AlO 에 의한 Glass 광학부품 Bonding
Optical components assembly by AlO bonding method

S. Potapov, Janam Ku, Eungyeoul Yoon, Donghoon Chang

MEMS Lab., Samsung Advanced Institute of Technology
P.O. Box 111, Suwon 440-600, Korea (potapov@sait.samsung.co.kr)

Abstract *Optical elements such as small glass lenses or optical fibers can be permanently bonded to substrates using Al inter-layer by applying pressure and heating. As an example aspherical lens was bonded on a silicon V-groove. The bonding has high shear strength and good thermal cycling stability.*

Introduction

There is a great need to use bonding methods which don't use adhesives in optical communication systems and in other packaging issues, because they are sources of contamination. One of the possibilities is to use metals for bonding processes.

Bonding method

The bonding of glass to metal causes many difficulties because of the differences in physical properties between these materials. Glass is disordered body, free from any internal crystalline structure. Difficulties in bonding glass to metal also arise from the low linear coefficient of thermal expansion of glass. The methods most frequently used for bonding glass to metal are fusion, soldering, glueing and diffusion bonding. There are three hypotheses to explain the bonding mechanism: chemical, mechanical, chemico-mechanical. According to chemical hypothesis, the interaction between glass and metal takes place by chemical reactions. Mass transfer encourage the formation of a transitional area and the bonded materials and the products of their chemical reactions enter into the composition of bonding area. Investigations of metal-glass bonds indicate the existence of transition layers made up of lower oxides. Both glass and metal oxides have ionic bonds. Tab.1. The mechanical hypothesis states that in bonding of metal to glass surface micro-cracks and their surrounding stress fields, originating during the processing of the glass, may become active locations of interaction. Since they are irregular defects. Fig.1. The chemico-mechanical hypothesis unite these both ideas: in the initial stage of glass-metal bonds the metal must be plastically deformed and its oxide layers broken. This enables active centers to be formed at the places where the materials contact, i.e. places at which the bonded materials can interact by chemical reactions. The reaction between the glass and the metal is of a local nature and is characterized by higher intensity in areas where defects occur on the surface of the glass. This hypothesis can be used to explain the effectiveness of joining by AlO bonding method Fig.2. AlO bonding technique was invented and patented by Coucoulas et al. at Bell Laboratories, USA. (1) This technology was elaborated as alternative joining method for opto-electronic packaging (2). We used AlO bonding technique to join glass aspheric lens to the V-groove silicon cavity and found out technological parameters and restriction of this process. Fig.3.

Experimental result

Deposition of Al film on the silicon substrate was made by DC magnetron at pressure 3.1 mTorr and discharge power 300 W. Rate of argon flow was 20 sccm. Deposition rate was 5 nm/s. Thickness of Al film was 3 or 6 μm. Optimal adhesion of Al film to silicon substrate was achieved by using adhesion Cr layer.

Microscopy examination of bonded areas showed that a failure mechanisms of the joining were different: aluminum shear , lens fracture and failure of interface joining. Dimensions of aspheric lens were: diameter 800 μm and length 1000μm, so bonding area was pretty big. It was difficult to create sufficient pressure to penetrate into the Al film. If the load was more than 3.5 kg silicon optical bench cracked. We had to use loads less than 3.5kg because of fragility of silicon optical bench. Shear strength of samples had strong dependence of thickness and properties (internal stress and structure) of Al film. In the case of 3μm's thickness of Al film shear strength was 30±7gr, and in the case of 6μm's -80±30 gr. This fact can be explained from the dependence of film hardness of thickness. Strength and hardness of thin films consist of complicated factors in a film / substrate composite. Previous studies have shown that hardness and Young's modulus of films depend on various factors such as yield stress and elastic modulus of substrate, film substrate / adhesion, film thickness, and indenter geometry. One of the most important problems is that films are constrained by the substrates, hence the properties of them depend on a penetration depth even in a depth shallower than film thickness. It is obvious if we want to reduce influence of substrate we have to increase film thickness. So our experiments showed that when thickness of Al film was greater, penetration depth was also greater. By increasing film thickness we could reduce needed load for effective AlO bonding.

All samples passed the 20 G, 20-2000Hz, 4min/cy, 4cy/axis tests and survived temperature cycling.

