出國報告（出國類別：出席國際會議）

第 12 屆材料物理國際研討會

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摘　要

本報告旨在針對出席由查理大學材料物理系和捷克共和國的金屬科學協會所主辦的第十二屆材料物理國際研討會，此會議從1972年起至今已經邁入第十二屆，依照參加此會議經過、討論心得與建議等事項說明其內容。本報告除了將參加會議行程與時間做一交代， 並且在參加不同主題討論會時之現場狀況，也依論文逐篇說明以增加臨場感。整體言之，此次會議在捷克首都布拉格的查理大學材料物理系之古老建築內舉辦，但此建築內有先進會議中心。本會議參與國家超過三十幾個國家，人數超過二百多人以上，研究主題相熱烈。尤其，邀請演講內容相當有深度及各場發表內容相當前瞻性，而且攜回資料相當具有參考價值，對參加者而言應不虛此行，值得未來再參加相關之國際會議。許多文章發表後直接收錄於國際著名SCI期刊Acta Physica Polonica A，本人發表文章也直接被接受發表於此期刊內。最後本報告附上參加會議照片與發表論文被收錄之全文， 以增加報告內容之充實度。

目次

(一)、參加會議目的與經過

本次國際會議是由捷克首都布拉格的查理大學材料物理系(Department of Physics of Materials, Charles University Prague) 所主辦。在該系之古老建築物內舉辦，此建築內包含先進國際會議中心、表演廳及餐廳，顯示此建築設計相當有遠見，合於未來趨勢。此國際會議從1972年舉辦第一屆金屬和合金可塑性國際研討會後，一直與捷克共和國的金屬科學協會（Metals Science Society of Czech Republic）定期舉辦材料物理國際研討會（International symposium on physics of materials，ISPMA)。今年邁入第12屆材料物理國際會議，會議時間是從2011年9月4日至9月8日，總共5天的時間。會議主題是集中在合金、金屬間化合物、非金屬材料、複合材料、納米材料及材料科學會議。整體會議所探討的材料物理主題很廣泛，只要跟材料物理學的基礎研究和應用方面等有關的如鋁合金、鎂合金、鈦合金、電子材料、能源及生醫用等，都是其所涵蓋範圍，本人所要發表的「Electrochemical behavior of Ti-7Cu alloys for medical applications,」論文也是其中之一環，可藉由各種領域之物理基礎觀點，進一步提昇學術素養交流。

依據維基百科資料，捷克共和國是位於歐洲核心地帶的捷克為一中歐內陸國，其四個鄰國分別為北方的波蘭，西北方的德國，南方的奧地利，與東南方的斯洛伐克 (1993年從捷克分離、獨立國家)。首都與最大城市為布拉格，跨伏爾塔瓦河兩岸，風景秀麗。布拉格是一座歐洲歷史名城。城堡始建於公元9世紀，在查理四世統治時期(345—1378年)，布拉格成為神聖羅馬帝國兼波希米亞王國的京城，而達到鼎盛時期，並興建了中歐、北歐和東歐第一所大學—查理大學（1348年成立)，本次會議為查理大學材料物理系所承辦。本人從台北搭乘華航的飛機，出發先到奧地利首都維也納，再進行相關事務後，再轉火車進入捷克布拉格，可說路途遙遠耗時費力，總算順利抵達目的地-布拉格火車站，此火車站相當現代化、人性化，處處以觀光客考慮，簡單詢問服務人員後，搭地鐵入住旅館。經過火車旅程勞累，適當休息後。依照會議通知下午進行報到及參與晚上歡迎會，然而，依照地圖之路示，走路到查理大學材料物理系之古老建築物的四周圍。誰知當天下午下雨，該會議將重要指標移入室內，促使外面完全沒有任何標示，而且當地人士大部分是觀光客，且英文能力有限，難以溝通問出所以然，何況該大學各學院分佈於整個布拉格分有好幾個校區， 也不知哪一個才正確?最後遇見參與

