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Visual Contact Angle Analyzer (VCA)

Application in Electronics industry

This technical note introduces applications of Contact Angle Analyzer in electronics industries.

發行版本：V2.00

TRUTH

GOODNESS

BEAUTY

Introduction

In electronic manufacturing, multiple materials are involved to be bound, adhered to, or conjunct to each other. It could be either permanently or for a process step. Regardless of which types or scale the manufacturing sector is dealing with, cleanness and adhesion need to be reliable and repeatable to yield a good product quality. On the technical note, we will introduce the application of Contact angle analyzer (VCA) in electronic industries, with particular emphasis on the applications of silicon wafer processing, lithography, and printed circuit board (PCB).

Quality control of wafer cleanliness with water contact angle

The surface hydrophobicity of a silicon wafer is important in many applications. For example, the silicon hydrophilic property plays an important role in the process of direct wafer bonding, silicon-on-insulator (SOI) products, silicon-based sensors, biochemical systems, and microelectronics-mechanical systems (MEMS) [1]–[3].

A silicon surface is hydrophilic because the silicon surface is generally covered by a thin native oxide layer, which links many silanol (Si-OH) groups, which tends to adsorb one or two monolayers of water on top. The native silicon oxide (SiO_2) on a silicon surface could be formed in the presence of water molecules. This might be due to the extraction of moisture or the polymerization of Si-OH on the surface. These singular and associated –OH groups are relatively stable on a silicon dioxide surface, and hard to remove via a heating process.

Nevertheless, a variety of methods could be utilized to remove the native oxide on the silicon surface, and consequently the wettability on the silicon surface. The silicon wafer cleaned using a piranha solution is hydrophilic, but the silicon wafer cleaned by an HF solution is hydrophobic, and the hydrophilicity could be restored after a long time of exposure to moisture or by a plasma activation treatment. Therefore, A simple way to evaluate the hydrophobicity of a surface is to measure the contact angle of a water drop, as shown in Figure 1(a) [4]. Various contact angles are exhibited in **Fig. 1(b)–(e)**, in which the hydrophilicity of the silicon wafer results from singular and associated –OH groups [1].

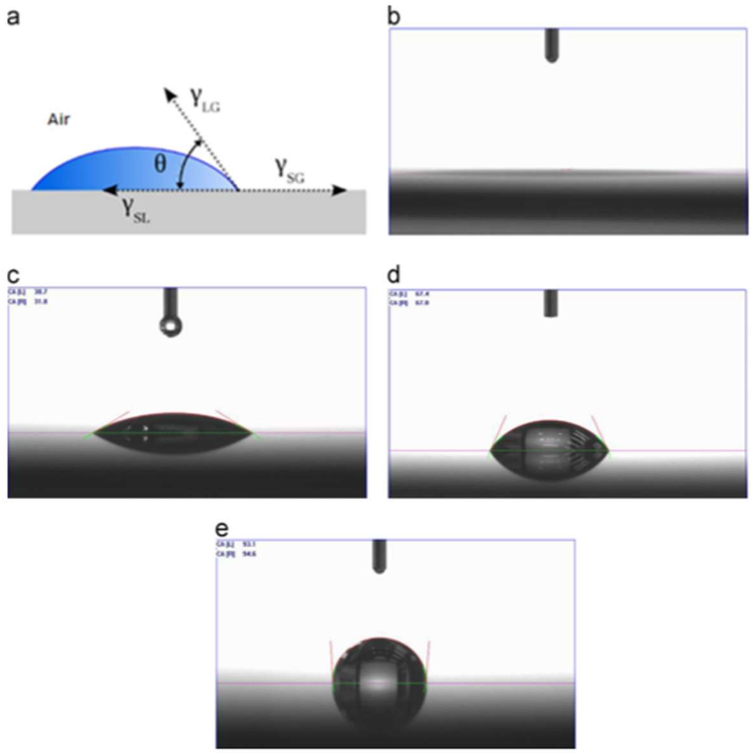

Figure 1 *(a) Diagram showing the contact angle measurement method. (b) Image of the contact angle of a water drop on a wafer surface that has gone through an oxygen plasma treatment for three minutes. (c) Image of the contact angle of a water drop on a silicon wafer in a vacuum for 2 h after the piranha cleaning. (d) Image of the contact angle of a water drop in a vacuum for 96 h after the piranha cleaning. (e) Image of the contact angle of a wafer drop in a vacuum for 96 h after the HF solution cleaning. (Graph adapted from Ref [4])*

