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Adhesive bonding using thick polymer film of SU-8 photoresist for wafer level package

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Abstract

For the application to optic devices, wafer level package including spacer with particular thickness according to optical design could be required. In these cases, the uniformity of spacer thickness is important for bonding strength and optical performance. Packaging process has to be performed at low temperature in order to prevent damage to devices fabricated before packaging. And if photosensitive material is used as spacer layer, size and shape of pattern and thickness of spacer can be easily controlled. This paper presents polymer bonding using thick, uniform and patterned spacing layer of SU-8 2100 photoresist for wafer level package. SU-8, negative photoresist, can be coated uniformly by spin coater and it is cured at 95 °C and bonded well near the temperature. It can be bonded to silicon well, patterned with high aspect ratio and easy to form thick layer due to its high viscosity. It is also mechanically strong, chemically resistive and thermally stable. But adhesion of SU-8 to glass is poor, and in the case of forming thick layer, SU-8 layer leans from the perpendicular due to imbalance to gravity. To solve leaning problem, the wafer rotating system was introduced. Imbalance to gravity of thick layer was cancelled out through rotating wafer during curing time. And depositing additional layer of gold onto glass could improve adhesion strength of SU-8 to glass. Conclusively, we established the coating condition for forming patterned SU-8 layer with 400 μm of thickness and 3.25 % of uniformity through single coating. Also we improved tensile strength from hundreds kPa to maximum 9.43 MPa through depositing gold layer onto glass substrate.

Key Words : adhesive bonding, polymer bonding, SU-8, wafer level package

1. Introduction

The use of thick polymer for MEMS technology is recently extended. SU-8 or polyimide is mainly used for electroplating mold[1,2], micro structure such as micro channel[3] or encapsulating material[4,5]. In this paper, we use thick photoresist to apply to polymer bonding for packaging. Most application of thick photoresist is electroplating mold. There is no importance of uniformity of film thickness and flatness of film surface. But, thick interlayer is often required for particular application such as optical devices or packaging[6]. Especially in these cases, fine control of thickness and uniformity of photoresist is necessary. Polymer bonding has several potential advantages. It is compatible with most CMOS process because it is low temperature bonding, can be applied to various substrates and is low cost fabrication precess[7]. The ultimate goal of this research is glass to glass bonding using thick photoresist interlayer for wafer level package. We have to establish the condition for coating thick photoresist film very uniformly and improve the adhesion strength of SU-8 onto glass wafer for packaging. We established the condition of coating 400 μm thick film with uniformity not exceeding 5 % and obtained the improvement the adhesion strength of SU-8 onto glass wafer for packaging by using additional adhesion layer.

2. Design

We chose SU-8 negative photoresist due to relatively good adhesion to silicon, the mechanical and chemical stability, and its high viscosity. The experiment for coating thick layer of SU-8 2100 of Microchem Co. uniformly was performed. We aimed for 400 μm of thickness and below 5 % of uniformity. It is known that adhesion of SU-8 to glass is poor[8]. Thus, the experi-

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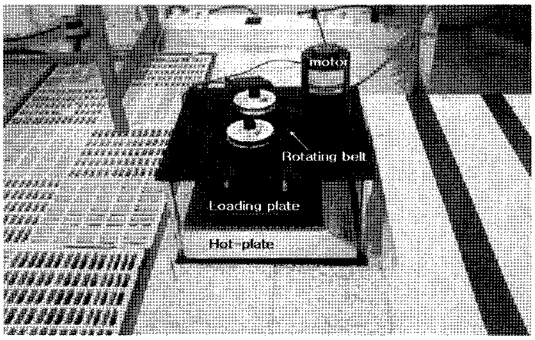


Fig. 1. Wafer rotating system.

ment for improving adhesion strength of SU-8 film to glass wafer was performed.

