Chapter 2

Concept and Design

2.1 Wafer Level Package by Using UV Curable Adhesive

The main concept of wafer level package by using UV curable adhesive is shown as Fig. 11

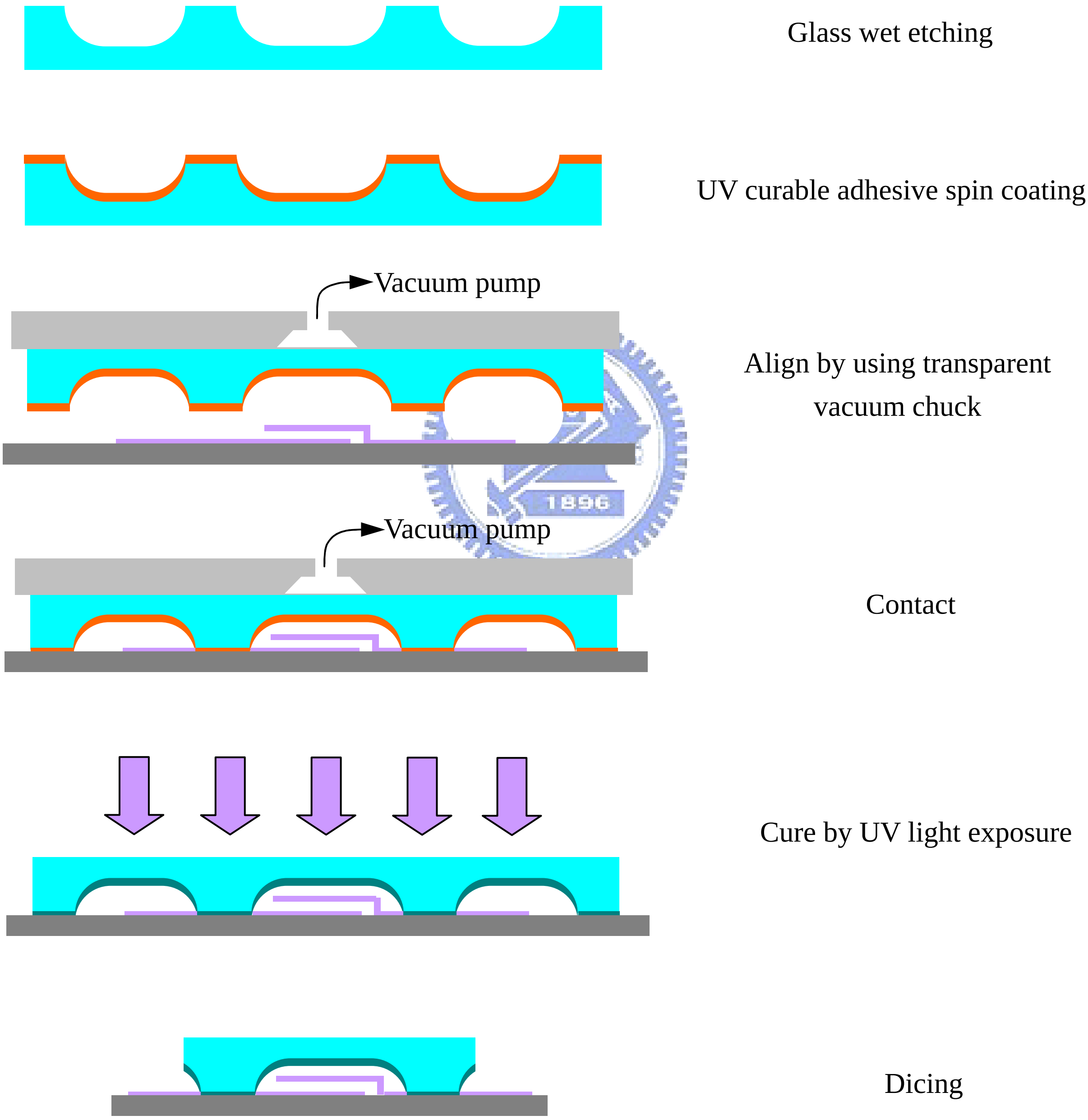


Fig. 11 Process flow of wafer level package by using UV curable adhesive

There are three major elements of this wafer level package process: a cap for protection, device for testing, and proper adhesive. Each of them will be discussed in the following sections.

