Active Brazing of Tantalum – to – Tantalum

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Abstract

The aim of this study is to start a work about the bonding mechanism of tantalum -to- tantalum brazed by active filler metal alloy which basely stand on using copper or silver with active element such as titanium. Brazing will happen under inert gas (argon). Ag4Wt% Ti,Cu8wt %Ti , and the eutectic Ag 26wt% Cu 4 wt % Ti are the active filler metal which are used , and the bonding phases at the filler metal / tantalum interface line almost contain ($Ti Ta_2O_7$) and ($Ti_{0.51} Ta_{0.49} O_2$) . Which means that active element (titanium) shares oxygen with tantalum to make this bond as a cheap filler .

لحام المونـة الفعال للتتاليوم

المستخلص

ان هدف هذه الدراسة هو البدء في معرفة الية الربط لوصلة لحام التنتاليوم باستخدام سبيكة المونـة الفعالـة والتـي تعتمد علـى عناصر مثل النحاس ، الفضة والعنصر الفعال (التيتانيوم) . يجري اللحام بالمونـة فـي ظـروف خاملـة باستخدام غـاز الاركـون . المونة المستخدمة هي الفضة مع نسبة وزنية 4% من التيتانيوم ، النحاس مع نسبة وزنيـة 8 % مـن التيتـانيوم ، وايوتكتك الفضـة والنحاس (Ag 26wt% Cu 4 wt % Ti) مع نسبة وزنية للتيتـانيوم 4 % ، امـا طـور الربط فقد وجد بأنـه دائمـا يكـون علـى شـكل ($Ti Ta_2 O_7$) أو ($Ti_{0.51} Ta_{0.49} O_2$) حيث ان التيتـانيوم يتقاسم ارتباطـه مـع التنتـاليوم مـع الاوكسـجين . وفـي النـهاية فأن هذه الوصلة تعتبر قليلة الكلفة .

1. Introduction

From literature survey between 1960 to 1997 as shown in Table (1) [1 – 6] it was pointed that , refractory metals didn't have the data base that exists in the literature . Because of specific details on brazing equipment , such as vacuum levels , type of vacuum equipment , quality of inert gases and heat brazing cycles are not reported in most of the development work on the refractory metals [5] . Tantalum can be brazed with nickel-base filler metals , such as (Ni-Cr-Si) alloys . However , tantalum and nickel form brittle intermetallic compounds , such as (Ni_2Ta) in brazed joint [1 , 2 , 3] . In 1985 F.M Hosking studied sodium compatibility of refractory metal alloys – to – A ISI 304L stainless steel joint [7] . He brazed (Mo , Re , Ta , and W) alloy to AISI 304L stainless steel with nickel base filler metal in two forms (metallic glass and powder) by vacuum furnace . Silver – copper filler metals can produce joints with useful strength at room temperature [8] . The active-metal modifications (Ti additions) to (Ag – Cu) and (Au – Ni) alloys may be useful for tantalum joining particularly if residual oxide on the surface presents a wetting problem [5] .

Ta – V – Ti and Ta – V – Cb alloys given in Table (2) [3] , may be suitable for certain high temperature applications . Brazing should be done in vaccum of 10^{-4} torr or better , but there is affinity to vaporize titanium and vanadium from molten filler metal during the brazing cycle because of their high vapor pressure [3] . Also pure titanium and titanium alloys might be suitable for brazing tantalum . 1n 1977 , Scientific Oak Ridge National Laboratory (ORNL) has been instrumental in the development of brazing filler metals for applications at temperature above (1000 ˚C) [6] . The filler metals and brazing temperatures employed in the development of these alloys are presented in Table (3) [6] . They used tantalum as refractory , aluminum oxide samples as ceramic were bonded with vacuum of 10^{-6} torr . The excellent flowability of these alloys on tantalum was recorded . The aim of this study is to recognize the Ta – to – Ta joint characteristics by usual brazing filler containing titanium depending on optical micros copying (OM) , and X-ray diffraction (XRD) testing .