Generally, thick photoresist lean on one side because surface of hot plate isn't accurately perpendicular to the gravity and so isn't surface of glass wafer. In case of thin photoresist this phenomenon doesn't happen because the viscosity of photoresist is increased by evaporation of most of solvent which was in photoresist during spin coating and soft bake time of thin photoresist film is short. But viscosity of thick photoresist is not increased by much after spin coating and free stream region beyond the boundary layer of thick film is much wider than that of thin film. These can make far more flow in thick photoresist film than thin photoresist film, and moreover flow volume is increased in proportion to the soft bake time which is increased according to film thickness. The effect of glass surface not perpendicular to gravity can be cancelled out by rotating glass wafer. So wafer rotating system was made which can rotate wafer continuously during bake time.

Wafer rotating system consists of motor, rotating belt, rotator, rotating plate and controller as seen in Fig. 1.

Optimal condition for thickness and uniformity of photoresist film was established with varying spin speed, spin time, temperature and time of flattening. And optimal patterning condition is established by profile measurement of photoresist film varying exposure energy and develop time.

Experiments to improve adhesion of SU-8 were performed also. Adhesion layer was deposited onto glass substrate and SU-8 was coated on adhesion layer. Gold, Nickel, silicon dioxide, polycrystalline silicon, silicon nitride and Chrome were chosen as adhesion material. Tensile and shear strength of SU-8 to several adhesion materials were measured respectively.

3. Experiment

Bare glass wafer was cleaned to improve adhesion between glass wafer and SU-8 with acetone/methanol/isopropyl alcohol for 3 minutes, respectively. Then, the wafer was cleaned again in $H_2SO_4+H_2O_2(4:1)$ for 10 minutes and put on hot plate at 200 °C for 10 minutes for dehydration. First, coating experiment for 400 μm thickness was performed varying spin speed and spin time. And coating experiment varying temperature and time of flattening was performed for uniformity. Then, spin time and speed were modified again for uniformity.

MA-6 aligner of Karl-suss was used for exposure and it has 14 mW of power intensity and uses unicolor light

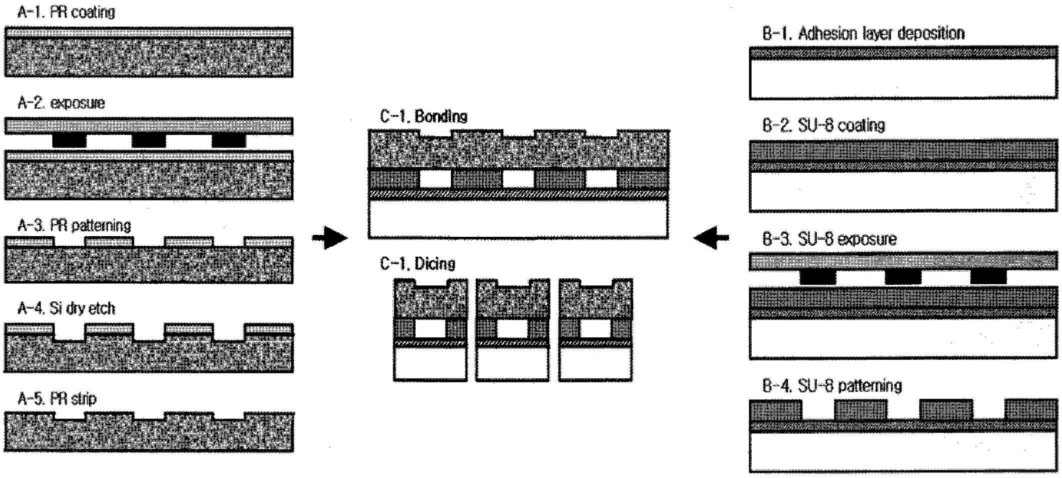


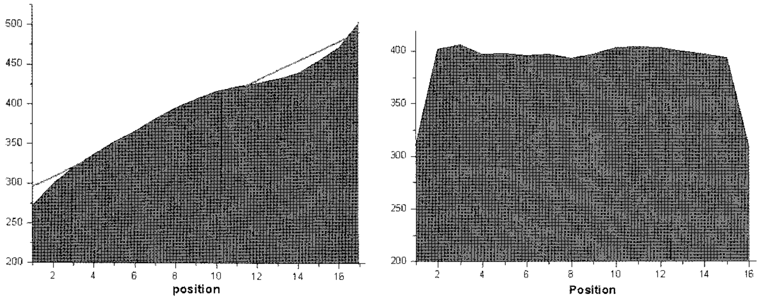
Fig. 2. Process flow of adhesion layer experiment.