2.2 The Selection of Glass Protection Cap

UV curable adhesive cures through UV light exposure with correct wave length and sufficient dosage. Due to this nature, the protection cap has to be transparent to UV light. Corning Pyrex 7740 glass is chosen since it is transparent to UV light, mechanically robust, and shows good resistance to various chemicals. In addition, Pyrex 7740 glass has close CTE (Coefficient of Thermal Expansion) to single crystal silicon. In high temperature accelerated test, this characteristic could minimize possible residual thermal stress at the silicon/glass interface, reduce the variables in the experiment.

Properties	Value
Coefficient of Thermal Expansion (273-573K)	3.25×10^{-6} /K
Transmission @ 365 nm (525µm thick)	95.4%
Transmission @ 400 nm (525µm thick)	95.6%
Relative Index	1.4727 (@ 589nm)
Typical Composition	SiO_2 80.6wt% ; Na_2O 4.0wt% ; B_2O_3 13wt% Al_2O_3 2.3wt% ; K_2O 0.1wt%

Table 2. Some properties of Pyrex 7740 glass

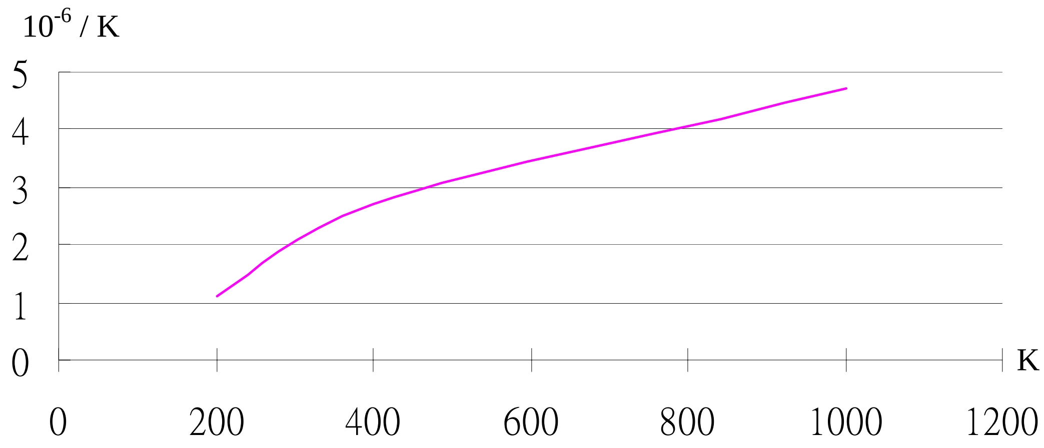


Chart 1. Temperature v.s. CTE of single crystal silicon

2.3 The Selection of UV Curable Adhesive

UV curable adhesive is widely used in many applications. Different kinds of UV curable adhesives have been developed for different purposes. Since there are no UV curable adhesives which design for glass/silicon wafer bonding, we choose suitable UV curable adhesive from commercial products. The selection is based on the following criteria:

1. Low viscosity for spin coating
2. Good adhesion between glass to glass
3. Good resistance to water immersion and humidity
4. High bonding strength
5. Single component for easier use

UV curable adhesive is provided by Henkel, Taiwan. LOCTITE® product 3492 is recommended because it is a low viscosity, single component, designed for bonding glass to itself and to a variety of other surfaces. Product 3492 also shows excellent resistance to prolonged humidity or water immersion. [10]

2.4 Design of Testing Devices

Testing devices are utilized to estimate the hermeticity and bonding strength of UV curable adhesive wafer level bonding. Two different testing devices are designed and fabricated: dew point sensor and overlapping parallel capacitor. Dew point sensor is made to evaluate the hermeticity and lifetime in the accelerated test. Overlapping parallel capacitor is a freestanding microstructure, and utilizes to prove that wafer level bonding by using UV curable adhesive is good enough to prevent stiction or structural damage after dicing operation.