德國Wollmann教授也再找進入入口，兩人一起邊走邊找，終於找到此巨大古老建築物之會議入口。顯然地，東歐國外舉辦相關國際會議形式與台灣相當不同，不會注重會議旗子、指標等，而是注重歡迎人文氣息，如歡迎會、音樂會等，且在捷克查理大學之最古老音樂廳，也捷克最老音樂廳進行相見歡。這也許這是歐洲辦事的風格，但比起台灣舉辦類似的活動而言，好像在場面上表現是有些落後的感覺，但在人文氣息優於東方國家。

(二)、與會心得

這屆材料物理國際會議議程於9月4日下午報到， 這時在查理大學材料物理系之古老建築看到幾張小小的會議標示，隨即依照箭頭指標找到2F以上等國際會議廳及相關報到場地，並完成報到手續， 也領了議程表及論文集等資料，就此等待晚上相見歡活動的來臨。但據大會估計應該會有200人到場參加，後續進入相見歡活動音樂會，約有200-300人參與此活動，可算是具有規模的相見歡活動。9月5日開幕式大致按照節目時間表進行， 首先由司儀亦即本國際會議（International committee）主席F. Chmelík (Czech Republic)介紹貴賓，最主要是來自主辦單位的主席Prof. P. Málek，以及來自20個以上之各國際會議委員，並說明此會議宗旨、相關事務，表達交代與感謝合作團隊之努力，並提到發表之優秀論文，是經過相關國際委員審查後，將收錄於國際著名SCI期刊 Acta Physica Polonica A，這次國際會議所接受的論文，總共接受論文篇數應超過150 篇以上。即完成了開幕典禮，並隨即進入專題演講的部分。首先第一場專題演講瑞士 Kostorz G. 深入演說「Microstructure and the hardening of materials材料硬化過程與微結構關係」，可說是材料界經典研究，給於個人研究具有許多期許。後續進行各場次專題研講及論文發表，此次會議之專題演講安排的場次特別多，並且安排於各論文發表之前、中。第一天就有四場，其依時間先後分別是由來自澳洲 Deakin大學的的Prof. Siska F，他演講的主題是「Finite element modelling of stress/strain fields around twins 」。他從利用有限元素來分析雙晶周圍之應力/應變的關係，精要簡出之介紹材料科學雙晶現象，啟發聽者的新模擬觀念。

第二場邀請演講是Prof. Dobatkin S.V.演講，來自俄羅斯之冶金與材料研究中心， 主題

是「Structure and properties of ultrafine-grained SPD aluminum alloys and possibilities of its applications」， 這跟本人過去研究極細晶粒之鋅鋁合金進行超塑性加工相關研究與應用有關係，也瞭傑俄羅斯在塑性加工發展相當先進。當然，再各演講場次中有許多鋁合金、鎂合金及鈦合金之極細晶粒超塑性加工研究，很快就到了中午用餐時間及休息時間,大家到地下室餐廳用捷克風味餐點及互動聯誼, 筆者認識了與會幾個學者專家,包括本地主辦大學的教授Prof. P. Málek與來自德國的斯圖加特大學 Schaefer，談起筆者博士後研究之德國研究所相關研究發展事務。第三場主講德國斯圖加特大學(Stuttgart University) 的Prof.Schaefer H.-E. 主講， 主題是「 Vacancies and atomic processes in intermetallics - from crystals to quasicrystals and bulk metallic glasses」， 此教授服務單位正好與本人過去到德國斯圖加特大學進行博士後研究同單位，且演講內容與本人有近期研究內容有相關。後續聆聽筆者近期所發表之鎂合金相關塑性加工SCI論文之相關場次，如：「Vrátná J., Janeček M., Stráský J., Kim H.S., Yoon E.-Y., The influence of high pressure torsion on microstructural inhomogenities in AZ31 alloy」, 以及「Ryspaev T., Janeček M., Wesling V., Wagner L.Thermal stability of fine grain structure in friction stir welded magnesium alloys」, 其實從筆者的經驗看起來，這些論文並少有新的創新性，但使用設備相當新且工業化，這是台灣少見研究方式。

根據會議第二天(9月6日)的議程資料，最主要的重點還是去參加專題演講。隨雖然各專題場次安排於各發表場次之內，但主辦刻意保時間避開，讓有興趣人員能完全領聽專題演講，今天的主題演講也有五場， 包括:

(1) Janeček M., Complex investigation of physical properties of ultrafine-grained materials processed by severe plastic deformation

(2) Vitek V, γ-Surfaces an indispensable tool for determination of fundamental characteristics of individual dislocations and basic aspects of deformation behaviour in crystalline materials.