Table (1). Filler metals used in tantalum brazing between 1960 to 1997[1-6].

Filler Metal	Service Temperature (°C)	The References
Nickel – Base		
Ni-Cr-Si alloys	981 ≥	[1,2,3]
Copper –Base		
Cu-Au	Low Temperature	[4,1,2,3]
Cu-Sn	Not Specified	[3]
Cu-Ti	Not Specified	[3]
Silver –Base		
Ag-Cu	Room Temperature	[3]
Ag-Cu-Ti	Not Specified	[5]
Gold –Base		
Au-Ni	Low Temperature	[5,1]
Au-Ni-Ti	Not Specified	[5]
Au-Cu	Low Temperature	[5,1]
Tantalum –Base		
Ta-V-Ti	1482 ≥	[5,3]
Ta-V-Nb	1482 ≥	[5,3]
Titanium-Base		
Pure Ti	Not Specified	[2]
Ti-Cr	1927 ≥	[3]
Ti-V	Not Specified	[5]
Ti-V-Be	1927 ≥	[3]
Ti-Zr-Be	Not Specified	[2]
Ti-V-Cr	1000 <	[6]
Ti-Zr-Ge	1000 <	[6]
Ti-Zr-Ta	1000 <	[6]
Ti-Zr-Nb	1000 <	[6]
Ti-Zr-Cr	1000 <	[6]
Ti-Zr-B	1000 <	[6]
Ti-V –Nb	1000 <	[6]
Ti- V-Mo	1000 <	[6]
8-Platinum-Base		
Pure platinum	Not Specified	[2]
Pt-Ir	Not Specified	[2]
Pt-Rh	Not Specified	[2]
9-Zirconium-Base		
Zr-Nb-Be	Not Specified	[2]
Zr-Ti-V	Not Specified	[5]
10-Palladium-base		
Pure Palladium	Not Specified	[2]

Table (2). Typical brazing filler metal for tantalum alloys for service temperature up to 1482c^o [3].

Filler metal composition weight percent	Temperature (°C)	
	Brazing	Remelt
10Ta-40V-50Ti	1760	2381.10
20-Ta-50V-30Ti	1760	2381.10
25Ta-55V-20Ti	1825.5	2204.40
30Ta-65V-5Ti	1825.5	2381.10
5Ta-65V-30Nb	1815.6	2281.11
25Ta-50V-25Nb	1871.1	2481.90
30Ta-65Vv-5Nb	1871.1	2281.11
30Ta-40V-30Nb	1926.7	1981.90

Table (3) .Ternary system in which filler metal have been developed and their recommended applications [6].

Filler Metal System	Approximate Brazing Temperature (°C)	Materials		
		Refractory metals	Graphite	Al_2O_3
Ti-V-Cr	1550-1650	X (a)	X	X
Ti-Zr-Ta	1650-2100	X	X	-
Ti-Zr-Ge	1300-1600	X	X	-
Ti-Zr-Nb	1600-1700	X	X	-
Ti-Zr-Cr	1250-1450	X	- (b)	-
Ti-Zr-B	1400-1600	X	-	-
Ti-V-Nb	1650	X	-	-
Ti-V-Mo	1650	X	-	-

(a) (X) =Applicable for joining .
(b) (-) = Not applicable for joining .

2. Experimental Work

A 0.15 mm sheet thickness of pure tantalum manufactured by Pansee Metalwork Gmblt was used as a base metal in this work . High purity powders of copper , silver , and titanium metals were used to prepare the active paste filler metal alloy . The paste prepared by manual mixing