Understanding the relationship between wafer cleanness and contact angle is critical when it comes to large-scale industrial applications. The procedure begins with the formulation of a silicon ingot that gets sliced into extremely thin, highly-polished wafers about 1/40 th of an inch thick and usually 6-12" in diameter. The wafers are prepared for photolithography through a series of polishing, chemical etching, heating, and rinsing steps. These are used to clean the silicon of particulate, moisture, and organic impurities that could get in the way of the wafer bonding with the photoresist, vital to the photolithographic process. One of the most critical requirements is surface cleanliness.

RCA cleaning is the standard cleaning method for silicon wafers before processing. The purpose of the cleaning is to discard all unwanted material or particles from the surface, such as dust, oil, or silicon particles, etc.

The cleaning steps are divided into two; RCA1 and RCA2. RCA1 will remove any

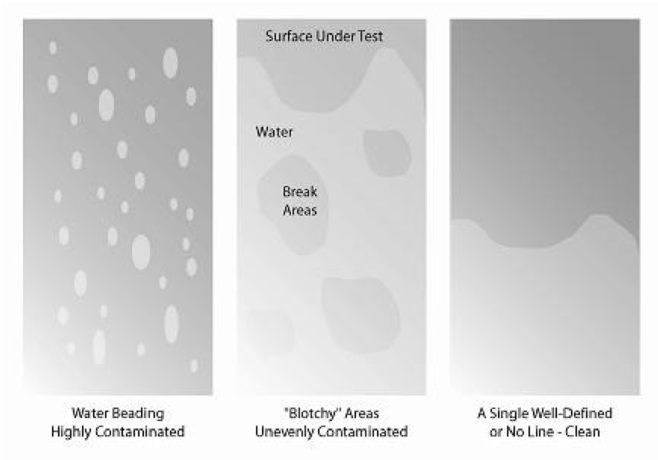

Figure 2::The water break test can detect contamination by oil and other hydrophobic contaminants on hydrophilic substrates (Ref: [5]).

organic contamination whereas RCA2 takes care of the ionic and metallic contamination. As mentioned earlier, dilute hydrogen fluoride (HF) solution is often used in between to remove the thin oxide layer. In practice, water break tests (see figure 2) are commonly used to check the status of the surface after the cleaning procedure, and the water contact angle measurements offer a traceable and quantitative way for the quality control of wafer cleanness [5]–[7].

The contact angle for the photolithography process

Creating the intricate features on the wafers typically requires the use of a multi-step process called photolithography, a printing method where UV light is illuminated to transfer patterns onto a photosensitive surface. However, silicon itself is not photosensitive so a material called a photoresist is applied to the surface of the silicon. The application of a photoresist film requires a strong bond between the photosensitive coating and the silicon substrate; therefore, proper photoresist adhesion is one of the most important factors for the successful lithographic process. loss of adhesion in the development or etching process will result in patterning errors that are fatal for the device being manufactured.

Hexamethyldisilazane (HMDS) is often used before the application of the photoresist. However, if the Si-OH layer on the surface is not completely removed before the photoresist application, there is a risk of complete delamination of the photoresist during subsequent development or chemical etching processes. In a standard process, a hydrophobic HMDS coating is often applied after a dehydration bake, to ensure the surface to be hydrophobic and thus less prone to water absorption. Water contact angle measurements can be used to find the optimum HMDS treatment protocol as well as to check whether the treatment has been successful [8].