(3) Goodall R., Despois J.-F., Diologent F., Mortensen A., Plasticity size effects in microcellular aluminium

(4) Wagner L., Wollmann M., Sin H., Janeček M., Effects of bulk and surface severe

plastic deformations on fatigue performance of cp-Cu

(5) Groma I., Ispánovity P.D., Plastic deformation of submicron sized specimens.

這五場場專題演講主題，主要演講近似奈米尺寸晶粒對材料物理特性，這與筆者感興趣的議題，並說明大型自動化多道次塑性加工機器，如何使金屬材料達到細化，這與台灣所採用實驗級研究設備具有許多差別。另外，這些教授演講內容從基礎學理、技術應用及產品開發一系列研發，才能建立材料工業紮實。這C場討論會的發表論文中，大部分是針對稀土之介金屬化合物的研究，如捷克查理大學Kopecek J.及阿爾及利亞Sekkal A.等深入研究稀土材料物理特性、電磁特性等，相當特別研究。尤其，鑭稀土介金屬在室溫情形下，其延伸率可高達21%，此現象與過去一般金屬之介金屬化合物是不同。

根據會議第三天(9月7日)的議程資料，最主要的重點還是去參加專題演講。今天的主題演講在A場次（鎂合金材料）也有三場， 包括:

(1)「Wrought magnesium materials: State-of the-art and what´s the future?」

by Prof. Kainer K.U.， Mg Innovation Centre. Germany.

(2)「Plastic anisotropy and deformation twinning in magnesium alloys」by Prof. Koike J., University ofTohoku,Japan.

(3)「Investigation of tension-compression asymmetry of magnesium by use of the acoustic emission technique 」by Prof. Máthis K.

, University Charles,Czech Republic.

這三場專題演講主題，與筆者研究有高度相關性且很感興趣的鎂合金議題，其中第一場次是德國鎂合金中心 Prof.Kainer K.U.,他是國際鎂合金首席，也是歷屆鎂合金國際會議的主席，筆者2009年參與德國第八屆鎂合金及應用國際會議也是主席（每四年一次），深入淺出說明鎂合金對未來電動車的影響及其他應用。由來自日本東北大學(Tohoku University) 的教授Koike J博士演講內容，鎂合金之雙晶變形及非等相塑性內容，基礎鎂合金物理現象相當深入，但英文表達稍嫌不順暢，但日本學者的研究內容較紮實。在Q&A過程中，聽眾問起日

本福島大地震距位於仙台的東北大學的影響如何？難於形容的殘！另外，捷克化學科技研究中心的Kubásek J. 博士，針對鎂合金在生醫的應用，並且說明稀土加入鎂合金中能有改善組織且能用於植入式生醫材料。但其他論文發表主講者列出研究內容創新缺乏，但基礎材料物理理論較深入。這一天另外的重點就是晚上7:00 的晚宴， 這是讓參加與會者彼此交誼最好的時機， 是屬於自助餐形式的聚會。大家在用餐交談中， 主辦單位逐一介紹會議的相關重要人物， 並透過簡單致詞感謝他們的辛勞， 大家報以熱烈掌聲。

根據會議第四天(9月8日)的議程資料，最主要的重點是筆者論文發表及其他論文發表者聆聽，發表內容是將最新開發成功生醫用三元鈦合金(專利申請中)之對照組Ti-7Cu母合金電化學行為在生醫應用，並且鑄造及熱處理後之顯微組織、機械特性及人工液體之電化學行為。另外，聆聽其他查理大學Jana發表Ti-6.8Mo-4.5Fe-1.5Al鈦合金在時效過程中相析出與成長，以及大陸華中大學之Wang. A.H 論文發表，利用雷射方法將Ti/Ti5Si3塗佈於Ti-6Al-4V材料表面，使Ti-6Al-4V具有好的特性，且具有好的生物相容性。本次會議在今日中午後正式結束。回國後，經國際委員審查建議，將題目「Electrochemical behavior of Ti-7Cu alloys for medical applications」增加「Base」成為「「Base electrochemical behavior of Ti-7Cu alloys for medical applications」，並收錄於國際著名SCI期刊Acta Physica Polonica A 。