2.4.1 Dew Point Sensor

Dew point sensor is utilized to estimate the hermeticity of adhesive and lifetime of packaged device in the accelerated test. The working principle of dew point sensor is like this: Packaged dew point sensors are put into water with different temperature. Water vapor penetrates through the bonding width during the testing. When water vapor inside reaches dew point, dew will appear between the comb fingers and change the capacitance. By monitoring the capacitance change, the hermeticity or lifetime can be evaluated.

The design and physical dimensions of dew point sensor are shown in Fig.12 and Fig.13

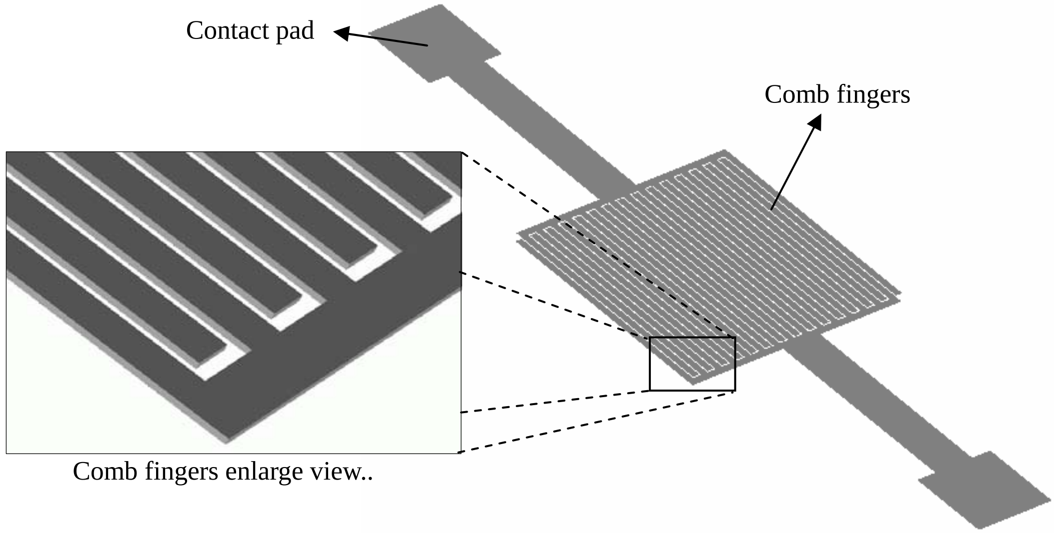


Fig.12 Design of dew point sensor. The film thickness of dew point sensor is about 2μm in order to get larger capacitance.