with 365 nm of wavelength. Exposure time was optimized by inspection of profile of photoresist film. The post exposure bake was performed at 65 °C and 95 °C after exposure. And then the photoresist was developed using SU-8 developer. Every heating and cooling process was gradually performed to minimize thermal stress.

SU-8 3020 was used for adhesion layer experiment because its component is similar to SU-8 2100 and its coating and patterning condition is well-known. The cleaning and dehydration process was performed identically with former experiment. Backside of glass wafer was patterned for dicing view and front side of glass wafer was deposited by adhesion material and then coated by SU-8. Ti/Au, Ni and Cr were deposited by sputtering, silicon oxide and silicon nitride were deposited by PECVD and polycrystalline silicon was deposited by LPCVD. After that, SU-8 was patterned and the glass wafer was bonded to bare silicon wafer. Bonding condition was decided as 1500 kPa of bonding pressure at 100 °C for 10 minutes according to optimization and the other side of bonding was decided as silicon wafer of which adhesion strength is good enough. Samples for measuring adhesion strength were obtained after dicing the bonded wafers. Process flow is described in Fig. 2.

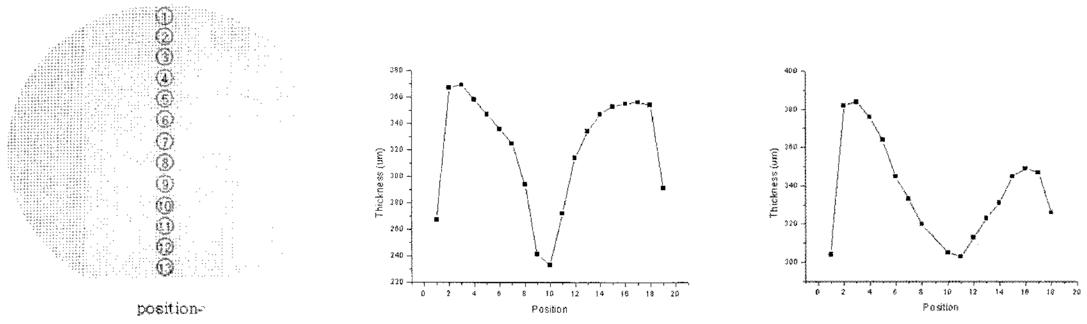
4. Result and discussion

Optimal condition for coating and curing thick SU-8

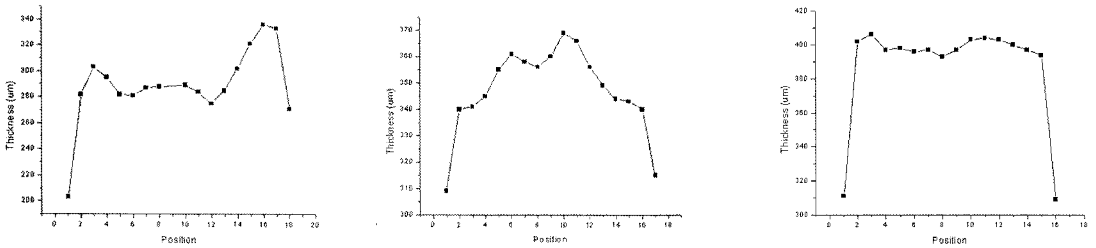


(a) Without wafer rotating system (b) With wafer rotating system

Fig. 3. Thickness distribution of SU-8 film.