(三)、建議

過去大部分國內出席國際會議者，大都傾向前往先進國家、交通方便或文化形式相近的國家，如先進國家西歐、美加、與紐澳， 或者文化相近之大陸、日及韓，在語言溝通或交通便利相對容易，參與人員相對多，其發表論文必須有創新性或非常突出，將難於顯得突出。此次國際會議由捷克共和國查理大學材料物理系所主辦，顯示該會議相當注重基礎理論研究及工業化實務，與台灣研究思維有所不同， 這或許是東歐捷克從1993年後從共產國家轉變開放，一直保有紮實風範。許多值得我們學習，鼓勵相關研究人員能走出見識，來增加新思維和寬度，已增加未來研究也會有所幫助。建議國內如有舉辦國際會議時，應該多多主動連絡這些東歐國家學術人員，並補助交通、住宿等費用，以增加對方來台參加國際會議之意願，

讓貴客能瞭解台灣發展及國際會議交流， 方可累增正面之意義。

另外，對於國內相關單位，如學校、國科會、或是其他單位，對於出國參加國際會議之經費補助，往往不補助或僅是部分補助，且規定嚴苛，或無法從其他計畫經費流用或報銷，以造成想出席開會者另一項負擔，導致學術交流一大障礙，建議可以全額補助方式，將可減輕個人負擔，增加以後台灣能見度及學術交流之原動力。

(四)、攜回資料

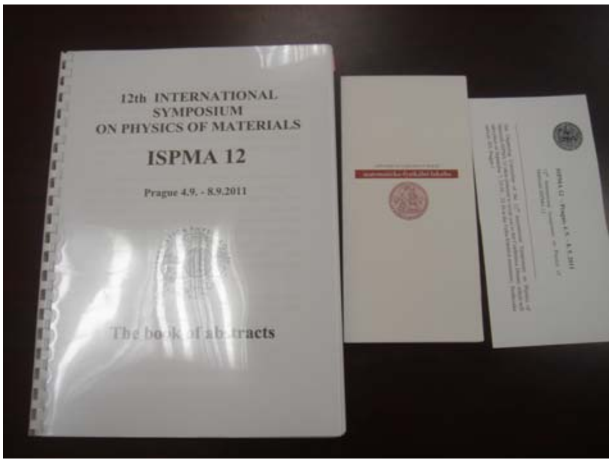
本次會議將優秀發表論文，經過國際委員審查後，將收錄於國際著名SCI期刊Acta Physica Polonica A，本人發表文章也直接被接受發表於此期刊內。攜回會議資料有論文摘要集一本，及參與活動相關照片。

附照

入口處

論文發表

壁報交流



論文集

此國際會議發表論文已收錄於SCI期刊Acta Physica Polonica A

Basic electrochemical behavior of Ti-7Cu alloys for medical applications

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Abstract

The aim of this study was to investigate the effects of two different treatments, as-cast set-up and solution heat treatment, on the general electrochemical corrosion resistance of Ti-7Cu alloy samples immersed in a 0.9wt.% NaCl solution at 25 °C. The microstructure was examined by scanning electron microscopy (SEM) and X-ray diffractometry (XRD). Corrosion behavior was tested by potentiodynamic polarization curves. Finer α' martensite and Ti_2Cu intermetallic particles provided by casting and heat treated processes, respectively. The results indicated that only corrosion potential is significantly more noble in the heat treated sample, but other characteristics are only slightly different.