The main restriction of AlO joining method is application this method only to optical components with small dimensions, less than two millimeter. Also this method can't be applied for bonding optical elements with flat surfaces which supposed to be bonded. One of the ways to circumvent these restrictions is to use stripped Al inter-layer. We have found that by making strip like structure of the aluminum material on silicon, ceramic or metal it is possible to bond with them glass components of arbitrary form and dimensions. Thus even a glass plate can be bonded to silicon substrate with striped aluminum film on it by applying pressure and heat.

Conclusions

AlO bonding technique can be successfully applied for bonding optical elements with dimensions up to millimeter in lens and diameter. We determined optimal parameters for deposition Al inter-layer and critical parameters for bonding procedure. The bonding strength meet all specifications of opto-electronic packaging.

References

1 Coucoulas et al. US Patent: 5,389,193. Feb.14,1995

2 A. Coucoulas, A.M. Benzoni, M.F. Dautartas, R. Dutta, W.R. Holland, C.R. Nijander, R. Woods, "AiO bonding: A Metod of Joning Oxide Optical Components to Aluminum Coated Substrates", 43rd Electronic Components and Technology Conference, 470(1993).

Free energy of formation of metal oxides and types of reactions entered into with SiO_2

Metal	Oxide	−ΔH kJ/mole	Type of reaction
Cu	Cu_2O	159.7	
Ni	NiO	246.6	
Co	CoO	289.7	$aMeO + bSiO_2 \rightarrow cMe_xSi_yO_z$
W	WO_2	293.0	
Mo	MoO	354.0	
Fe	FeO	359.1	
Cr	Cr_2O_3	532.5	
Ti	TiO_2	703.0	
Al	Al_2O_3	840.1	$aMe + bSiO_2 \rightarrow cMe_xO_y + dSi$
Zr	Zr_2O_3	844.4	
Mg	MgO	915.4	

Tab.1.Free energy of formation of metal oxides and types of reactions entered into with SiO2.

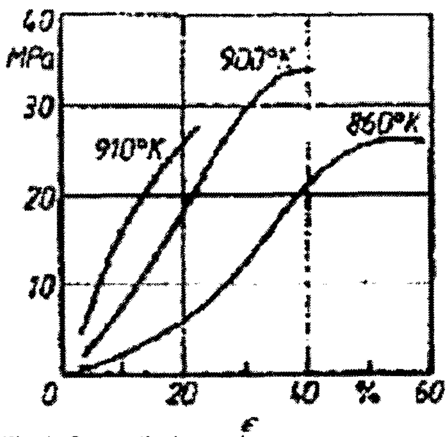

Fig.1. Strength dependence of aluminum-quartz bond on the mean percentage deformation of the Aluminum.

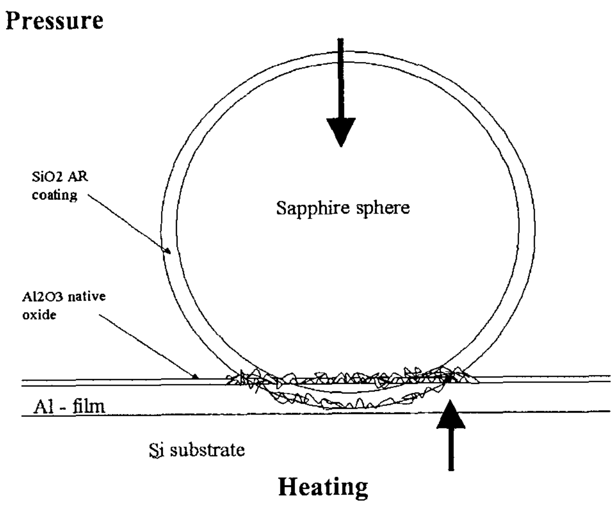

Fig.2. Sketchy presentation of the AlO bonding.

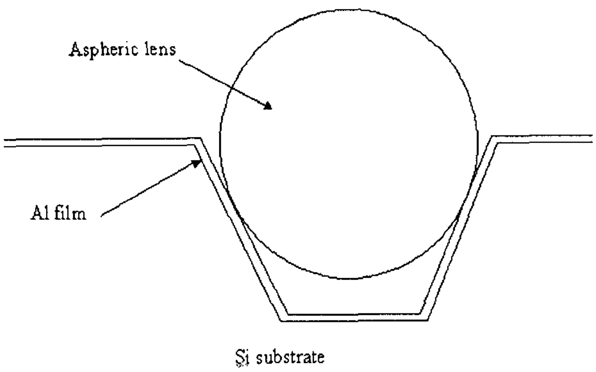

Fig.3. Cross section shows aspheric lens in the V-groove.

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