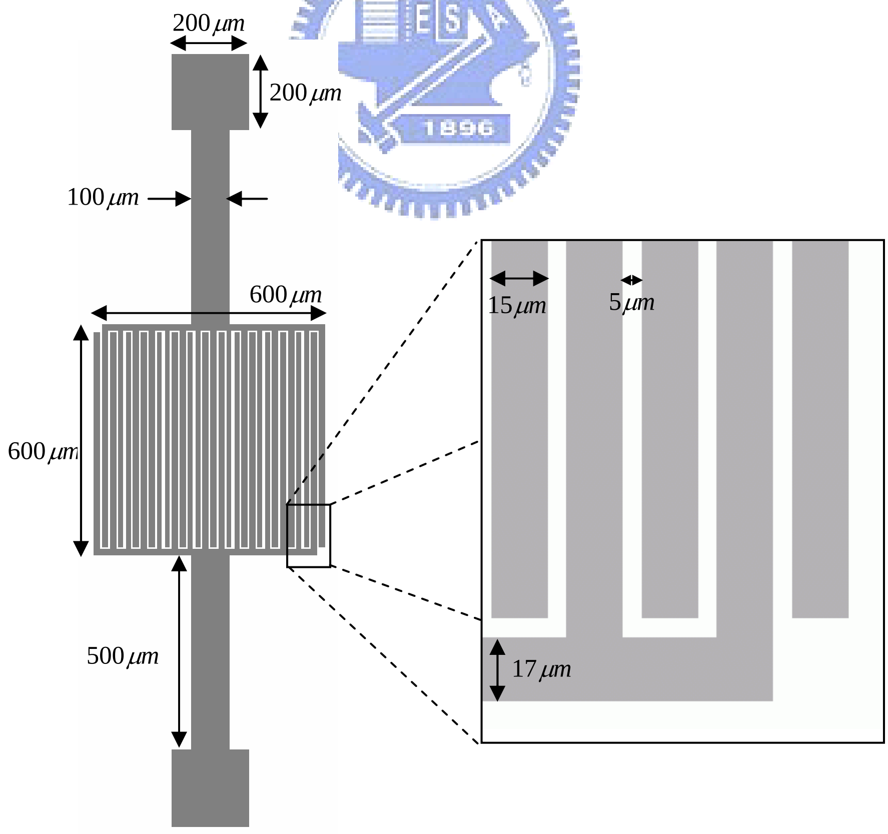


Fig.13 Physical dimensions of dew point sensor. [11] The gap between comb fingers is 5μm.

2.4.2 Overlapping Parallel Capacitor

The overlapping parallel capacitor is a freestanding microstructure. The purpose of this testing device is utilized to prove that UV curable adhesive wafer level bonding is adequate to protect a freestanding microstructure from possible damages and contaminations during wet dicing operation. Protection cap will be removed, and microstructure will be examined carefully under scanning electron microscope. Another testing would be performed by applying an electric potential between two electrodes. If there were no damage or stiction happened during dicing process, the upper electrode should be pull down by electrostatic force.

The design and physical dimensions of overlapping parallel capacitor are shown in Fig.14 and Fig.15.

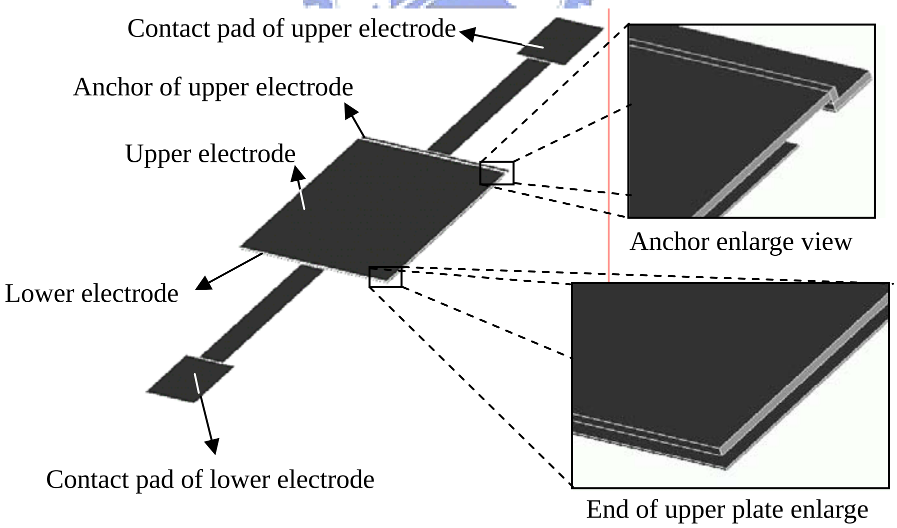


Fig.14 Design of overlapping parallel capacitor. Upper electrode is slightly over lower electrode about 5μm

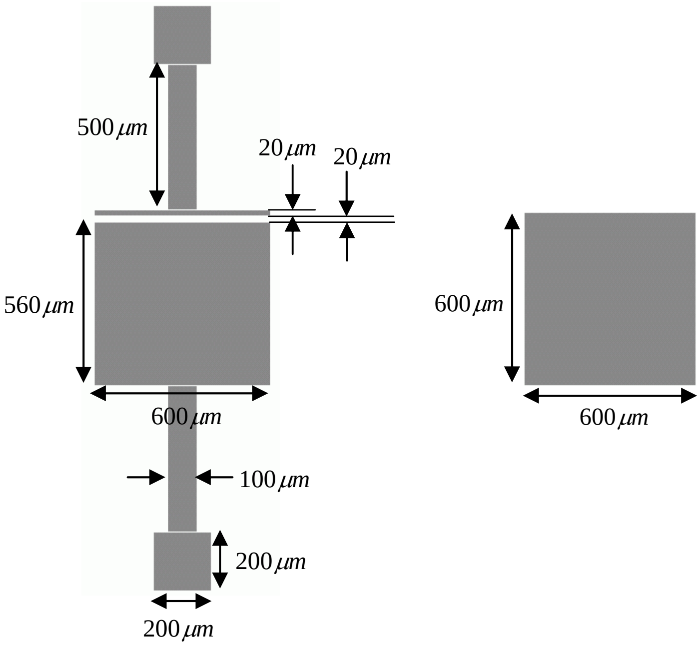


Fig.15 Physical dimensions of overlapping parallel capacitor. Lower electrode, anchor and contact pads (Left). Upper electrode (Right).