PACS: 68.35.bd, 68.37.HK, 65.40.gk, 81.40.Cd

1. Introduction

Titanium (Ti) and its alloys possess the advantages of high specific strength, good osseointegration, superior corrosion resistance, and biocompatibility. Thus, alloys such as commercially pure titanium (CP-Ti) and Ti6Al4V are used for dental implants and dentures. However, CP-Ti alloy is considered to be one of the more problematic, mainly because of its high melting temperature (1670^{o}C) and high chemical activation energy at high temperature. The alloy Ti6Al4V is the one most commonly used because of its superior physical and mechanical properties in comparison to CP-Ti alloy[1]. However, the harmful elements V and Al present in Ti6Al4V tend to be released into the human body [2, 3]. Hence, additional alloying elements need to be added to make this alloy biocompatible and decrease its liquidus temperature.

One of these elements is copper, which not only decreases the melting point of the alloy [4] but also provides adequate biocompatibility [5] and reasonable corrosion resistance [6, 7]. Casting procedures are greatly favored. Kikuchi et al. reported that Ti–Cu alloys may present very high mechanical strength associated with good formability [6]. The Ti–Cu system presents a eutectoid transformation with 7.1%Cu (wt.%) at 790 °C; under these conditions, α-Ti and Ti_2Cu are formed [8].

Many studies have been also published on the corrosion behavior of CP-Ti alloy in artificial saliva, Ringer and Hanks' solutions, and others [9-11]. The high corrosion resistance of these alloys is due to the formation on its surface of an adherent and highly protective oxide film, mainly formed of TiO_2 [12]. In addition, the microstructure of metallic alloys plays an important role in the mechanical properties and corrosion behavior of as-cast components [13–15].

The aim of this study was to evaluate the general electrochemical corrosion resistance of Ti-7Cu alloy samples obtained by casting and heat treatment. Potentiodynamic anodic polarization techniques was investigated in 0.9 (wt.%) NaCl solution at 25 °C.

2. Experimental procedure

Commercially pure metals (Ti 99.8wt.% and Cu 99.99 wt.%) were used to prepare the Ti-7Cu alloy (wt.%), which a nearly eutectoid alloy, respectively, according to the Ti–Cu equilibrium phase diagram [8]. An as-cast Ti-7Cu sample was prepared by arc-melting its constituent using a current of 300A on a water-cooled copper hearth under a pure Ar gas atmosphere. The as-cast Ti-7Cu alloy was repetitively melted and solidified with turning of the solidified ingots so as to obtain a completely alloyed state. Heat treated samples cut from the ingot were homogenized at 950^{o}C for 2 hours and then quenched in water. Hardness measurements, phase identification, and microstructure and corrosion analyses were then carried out on the as-cast and heat treated samples. Measurements were made at a minimum of five points on each specimen and averaged. X-ray diffraction (XRD, D/max 2500 V/PC) analysis was performed to determine the phase composition of the specimens. All specimens were ground with silicon carbide papers up to 2000 mesh, polished, and etched to reveal the microstructure (Keller's etchant, 1mL of HF, 2.5mL of HNO_3, 1.5mL of HCl and 95mL of H_2O). The microstructure of the alloys was examined by optical microscopy (OM) and scanning electron microscopy (SEM).

Potentiodynamic polarization were carried out in 0.9wt.% NaCl solutions. A saturated calomel reference electrode (SCE) and a platinum (Pt) counter-electrode were used. Prior to testing, the specimens were ground with 1200 grit SiC paper and cleaned in acetone for 2 min. These tests were conducted by stepping the potential, using a scan rate of 1 mV/s from −0.800/+2000mV (SCE).