(for one minute) , the suitable mass of filler with about (0.5 mm^3) of glycerin and (1 mm^3) of alcohol ethanel to form the paste , which is suitable for one butt joint assembly . The suitable gap size is about 0.1 mm , and the overall mass is about 0.6 gram , which was used for all testing samples . The dimension of tantalum samples are 25 x 25 x 0.15 mm . More than nine tantalum to tantalum butt joint assembly were used , the joining process done by three fillers , metal alloy types ; Ag4wt%Ti (Ag4Ti) , Cu 8 wt%Ti (Cu 8Ti) , and eutectic Ag 26 wt%Cu4wt% Ti . (AgCuTi) . For each filler, three joint assembles were carried out , one joint for microstructure testing , and the others for X-ray diffraction testing . Furnace brazing with argon , as a protection gas used to complete the brazing process . A muffle furnace type with a controlled-argon-atmosphere is prepared with gas flow rate of about 1-3 L/min in a stainless steel retort . The brazing temperatures are , 950 ˚C , 1050 , and 1100 ˚C for the fillers AgCuTi , Ag4Ti , and Cu8Ti respectively . The holding time at brazing temperature is about five minutes . Grinding and polishing processes were carried out to prepare the microstructure testing samples , while the broken samples at the bonding interface will be used for XRD testing after grinding process to the two broken sides , to be examined by Philips-PW1840 X-ray diffractometer . The X-ray tube target was copper (λ for Cukα = 1.5405 A˚) , the filter is nickel . The 20 ranges taken was from 10˚– 90˚, in the speed of 3 degree/min . Identification of phases was based on matching with powder diffraction files (JCPDS) [9] . The welded samples are fixed by simple two plates of molybdenum (50 x 50 x 0.25 mm) with two screws to maintain the joint in proper dimensions .

3. Results and discussion

Optical micrographs for a cross section brazed by Ag4Ti filler metals in Figure (1) show mutual dissolution of tantalum and filler metal in a wave form . This may be explained by the solubility of B-Ti in tantalum [9] . Closer scrutiny revealed formation of a distinct layer adjacent to the base metal and migration of separated particles from this layer to central region of filler metal as in Figure (2) . This morphology may represent the aggression and disruption of the bonding layer by active filler metal . Also dark points were observed in the braze joint , this may refer to the titanium oxide formation duo to the bonding mechanism by active filler metal alloy [10,11] .

The XRD results for Ta to Ta assemblies brazed by Ag4Ti as in Figure (3) show that ; the bonding phases are ($Ti\ Ta_2\ O_7$) and ($Ti_{0.51}\ Ta_{0.49}\ O_2$) , which refer to the oxide layer at the surface of tantalum , and the bond created by the action of tantalum sharing its passivity oxide film before combined with titanium [12] . The presence of Ag and Ti phases referes to (Ta-Ti) solid solution . While the separated phases of Ti and Ta refer to the limited solubility of Tantalum in B-Ti and tend to formation of intermelallic phases .

The brazing of Ta to Ta with silver – 4wt% Ti filler metal alloy results in an improved joining with low cost as compared with that brazed by expensive filler metal as in Tables 2 and 3 and part of Table (1) .

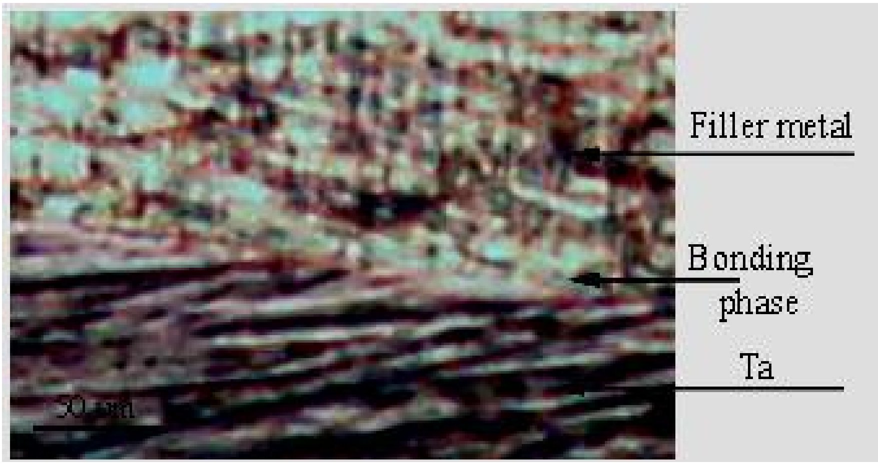

Figure (1) .Optical micrograph for (Ta – to – Ta) assembly brazed by Ag4Ti filler metal .