2.5 Design of Glass Cap

The design of glass protection cap includes four considerations: minimum bonding width, space for testing device and contact pads, tolerance for dicing saw adjustment in height, and compensation for isotropic wet etching.

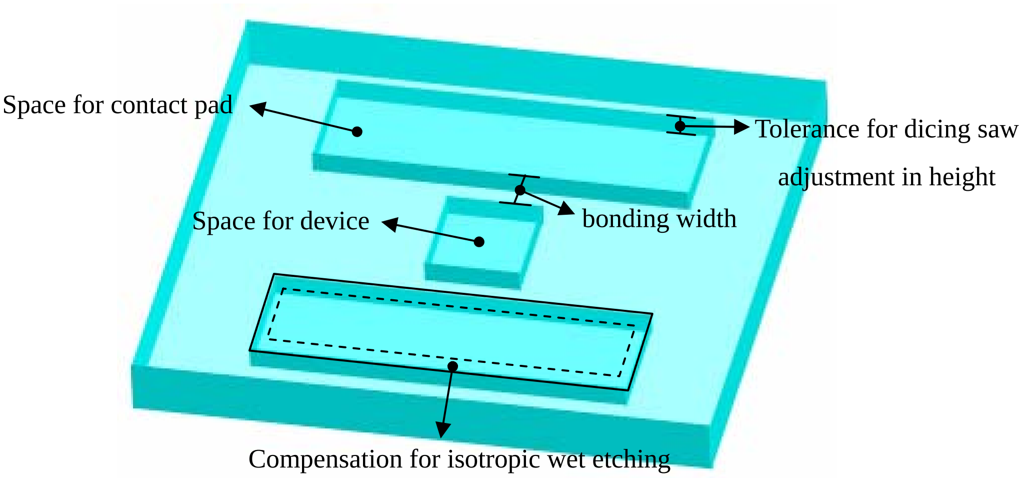
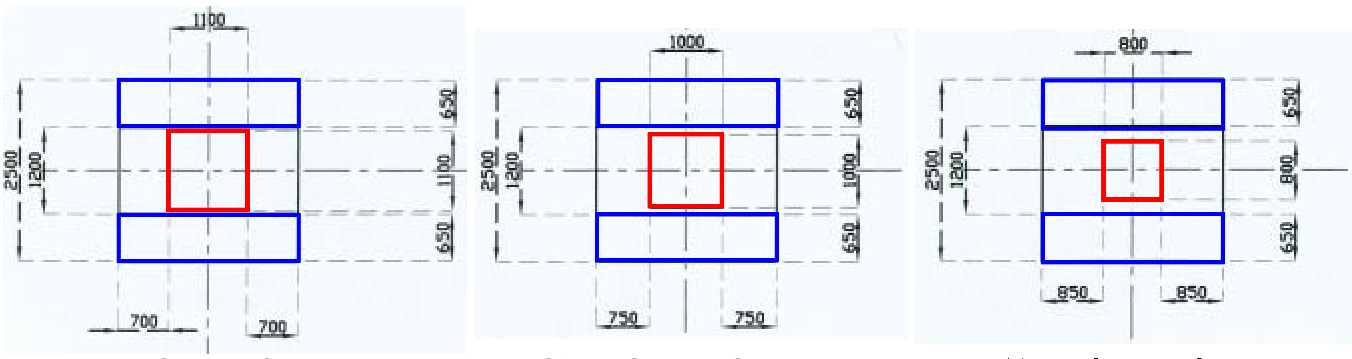


Fig.16 Glass cap design diagram

The design of different bonding widths are utilized to establish the relationship between bonding width and lifetime in accelerated testing. There are three different bonding width designs, 50μm, 100μm, and 200μm.