3. Results and discussion

The micrographs of as-cast and heat treated Ti-7Cu alloy samples are shown in Figs. 1 and 2, respectively. The microstructure of a rapidly solidified Ti-7Cu alloy sample is depicted in the OM and SEM micrographs of Fig. 1. Figure 1a shows α'-martensite plates of different sizes, which propagate within the pre-existing β-grains. Figure 1b shows the same microstructure in a high magnification BSE image. It is found that the martensite structure combined with basket-weave structure of acicular α-Ti (dark colour) and Ti_2Cu (light colour). Williams et al. [16] reported that martensite has a massive morphology in alloys containing 4% Cu or less, whereas alloys containing 6 and 8% Cu exhibit acicular martensite. The high cooling rate imposed on the samples promoted complete β-phase decomposition and formed acicular plates of martensite typically found in titanium alloys. Souza et al. [17] found α' martensite only with cooling rates higher than $9^oC/s$, as the volume fractions of eutectoid and martensite depend on the magnitude of the cooling rate. In addition, they found that Ti_2Cu may occur as spherical precipitates when high cooling rates are applied. The same phenomenon was also observed in the present work. Cardoso et al. [18] reported that rapidly quenched near-eutectoid Ti–Cu alloys present Ti_2Cu precipitates. Regardless of the cooling rate applied, such precipitation is unavoidable. The microstructure of the as-cast samples (in a copper mold) is in good agreement with the results from Cardoso et al.

Slow cooling of eutectoid Ti-7Cu alloy allowed eutectoid transformation to take place. An OM image of the slow cooled sample (Fig. 2a) shows an alternate typical basket-weave microstructure composed of lamellae of α-Ti and Ti_2Cu lamellae, as well as α lamellae. The detail seen in Fig. 2b shows the structure under higher magnification, revealing much larger lamellar Ti_2Cu phase (needles) than those found in the as-cast sample (Fig. 2b). The microstructure of the as-cast and heat treated samples (Fig. 1 and Fig.2) suggests that faster cooling hinders the growth of the α-phase and Ti_2Cu phase, which is supported by the fact that the thickness of the plates decreases with a decreasing distance from the source of cooling.

Figure 3 shows the X-ray diffraction XRD patterns of Ti-7Cu alloys obtained in as-cast and heat treated samples. It is well recognized that the microstructure of Ti-Cu binary alloys with low Cu content contains α phase and Ti_2Cu stable phases at room temperature [19]. The lattice parameters of α phase in a Ti–Cu binary system were determined to have a hexagonal structure (space group P63/mmc) with lattice parameters of a = 0.2945 nm and c = 0.4685 nm. Also, the crystallographic characteristics of Ti_2Cu compound are well defined in the literature as a tetragonal structure (space group I4/mmm) with lattice parameters of a = 0.29438 nm and c = 1.0786 nm [20]. It was found that the X-ray diffraction patterns of as-cast samples showed both α' martensite and α-Ti phases and slight peaks associated with the intermetallic Ti_2Cu, as observed in Fig. 3a. However, the X-ray diffraction patterns of the α phase and α' martensite are remarkably similar, which makes it difficult to differentiate the two phases. Additionally, the literature suggests that the lattice parameters of α phase in titanium alloys changes as a function of the alloying element in solution with titanium. After heat treatment, α peaks associated with Ti_2Cu were clearly detected, and the peak of α' martensite disappeared, as shown in Fig. 3b. These XRD results are in agreement with the SEM observations.

Figure 4 shows the polarization curves of the as-cast samples and those after heat treatment in a 0.9 wt.% NaCl solution. From the polarization curves, the corrosion potential (E_{corr}), the primary passive current (I_{pp}), the breakdown potential (E_b), and the dynamic corrosion current density (I_{corr}) were determined and are listed in Table 1. The dynamic corrosion current densities (I_{corr}) were obtained from the polarization curves by Tafel plots using both cathodic and anodic branches of the polarization curves. The polarization curves have the same shape and are typical of passive behavior. The E_{corr} of the as-cast sample is -712±23mV_{SCE}. Nevertheless, the E_{corr} of the Ti-7Cu alloy slightly shifted to positive values after heat treatment. On the other hand, the breakdown potential (E_b) of the as-cast samples became much more noble than that of heat treated samples, and the slightly large value of ΔE (= E_b − $E_{corr.}$; $E_{corr.}$ = corrosion potential) for the–as-cast samples reveals more stable passivation characteristics. This indicates that the pitting corrosion tendency of the as-cast sample can be alleviated due to elimination of the pitting nucleation sites in the matrix of the as-cast sample, in which a higher density of sub-micro Ti_2Cu phase and the α' martensite of the microstructure exist in the as-cast sample. In addition, it can be seen that the I_{corr} of the as-cast specimen (139±10 nA/cm^2) is slightly higher than that of the alloy after heat treatment (105±11 nA/cm^2). These current densities, shown in Table 1, can be considered satisfactory when compared to the corresponding values obtained for CP-Ti and Ti6Al4V (of about 90 nA/cm^2) [21] and quenched and heat treated Ti35Nb alloys (of about 60 nA/cm^2) [22]. The different primary passive current densities (I_{pp}) of as-cast (7.4±0.6$\mu A/cm^2$) and heat treated Ti–Cu alloys (10.2±0.9$\mu A/cm^2$)show similar values. Recently, very similar I_{PP} measurements were also obtained for Ti–Nb–Zr as-cast alloys [23].