Figure (4) shows the optical micrographs for Ta – to Ta joint which was brazed by Cu 8 Ti , in which a mutual dissolution of tantalum and active filler metal was remarked as a waved interface like what was happened with the joint by Ag 4 Ti . However the bonding mechanism completed by the existing of Ti Ta_2 O_7 phase only as shown in Figure (5) .

Using of eutectic AgCuTi filler metal alloy to braze Ta – to – Ta joint results in a good joining . Optical micrographs for AgCuTi filler / tantalum interface as in Figure (6) , shows a formation of a distinct layer adjacent to base metal . This layer has expanses in roots form , were expanded in eutectic braze metal as in figure 6 – a . This may refer to the formation of more than one bonding phase . The closer scruting of interface line shows separation part of roots and many particles from bonding phase . This morphology may represent the dissolution or erosion of tantalum by active filler . The XRD chart for this joint Figure(7) shows that the bonding phases are ; Ti Ta2 O7 , $Ti_{0.51}$ $Ta_{0.4}$, O_2 , Ti Ta_{13} O_{47} , and Ti O phase . The last phase explains the good bonding structure which means that the active element (titanium) forms a good bonding layer [11] .

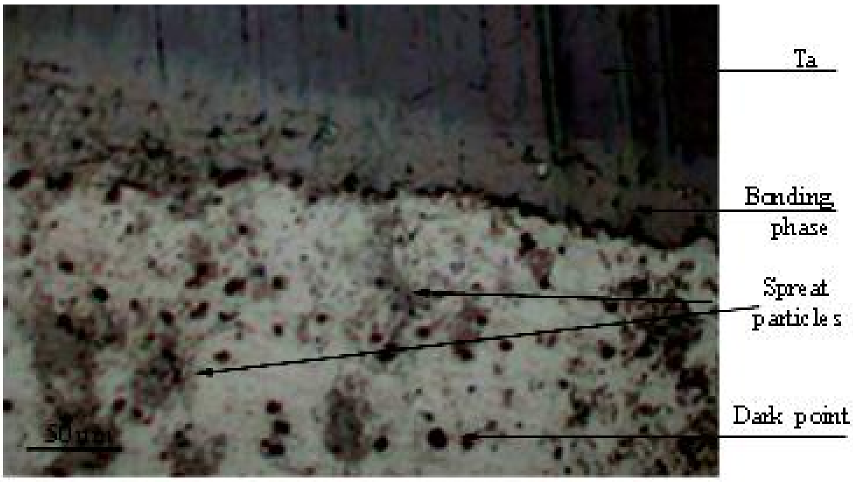

Figure (2) . (Ta – to - Ta) assembly brazed by Ag4Ti filler metal .

