residue Using Atmospheric Plasma

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Extended Abstract

The utilization of adhesive films for the handling and transport of microelectronic devices is usually required as wafers proceed from fabrication, singulation, and packaging. Common adhesive films include dicing tapes and silicone membranes that are chosen to secure components during processing and then subsequently release with minimal residue transferred to the contact surface. Unfortunately, this small amount of contact residue can decrease surface energy and introduce contaminants that are problematic to down-stream processing, particularly if the surface will be permanently bonded within an assembly. Example bonding types include adhesive-, thermocompression-, solder-, and especially direct- bonding, which has become quite popular for Heterogeneous Integration applications in 3DIC and Integrated Photonics.

Common methods for cleaning the contact residue include solvent cleaning and vacuum plasma treatment[1,2,3]. In this study, we examine the use of a plasma system capable of operating without a vacuum chamber under atmospheric conditions (i.e. an atmospheric plasma). Because an atmospheric plasma system is more compact, and can operate on-demand, it can be installed directly inline within production bonding equipment for potential benefits including reduced cost and greater effectiveness, simplicity, and speed.

To measure the effectiveness of atmospheric plasma cleaning in this study, water contact angle and FTIR spectroscopy are used to analyze metal surfaces that were contacted with several popular adhesive films and then cleaned using various plasma process gases including oxygen and hydrogen.

Keywords: Atmospheric plasma, surface cleaning, bonding, contact residue, surface energy, hydrophilic surface, dicing tape.

Materials and Methods

Four adhesive films were chosen for this experiment: Gel 4 (silicone membrane with tack level 4), Gel 8 (silicone material with tack level 8), Dicing Tape A (blue dicing tape), and Dicing Tape B (UV release dicing tape). These materials were chosen because of their common use in wafer and chip-scale processing.

Chrome-plated steel substrates (ferro-type plates, FTP) were used to contact the adhesive materials. Prior to contact, the FTP samples were cleaned using a solvent wipe followed by flame treatment. An atmospheric plasma system, Figure 1(A), was used to clean the FTP samples in an open environment. Three types of plasma process gas recipes were used in this study using oxygen, hydrogen, or both along with the carrier gas helium.

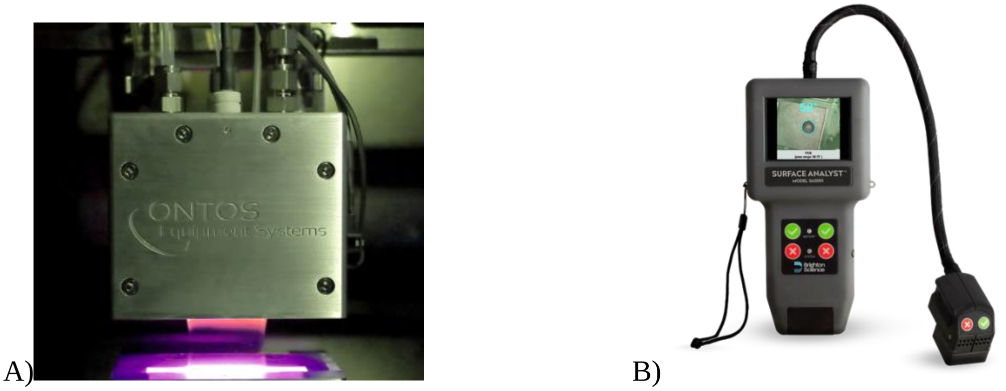

Figure 1: A) Atmospheric Plasma used for cleaning FTP plates. Main carrier gas is helium with additional process gas of oxygen, hydrogen, or combination oxygen+hydrogen. Atmospheric plasma plume is seen exiting from the bottom of the plasma head (pink plume). B) Goniometer utilizing top-down view for measuring water contact angle, which is a good method for gauging surface energy and hydrophilicity known to improve adhesion.

The contact surfaces of the FTP substrates were analyzed using a water contact angle (WCA) goniometer, Figure 1(B), which gauges hydrophilicity and surface energy. In addition, FTIR spectrometry was used to determine specific chemical groups apparent on the FTP surface. The surfaces were analyzed after contact and then again after plasma cleaning to understand what contamination residues are transferred and how they affect hydrophilicity as well as the cleaning effects of atmospheric plasma exposure.