(a) Position of measurement point (b) Curing at 100℃ for 2hours (c) Curing at 90℃ for 1hour and 100℃ for 1hour



(d) Curing at 70℃ for 1hour and 100℃ for 1hour (e) Curing at 50℃ for 1hour and 100℃ for 1hour (f) Curing at 50℃ for 2hours and 100℃ for 2hours

Fig. 4. Thickness distribution of SU-8 film according to curing condition.

film uniformly was established through experiments varying spin speed, spin time, flattening temperature and flattening time.

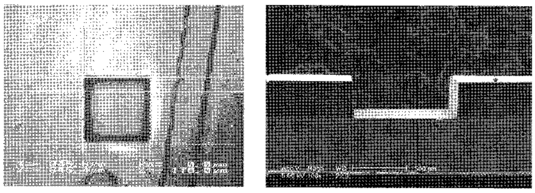
Fig. 3(a) and (b) shows the distribution of thickness of SU-8 without wafer rotating system and with wafer rotating system, respectively. Graph of Fig. 3(a) leans on one side, but graph of Fig. 3(b) is relatively parallel to the surface. These figures say the use of wafer rotating system cancel out the incline due to wafer surface out of perpendicular to the gravity.

Fig. 4 shows the distribution of thickness of SU-8 according to curing condition. As seen in Fig. 4(b), (c) and (d) when curing temperature is too high SU-8 is polymerized too quickly to spread out uniformly. And enough curing time is required for uniformity as seen in Fig. 4(e) and (f).

SU-8 film with 400 μm of thickness and 3.25 % of uniformity was able to be formed by spin coating with 500 rpm 30 sec and 780 rpm 30 sec consecutively and then baking for 2 hours at 50 °C and for 2 hours at 100 °C on hot plate.

As a result of experiment varying exposure time with measurement of SU-8 film profile, 87 ° of slope was able to be formed by 2400~2800 mJ/cm^2 of exposure energy. Fig. 5(a) and (b) are microphotographs of SU-8 pattern.

Both pull test for measuring tensile strength and shear test for measuring shear strength were performed as measurement of adhesion strength between adhesion layer and SU-8 photoresist. The methods of measuring strengths is described in Fig. 6.



(a) Top view (b) Side view

Fig. 5. Microphotographs of SU-8 pattern.

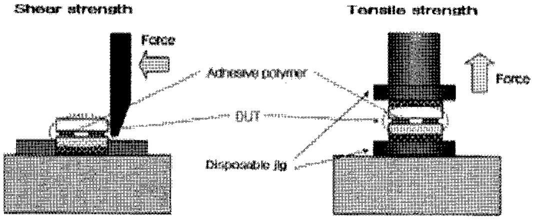
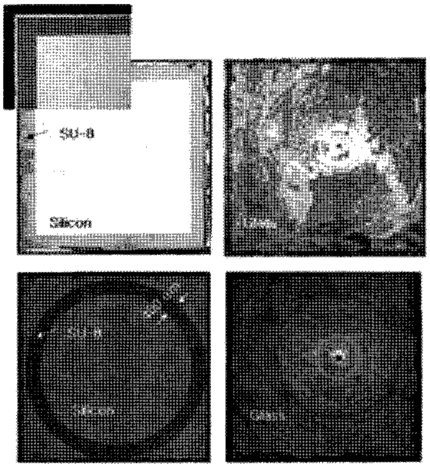
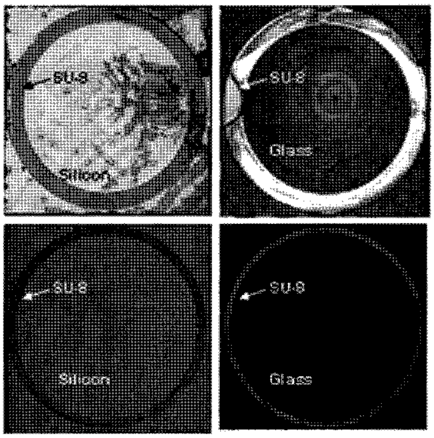


Fig. 6. Schematics of shear test and pull test.