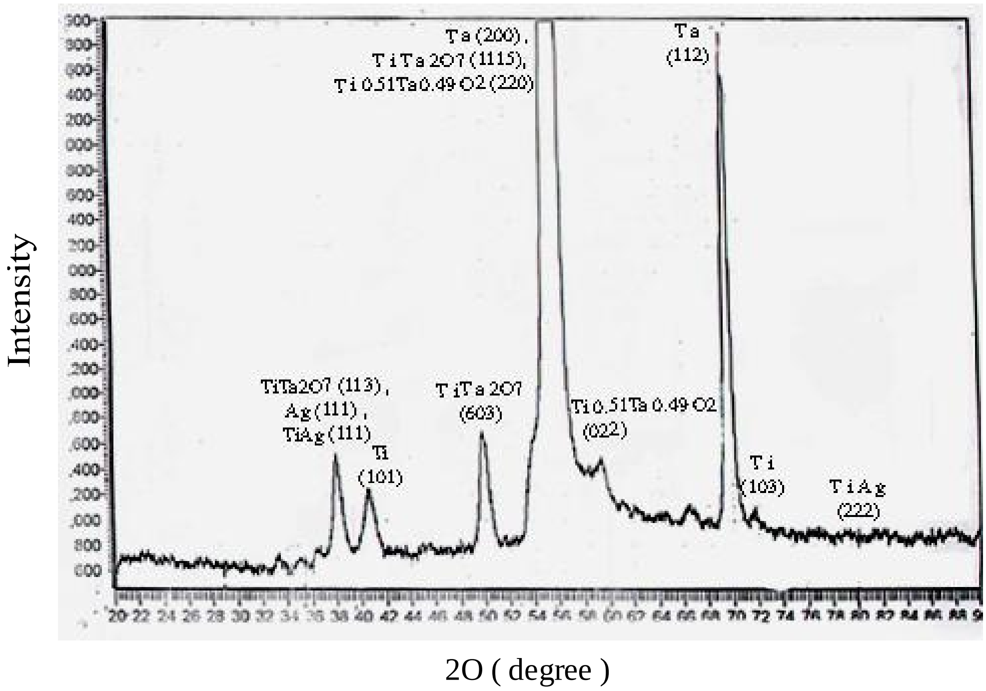

Figure (3) . X-ray diffraction chart for (Ta – to – Ta) assembly brazed by Ag4Ti filler metal .

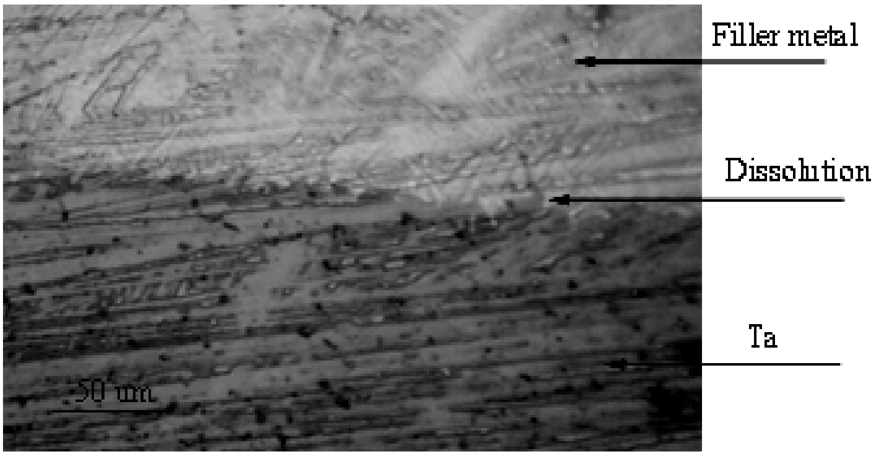

Figure (4). Interface of (Ta –Ta) assembly brazed by Cu^Ti filler metal.