<u>General procedure:</u>

1) Prepare clean FTPs and collect baseline WCA and FTIR data.
2) Contact FTP with each of the four adhesive materials, collect WCA and FTIR data.
3) Expose FTP surface to one of three types of ONTOS plasmas and immediately collect WCA data.
4) Collect FTIR data and WCA data after 3 days (aged).

<u>Results and Discussion</u>

WCA and FTIR data were collected at various test points and contact with Gel 4 as shown in Figure 2 and Figure 3 below. Results from all other materials will be given in full conference presentation.

Gel 4 (tack level 4)	
Sample	Plasma Gases
1	$He+O_2$
2	$He+H_2$
3	$He+O_2+H_2$

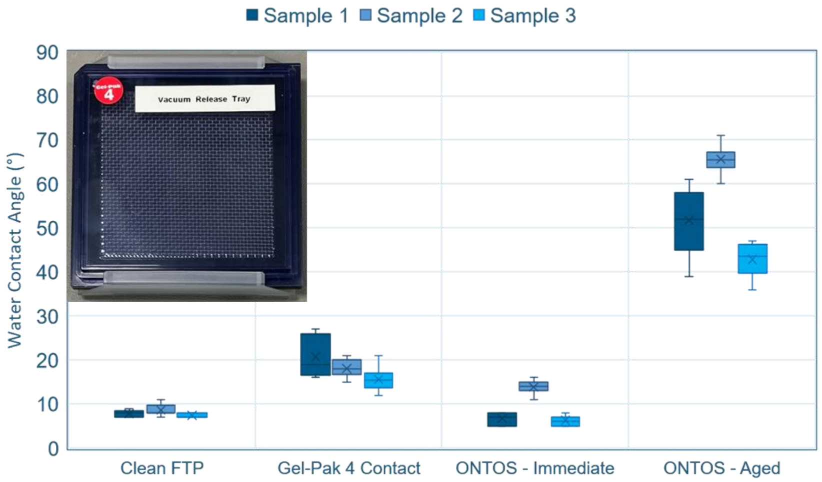

Figure 2: Table with process gases used for each of the three FTP samples tested with Gel 4. The bar graph shows the water contact angle at various test points including after initial cleaning, after contact with Gel 4, after exposure to ONTOS atmospheric plasma, and after aging 3 days.

Water contact angle (WCA) is used to measure the hydrophilicity and surface energy of a surface. Lower contact angle, which is indicative of a high surface energy, is generally correlated with improved bond strength. The low WCA of 9° for the three FTP samples prepared for this experiment confirms that the initial cleaning works as expected. However, after touching the surface of the three FTP samples with the Gel 4 silicone membrane, we see a significant rise in WCA now measuring up to 25°. Clearly, some amount of contact residue has transferred to the FTP, which can reduce the wetting and decrease surface energy.

Following the contact with Gel 4, each of the three samples were exposed to an atmospheric plasma with different process gas recipes. Sample 1 was exposed to an atmospheric plasma containing He+O_2 gases. The resulting WCA is brought back down to the initial 9°, indicating a good cleaning effect. This was expected since oxygen is the typical gas used in vacuum plasma systems. Sample 2 was exposed to He+H_2 atmospheric plasma and shows a mild reduction in WCA to about 14°, which indicates only a partial reduction of surface contaminates or slight increase in surface energy. Sample 3 was exposed to He+O_2+H_2 atmospheric plasma and shows similar WCA reduction as Sample 1 bringing the WCA back down to 9°.

The samples were then aged approximately 3 days and the WCA measured again. All three samples show an unexpected large rise in WCA with Sample 2 showing the largest WCA of 65°. It is thought that perhaps these samples were re-contaminated by using the same foil used to wrap the contaminated samples.

The FTIR data was also measured after the 3 days of aging time and shown in Figure 3 below.