4. Conclusions

From the present experimental investigation with as-cast and heat treated Ti-7Cu alloy samples, the follow conclusions can be drawn:

(1) The Ti_2Cu phase is always present in the microstructure, regardless of the processing condition. In addition, after heat treatment, the volumetric fraction of Ti_2Cu also increases.
(2) The as-cast sample showed a finer α' martensite structure combined with α-Ti and Ti_2Cu in the Ti–7Cu alloy when compared to the corresponding microstructures of the heat treated samples.
(3) Both as-cast and heat treated samples present a passive behavior in this medium and high corrosion resistance. Nevertheless, their E_{corr} and the stability of their passive oxide films are quite similar.
(4) The experimental results of corrosion tests have indicated that only corrosion potential is significantly more noble in the heat treated samples but other characteristics are only slightly different. E.g. passive current density (I_{pp}) is better in as cast alloy.

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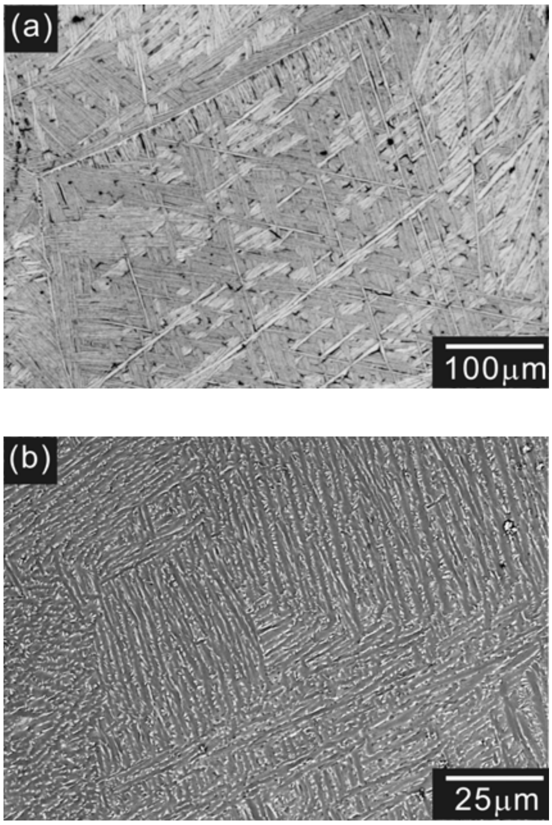

Figure 1 Images of as-cast Ti-7Cu alloys: (a) OM, (b) SEM-BSE.