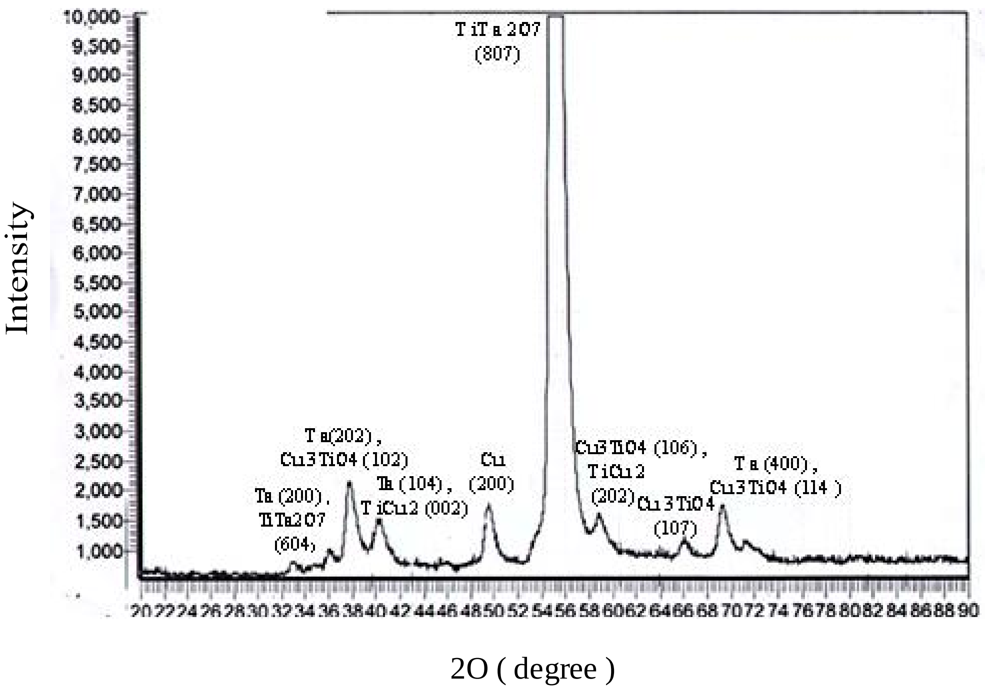

Figure (5) . X- ray diffraction chart of (Ta – to – Ta) assembly brazed by Cu8Ti filler metal.

