"Future Trends for Joining of Advanced Materials"

Prof. D.W. Dickinson

Comment *(Dr. J. Tanaka)*

Abstract

The necessity for advance of joining technique suitable for dissimilar metals was discussed. The trial results for joining of zirconium with austenitic stainless steel by means of diffusion bonding were presented.

As many keynote lecturers have pointed out, the industries in the coming 21st century are going to necessitate several kinds of materials having resistance against more severe environments, ie, high temperature, extra high vacuum, low temperature, severe corrosion conditions and so on.

There would be several ways to meet these requirements, ie, to find a new solid material, to produce a new composite material, to develop a new coated or surface modified material. Many efforts in line of above mentioned ways have been made nowadays and will be continuously taken in future, because this is one of the permanent subjects of materials engineers.

In actual structures, it is usual that some parts are exposed to severe environment and the rest to mild one. In this case, it will become the most important subject how to join the special material which stands against severe environment with the material suitable for mild one from the standpoint of cost performance as well as construction technique. With the increase in needs for various structures adaptable for various environment, the development of joining methods between dissimilar metals would become very momentous subject.

Even in the present technique, there are many combinations of metals to which the fusion welding can not be applied, such as Fe-Ti, Al-Fe, Zr-Fe etc, although some of them are found to be joined successfully by means of diffusion bonding process. The reason why these dissimilar joints can not be obtained with fusion welding is associated with the formation of an brittle intermetallic compounds. The successful dissimilar joints would be expected under the conditions where either no brittle compounds is formed or, if formed, its thickness is thin enough not to affect the performance.

Nowadays, several approaches have been conducted and some of them are practically applied to produce special pieces, named transition pieces. For example, friction welding is applied to make an Al-stainless steel pipe joint. In this case, a very precise control of welding time, power-input is required (by Mr. Morii et al). Electromagnetic (capacitor discharge) welding is also adopted for Al-Fe, Al-Ti, Al-Cu etc by Prof. Tamaki et al and Si/Al composite by Prof. Dickinson et al. Explosion welding is used for the production of transition pieces as well as clad steel plates. The selection of these joining processes is made based on its short welding time, resulting in the restriction of fused zone, rapid solidification and the reduction of brittle reaction layer. HIP method is also adopted for the production of transition pieces by Mr. Kuroki et al. In this case, the precise control of temperature, pressure and time enables the joining without excessive formation of brittle intermetallic compound caused by diffusion.

The case of diffusion bonding of commercial pure Zr to austenitic stainless steel is not exceptional. NKK is now advancing the experiment on diffusion bonding of the above combination without an interlayer material. The objective of this study is mainly placed on the examination of the influence of Zr's superplastic behavior caused by alternating thermal cycles including transformation temperature range (e.g. 950K-1300K) on the quality of the joint.

It is noted from the tensile test results of joints that an appropriate alternating thermal cycle leads to superior joining strength, thereby resulting in the fracture at the base metal(Zr). Accordingly, it would be suggested that Zr's superplasticity may serve to not only activate its joining surface but facilitate their adhesion at the former stage of diffusion bonding.

Based on microscopic observation of the joining interfaces, however, too many alternating thermal cycles tends to have formed a thick reaction layer, resulting in a deterioration of the joining strength. Such a fact indicates the importance of controlling the reaction layer (intermetallic compound) with respect to the improvement of joint quality.

"Soldering Microelectronic Assemblies: Some Problems and Studies"

Dr. C.J. Thwaites

Question *(Prof. I. Okamoto)*

Thank you very much for your presentation about the details of microsoldering in electronic fields.

I have two questions for your lecture. Firstly, it has been explained in your paper that the silver loaded solder namely, 62%tin-37%lead-2%silver solder reacted a similar rate with the Ag-Pd metallised layers to the eutectic tin-lead solder. This is contray to common belief. Then, I read again your paper published in "Brazing and Soldering", No. 2, Spring, 1987, page 60. This table is seen in the page.

In this table, the initial compound thickness in eutectic solder is 1.1um and for the silver loaded solder is 0.7um. The difference of both values is 30% and this percentage is comparatively large. Moreover, the same percentage is recognized also for the growth rate in the table. Therefore, the pre-added effect of silver is considered to be appreciated ovbiously from these measured values. How about my discussion?

Secondly, a thin-foil of rubber solder which contains many solder particles of very small size in a polystyrene-butadiene rubber foil is developping at a certain Company in Japan. This solder foil is researching for wireless bonding between a VLSI and an alumina substrate, applying a similar method to flip-chip bonding method. Would you please teach us about such a solder that follows solder paste being developped newly in your Institute or in Europe, if possible?