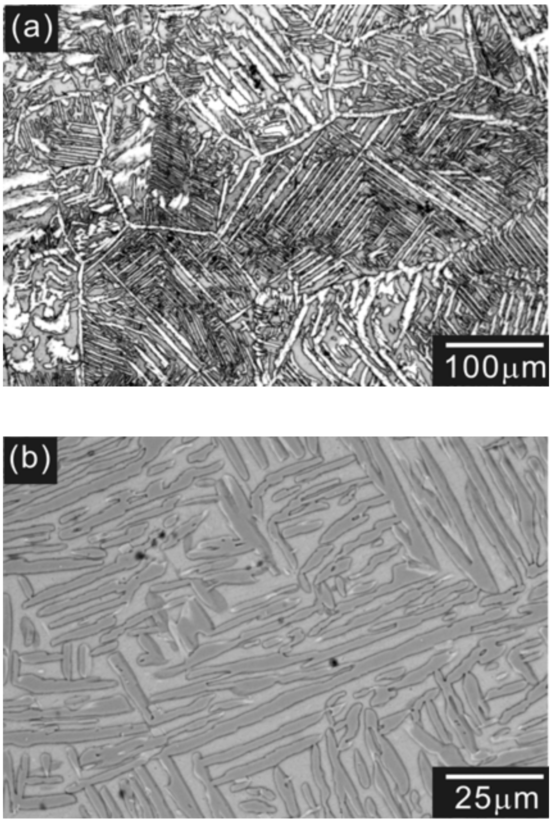

Figure 2 Images of heat-treatment Ti-7Cu alloys: (a) OM, (b) SEM-BSE.

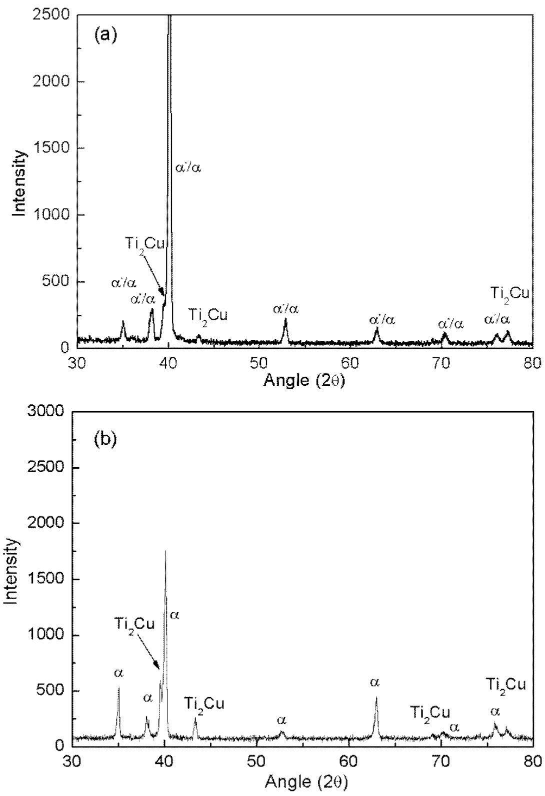

Figure 3 X-ray diffraction patterns of: (a) as-cast sample and (b) heat treated sample.

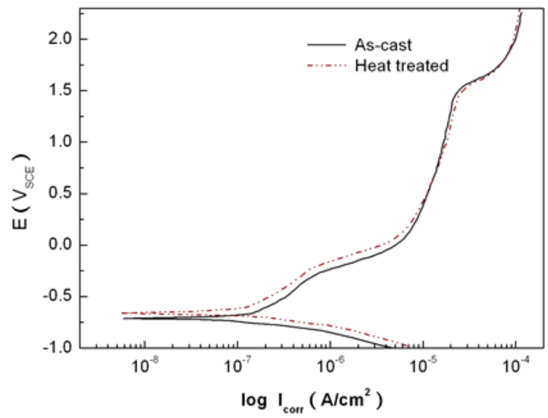

Figure 4 Experimental potentiodynamic anodic polarization curves for Ti-7Cu alloys samples in a 0.9 wt.% NaCl solution at 25 ◦C.

Table 1 Corrosion properties of the as cast and heat treated Ti-7Cu alloys in a 0.9 wt.% NaCl solution.

Specimens	E_{corr} (mV_{SCE})	E_b (mV_{SCE})	ΔE (mV)	I_{corr} (nA/cm^2)	I_{pp} ($\mu A/cm^2$)
As-cast	-712±23	1516±50	2228	139±14	7.4±0.6
Heat treated	-527±18	1511±43	2038	105±11	10.2±0.9

E_{corr}: corrosion potential(mV_{SCE}), E_b: breakdown potential(mV_{SCE}),
$\Delta E = E_{corr} - E_b$, I_{corr}: corrosion current density(nA/cm^2),
I_{pp} :primary passive current.