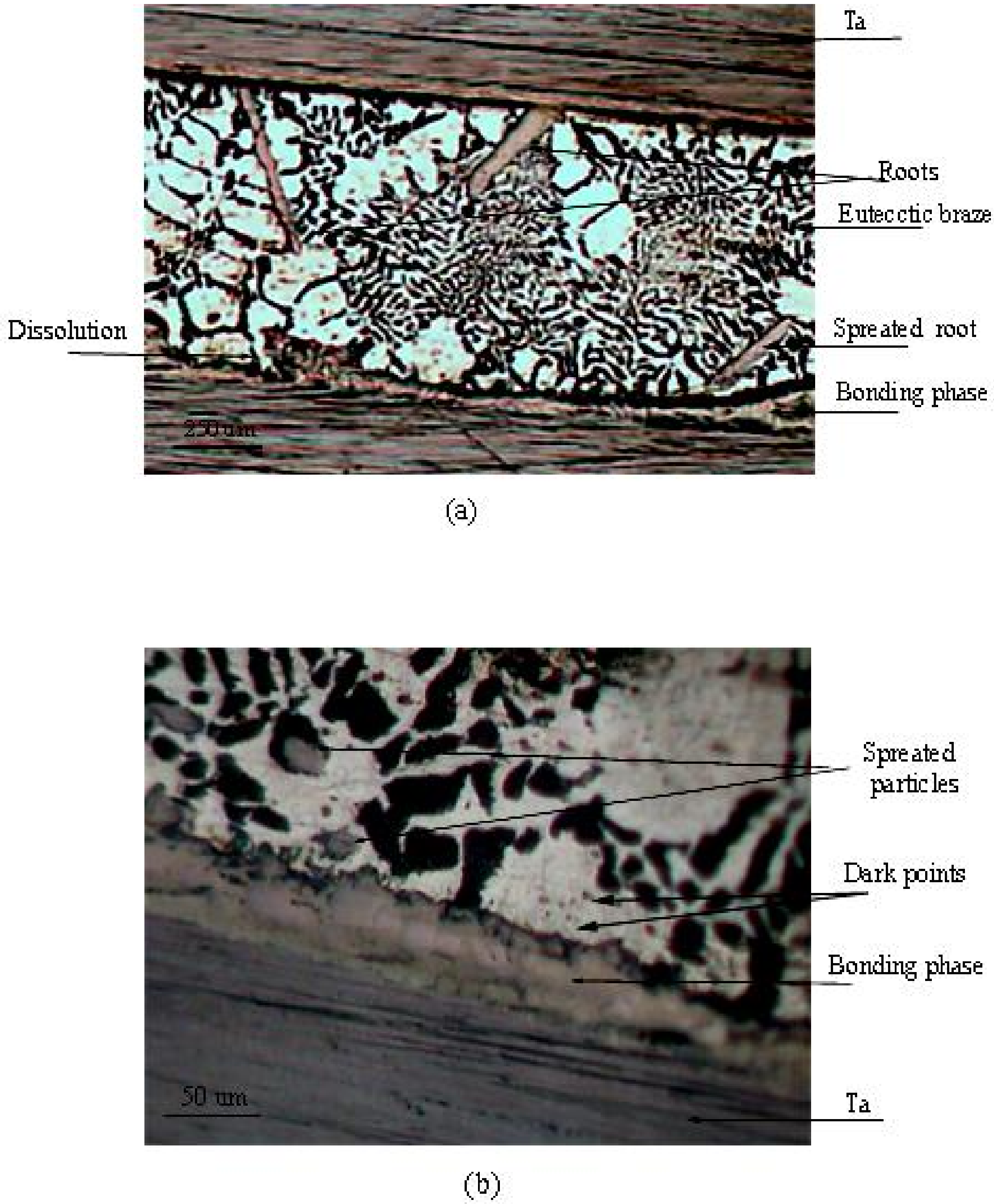

Figure (6). (a and b) Represents optical micrographs for (Ta – to – Ta) assembly brazed by eutectic AgCuTi filler metal .

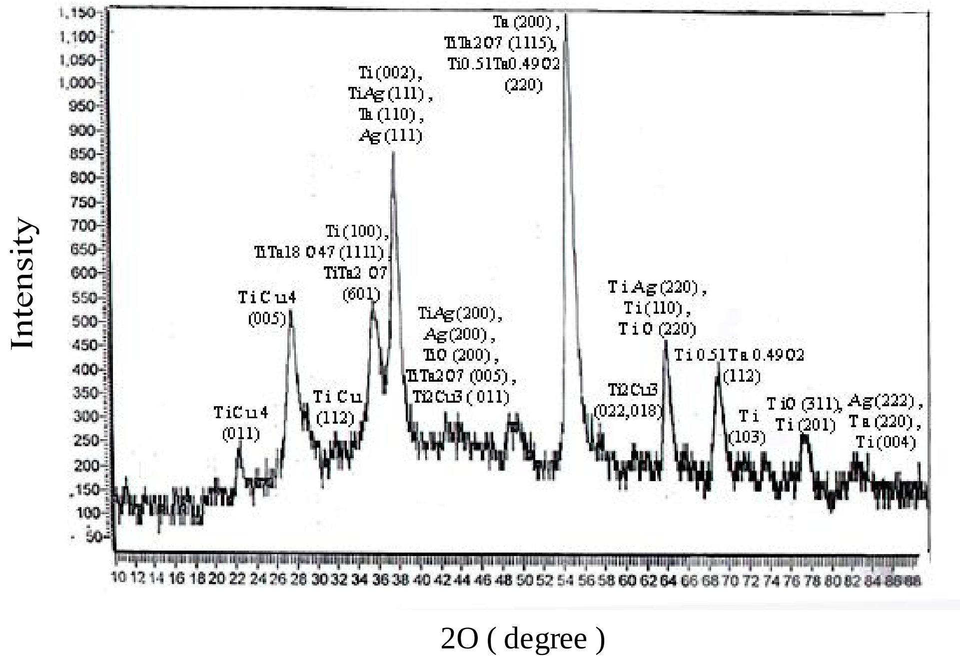

Figure (7) . X- ray diffraction chart for (Ta – to – Ta) assembly brazed by eutectic AgCuTi filler metal .

4. Conclusions

1. The Tantalum to tantalum brazed assembly by Ag4Ti exhibits good joining with aggression of tantalum and dark point were observed in brazed region .
2. The Tantalum to tantalum brazed assembly by Cu8Ti exhibits additional improvement in joining with low cost as compounded with high active filer metal alloy .
3. The bonding phases in most assemblies brazed by CuTi , AgTi and AgCuTi filler metal are $TiTa_2O_7$ and Ti0.51 $Ta_{0.49}O_2$ with good interface bonding layer with TiO for using autectic filler metal alloy .

5. References

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