(a) interface of SU-8 and glass

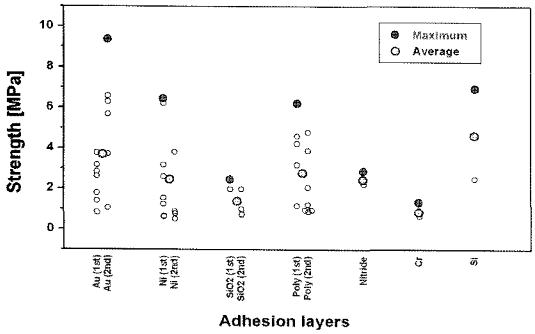


(b) interface of SU-8 and polycrystalline silicon

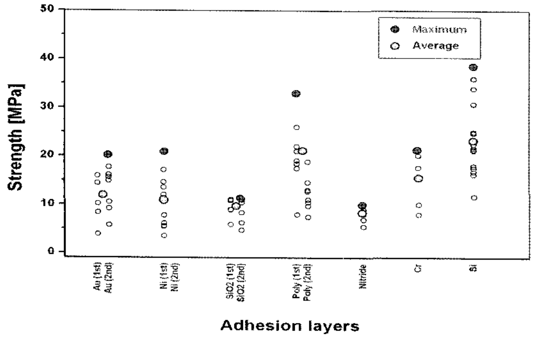
Fig. 7. Microphotographs of interfaces of fracture.

Fig. 7(a) and (b) are microphotographs of interfaces after fracture test. Fracture was occurred in SU-8/glass interface in case of SU-8/glass bonding, that is, no additional adhesion layer. But in case of SU-8/poly bonding, fracture was occurred in SU-8 layer. It means SU-8/poly bonding is much stronger than SU-8/glass bonding.

In pull test, the sample was attached to the chuck with glue. And then, Pulling the chuck with fixed velocity, fracture strength was measured. Applying shear force to sample, fracture strength was measured in shear test. Fig. 8(a) and (b) show average and maximum value of tensile and shear strength according to several materials, respectively. We could know that the use of gold or polycrystalline silicon as adhesion layer can improve



(a) Tensile strength



(b) Shear strength

Fig. 8. Adhesion strength according to adhesion materials.

adhesion strength to a great extent. Using gold or polycrystalline silicon layer, tensile strength was improved below 1 MPa to maximum 9.43 MPa.

5. Conclusion

Experiments to form thick and uniform SU-8 layer and to improve adhesion strength of SU-8 to glass substrate were performed. The wafer rotating system was introduced to eliminate incline of thick SU-8 film. Using it, we established the coating condition for forming SU-8 layer with 400 μm of thickness and 3.25 % of uniformity through experiments varying spin speed, spin time, flattening temperature and flattening time. And we improved adhesion strength by using gold or polycrystalline silicon as adhesion layer. Using gold layer as adhesion layer, maximum 9.43 MPa of tensile strength was obtained.

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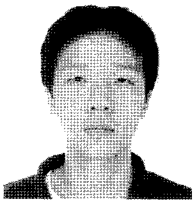

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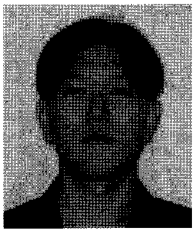

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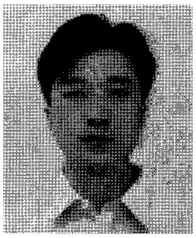

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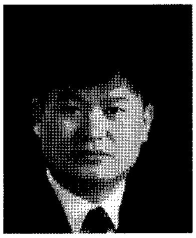

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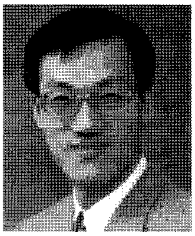

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