The square cavity on glass is utilized to provide a working space for MEMS device. Unlike solid state device, MEMS device contains moving parts and needs additional space for sensing or actuating purpose. The size of square cavity accompanies with the bonding width. As mentioned above, the major part of two different testing devices is about 600μm×600μm. Thus, the dimensions of cavities with different bonding width design are 1100μm×1100μm, 1000μm×1000μm, and 800μm×800μm with 50μm, 100μm, and 200μm, respectively. The minimum height of testing device is about 10μm, so additional height is needed to avoid UV curable adhesive enter into devices.

The cavity size for contact pad is independent from other design parameters. Larger design is preferred for complex device in the future, which needs more contact pads and interconnections.



(a) Cap design with 50μm bonding width

(b) Cap design with 100μm bonding width

(c) Cap design with 200μm bonding width

Fig.17 Three different cap designs. Square with red line is cavity for device. Rectangle with blue line is cavity for contact pad. Compensation for isotropic etching does not include

Undercut, or lateral etching, differs from the masking material, glass substrate, and composition of etchant. From one and half [12] up to eight times [13] of lateral etching has been reported. For the convenience of process, Cr/Au/Photoresist masking layer is used, four times of lateral etching is estimated and compensates in the design of dimensions.

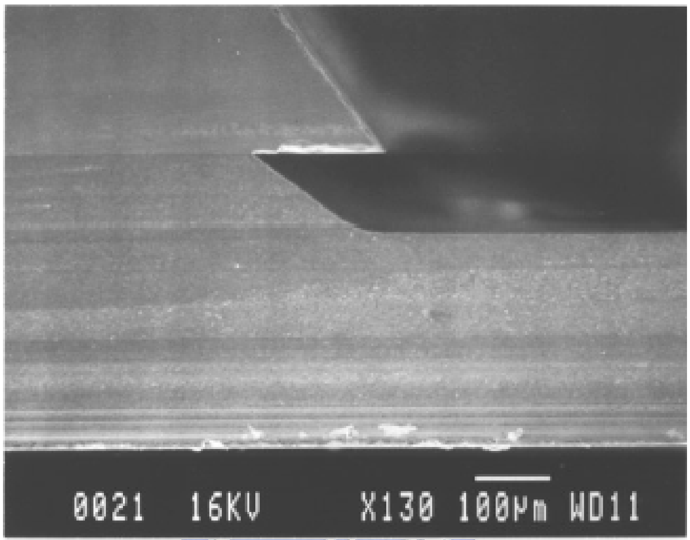


Fig.18 Undercut of glass wet etching. The masking material is single crystal silicon with anodic bonding on glass [12]

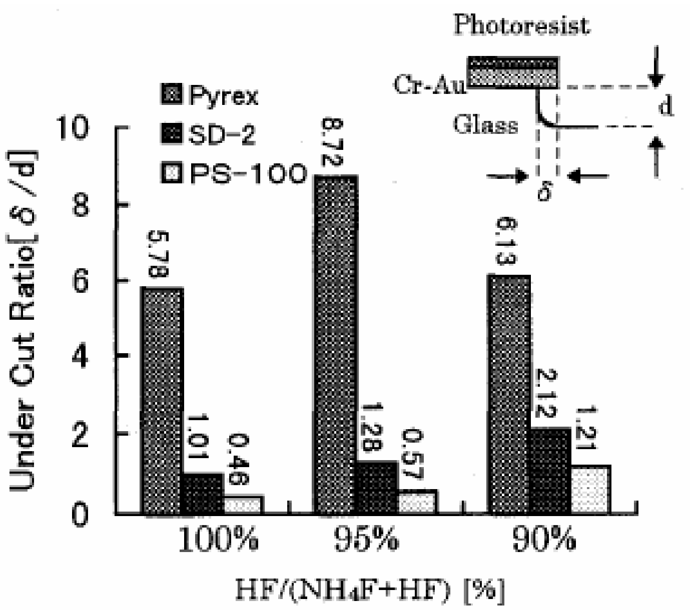


Fig.19 Undercut ratio of different glass and etchant[13]