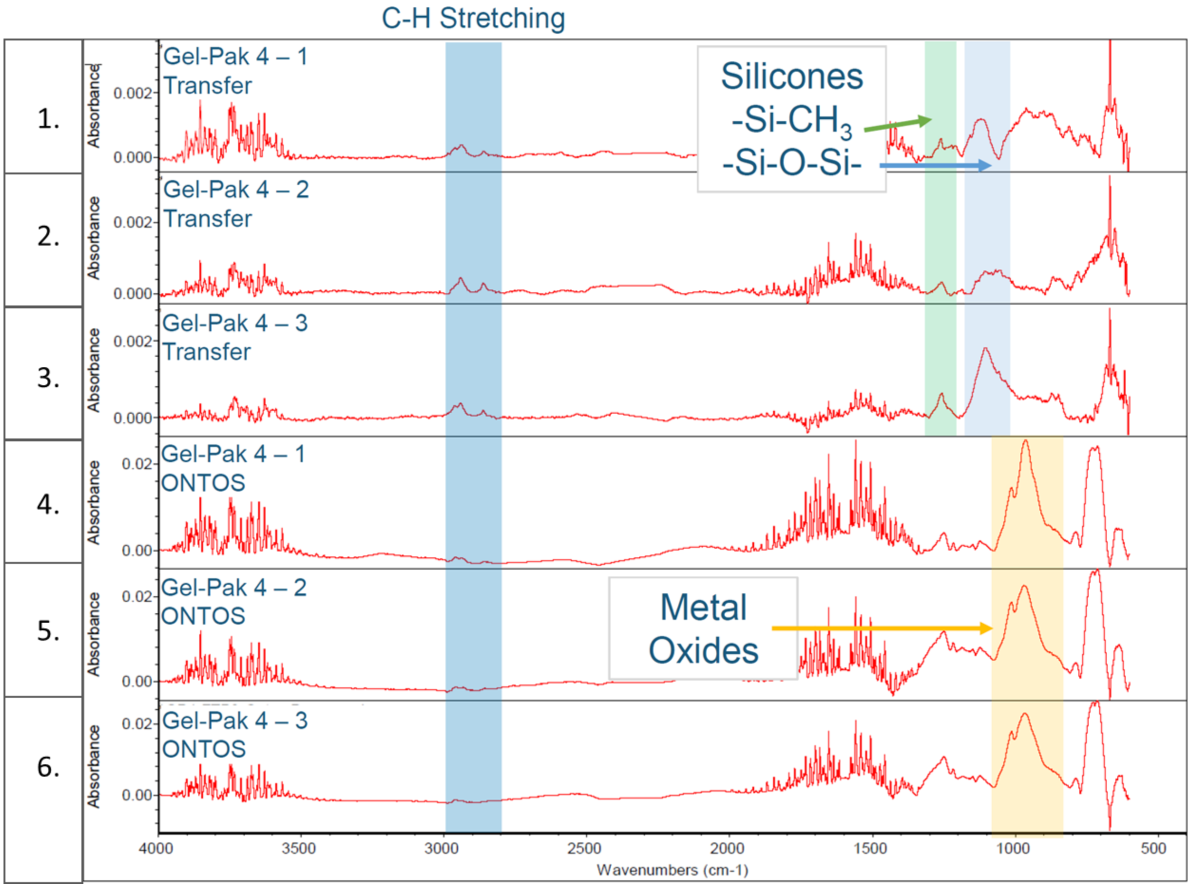

Figure 3: FTIR spectrometer data for samples 1-3 after contact with Gel 4 (spectra 1-3) and after exposure to ONTOS plasma (spectra 4-6).

The FTIR spectra 1-3 were used to determine the basic chemical groups present in the contact residue from Gel 4. The spectra show traces of C-H stretching (hydrocarbon) and silicone chemical groups, which identify the contaminates that increase the WCA. All three plasma-treated samples (spectra 4-6) show a reduction in hydrocarbon and silicone peaks with spectrum 4 (He+O_2) almost eliminating the silicone peaks. The data also shows an increase in metal oxides after plasma treatment and aging. It is thought that this metal oxidation is due to oxidation processes during plasma treatment (especially oxygen-containing plasmas), aging in an atmospheric air environment, or perhaps transformation of the silicone groups into silica (SiO_2) as seen in another study[4].

Conclusion

Experiments have been conducted to determine the types of contact residue transferred from common adhesive films used in semiconductor fabrication and packaging. WCA and FTIR data confirm the transfer of hydrocarbon and silicone contaminant residue that reduce hydrophilicity and surface energy. Atmospheric plasma has been shown to significantly reduce or eliminate these contaminants, which should be beneficial for the quality of bonding in downstream processes.

References

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