Table 1 Materials used under severe service conditions with welding technologies

Material	Severe Service Condition						Industrial Example
	Low Temp.	High Temp.	High Vac.	High Press.	High Strength	Special	
(1) HY-type Steel				◎	◎		Submarine Shell, Pressure Vessel
(2) Maraging Steel				◎	◎		Rocket Casing
(3) High Mn Steel					○	○	Non-magnetic Structure
(4) High Cr-Mo Steel						○	Reactor Tube, Chemical Vessel
(5) Ferrite/M Stainless Steel		○	○			○	Fusion Reactor Vessel, Chemical Plant
(6) Austenitic Stainless Steel	◎	○	◎			○	Low Temp., Vacuum, Chemical Plants
(7) Inver	◎						LNG Vessel Wall
(8) Ni-heat Alloy		◎				○	JT-60 Vessel Wall, Engine, Vessel
(9) Al Alloy	◎		◎			○	Low Temp. Vessel, Vacuum Vessel, Aircraft
(10) Ti Alloy				◎		○	Submarine Shell, Aircraft, Chemical Plant
(11) Ta Metal						◎	Chemical Plant
(12) Mo Metal		◎					JT-60 Wall, Furnace
(13) Ceramics		◎				○	Ultra High Temp. Material, Chemical Plant

Answer *(Dr. C.J. Thwaites)*

Thank you very much, Professor Okamoto, for your questions on my presentation. I accept that in my typescript I state that there were "no significant differences" in the initial thickness of intermetallic formed, and also in the growth rate of compound, between 63-37 solder and the 62-36-2 alloy. The values obtained were on polished microsections and 80 readings were made for every heat-treatment time and the results treated statistically. For space reasons the correlation coefficients and standard deviations were not given in the tables but were such as to reflect the extremely irregular nature of the interfaces between which measurements were being made. Therefore although the 30% difference seen was statistically correct, in my opinion, for a useful decrease in leaching or compound formation rate to be seen one would be looking for perhaps a faster of 2 difference between the two solder alloy reaction rates. Also, the problem is none readily eliminated if the metallized layers were of nickel or copper and not a precious-metal basis, and high reliability components now tend to utilize such finishes.

With regard to a foil of rubber-like material in which solder powder or particles are escapsulated, being developed in this country, I am aware of approaches such as this but do not have any details. The International Tin Research Institute is not working or such materials and I would ask in return what happens to the basis organic material at soldering temperature? Unless formulated to melt and flow away or vaporize, it must oxidize to a vicious, carbonaceous film which would interfere with wetting the substrate by the solder. Currently, there is also much work or conducting adhesives which are satisfactory for a very limited type of application but I seen so way of using them for making 1000's of joints at one as in the reflow or wave-soldering processes.

I hope that the JWRI will continue to make more valuable contributions to soldering science in the future.

Table 2 Main welding processes used

	Fusion Welding*							Pressure Welding			Brazing
	Manual (MMAW)	Sub-merged (SAW)	MIG⁺ (GMAW)	MAG⁺ (GMAW)	TIG⁺ (GTAW)	Plasma arc	Electron -Beam (EBW)	Resis-tance	Fric-tion	Explo-sion	Brazing Diffu-sion TLP Bonding
(1) HY-type	○			○	○		○				
(2) Maraging					○	○	○	○	○		○
(3) High Mn	○			○			○				
(4) High Cr-Mo	○	○		○					○		
(5) Fe/M Steel	○	○		○			○	○	○		
(6) Aust. Steel	○	○		○	○		○	○	○		○
(7) Inver					○			○			
(8) Ni-heat Alloy	○	○	○	○	○	○	○	○	○		○
(9) Al Alloy			○		○	○	○	○		○	○
(10) Ti Alloy			○		○	○	○	○	○		○
(11) Ta Metal			○		○		○	○	○	○	○
(12) Mo Metal					○		○	○	○		○
(13) Ceramics									○		○

"Progress of Diffusion Bonding of Various Materials"

Dr. E.R. Wallach

Question *(Dr. K. Ikeuchi)*

1. I am deeply impressed by your model calculation of the diffusion bonding which shows good agreement with experimental data. My first question is concerned with this model calculacion.

   You showed that the bonded area calculated by using your model was in good agreement with the experimental. My question is about the experimental method for estimating the bonded area to be compared with the calculated. I think you estimated the experimental bonded area from the fractured surface of the joint. However, you talked about several kinds of mechanical