Conformal coatings and plasma process of PCB

Conformal coatings are used to protect PCBs from environmental conditions such as high humidity [9]. For instance, a range of airborne contaminants, and varying temperatures, humidity, and mechanical banding can possibly damage the functionality of PCB. Therefore, conformal coating adhesion plays a critical role for PCB to work functional [10]–[12]

Most of the carrier materials for PCBs are made of glass fibber reinforced plastics which typically have a low surface free energy value at around 40 to 45 mN/m. Furthermore, the surface free energies of the individual components and assemblies vary greatly. This makes the conformal coating difficult. Surface modification or cleaning process might not be sufficient to increase the surface-free energy to the required level [11].

As a common rule, the surface tension of the conformal coating should be at least 10 mN/m lower than the surface free energy of the substrate. Plasma activation of the PCBs can be used to increase the surface free energy and thus ensure more homogenous wetting of the PCB. Thus, in the PCB industry, contact angle measurements can be used at various stages of the process. First to check the surface wettability at the beginning and then to find proper plasma treatment parameters to reach the required levels. Contact angle also provides an excellent tool for quality control purposes to make sure that the process is under control [11], [12].

Reference:

[1] T. Suni, K. Henttinen, I. Suni, and J. Mäkinen, "Effects of plasma activation on hydrophilic bonding of Si and Si02," J. Electrochem. Soc., vol. 49, no. 6, pp. G348–G351, 2002.

[2] U. Gösele and Q.-Y. Tong, "SEMICONDUCTOR WAFER BONDING," http://dx.doi.org/10.1146/annurev.matsci.28.1.215, vol. 28, no. 1, pp. 215–241, Nov. 2003.

[3] M. M. R. Howlader, T. Suga, H. Itoh, T. H. Lee, and M. J. Kim, "Role of Heating on Plasma-Activated Silicon Wafers Bonding," 2009.

[4] X. M. Yang, Z. W. Zhong, E. M. Diallo, Z. H. Wang, and W. S. Yue, "Silicon wafer wettability and aging behaviors: Impact on gold thin-film morphology," Mater. Sci. Semicond. Process., vol. 26, no. 1, pp. 25–32, Oct. 2014.

[5] "The Water Break Test as a Surface Measurement Gauge." [Online]. Available: https://www.btglabs.com/blog/the-water-break-test-as-a-surface-measurement-gauge. [Accessed: 12-Jul-2021].

[6] E. Portuguez, A. Alzina, P. Michaud, and A. Smith, "Evaporation Kinetics and Breaking of a Thin Water Liquid Bridge between Two Plates of Silicon Wafer," Adv. Mater. Phys. Chem., vol. 06, no. 07, pp. 157–166, 2016.

[7] T. Takahagi, H. Sakaue, and S. Shingubara, "Adsorbed water on a silicon wafer surface exposed to atmosphere," Japanese J. Appl. Physics, Part 1 Regul. Pap. Short Notes Rev. Pap., vol. 40, no. 11, pp. 6198–6201, 2002.

[8] "The Best Method of Controlling HMDS Use in Semiconductor Manufacturing." [Online]. Available: https://www.btglabs.com/blog/the-best-method-of-controlling-hmds-use-in-semiconductor-manufacturing. [Accessed: 12-Jul-2021].

[9] C. Montemayor, "Effect of Silicone Conformal Coating on Surface Insulation Resistance (SIR) For Printed Circuit Board Assemblies."

[10] A. Siewiorek et al., "Effects of PCB Substrate Surface Finish and Flux on Solderability of Lead-Free SAC305 Alloy," J. Mater. Eng. Perform. 2013 228, vol. 22, no. 8, pp. 2247–2252, Feb. 2013.

[11] D. K. Shin, H. S. Lee, and J. Im, "Chemical and mechanical analysis of PCB surface treated by argon plasma to enhance interfacial adhesion," IEEE Trans. Electron. Packag. Manuf., vol. 32, no. 4, pp. 281–290, 2009.

[12] "Plasmatreat Releases Surface Cleaning for a Reliable Wire Bonding Process." [Online]. Available: https://pcb.iconnect007.com/index.php/article/125055/plasmatreat-releases-surface-cleaning-for-a-reliable-wire-bonding-process/125058/?skin=pcb. [Accessed: 12-Jul-2021].

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