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Laser weldability of Pt and Ti alloys

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Abstract

Crack susceptibility of laser spot welds between Pt and Ti alloys was studied by characterizing the surface and the cross-sections of the welds produced at different pulse energies. Increase in laser pulse energy increased the dilution by the Ti alloy, giving rise to the evolution of microstructures with varying Ti contents across the entire fusion zone. Hardness results showed that regions with 66–75% Ti, i.e. consisting of primary Ti_3Pt and/or $Ti_3Pt + TiPt$ eutectic, have a hardness higher than 700 Vickers hardness numbers (VHN), while regions with 42–66% Ti, i.e. consisting of primary TiPt, possessed hardness between 400 and 700 VHN. The extent of cracking increased with the increase in pulse energy and the cracked regions consisted of Ti contents between 50 and 75%. Brittle cracking in microstructures consisting of Ti_3Pt and TiPt phases suggested that one or both of the constituent phases are susceptible to cracking. However, crack arrest in microstructures predominantly consisting of TiPt showed that Ti_3Pt is the most susceptible phase to cracking in Pt–Ti alloy welds.

Keywords: Pt–Ti; Weldability; Crack susceptibility; Medical applications; Intermetallics

1. Introduction

Laser welding has been used as one of the major manufacturing processes in the medical device industry because it offers number of advantages such as precision and non-contact processing, with a small HAZ, consistent and reliable joints etc. [1]. Laser welding has been used to produce many kinds of medical products such as pacemakers, defibrillators, catheters, cochlear, insulin pumps, stents, and orthopedic implants [2]. For implantable devices, biocompatible metals and alloys such as titanium, nitinol, cobalt-based alloys, stainless steel, platinum, and niobium, must be used. However, laser weldability of these materials, especially dissimilar material combinations, is still poorly understood. One the extensively used material combinations in implantable medical devices, but very rarely reported, is laser welding of platinum alloys to titanium alloys.

High strength, low weight, outstanding corrosion resistance, and bio-compatibility make Ti and its alloys suitable for medical devices such as pacemakers and defibrillators. Excellent electrical conductivity, durability, biological compatibility, and oxidation resistance make the Pt–Ir wires well suited for electrodes in these medical components [3]. Although good mechanical and electrochemical properties are required, the primary purpose of joining the Pt alloy wire to the Ti alloy component in medical devices is to form an electrical connection. However, electrical conductivity along with corrosion and mechanical properties of a weld joint are primarily dependent on the structure and properties of the fusion zone. Cracking in Pt–Ti alloy welds is a problem. The medical industry is investigating to improving the integrity of these joints by process modifications and evaluation of alternative materials. Although it has been reported that Pt–Ti welds are brittle in nature [2], to the authors' knowledge, no previous study of the effects of weld process conditions on Pt–Ti alloy weld quality has been published to understand the properties of these weld joints. An examination of the Pt–Ti phase diagram [4] in Fig. 1 shows that various intermetallic phases (Ti_3Pt, TiPt, Ti_3Pt_5, $TiPt_3$, etc.) can form between

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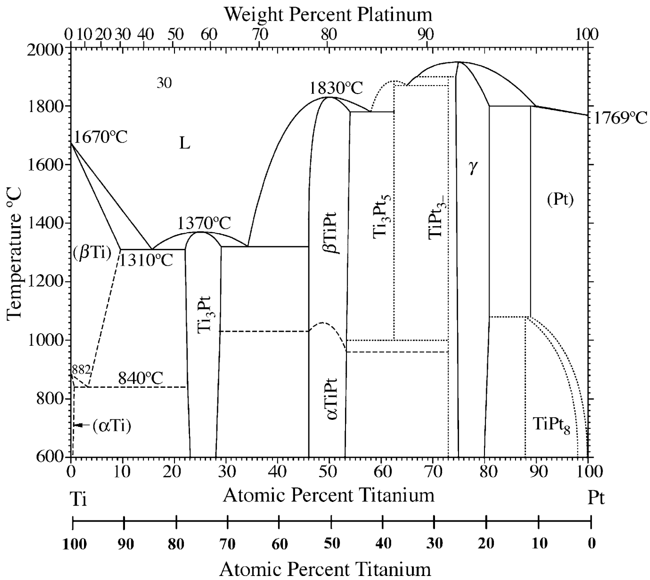

Fig. 1. Binary phase diagram showing the possible phases between Pt and Ti [2].

Pt and Ti and could possibly affect the weldability between their alloys. The purpose of the present study is to gain an understanding of the weldability of laser spot welds between Pt and Ti alloys.

2. Experimental methods

Single pulsed laser spot welds were produced between Pt–10Ir wire of 400 μm diameter and Ti–6Al–4V component of 1 mm thickness by varying the laser pulse energy between 6 and 10 J, but at a constant pulse time of 6 ms. Prior to welding, the specimens were soaked in acetone, then in methanol, and dried in air. They were assembled in the configuration shown in Fig. 2, with the laser beam at 75° to the surface of the Ti alloy component to avoid laser back reflection. The Pt alloy wire was held down onto the Ti alloy component using a one-sided tape. The laser was focussed on the surface of the Ti alloy component and welding was performed with a Lumonics JK 702H pulsed Nd:YAG laser with a Gaussian beam distribution and a spot size of about 413 μm [5]. Argon shielding gas at 30 cfh flow rate through a nozzle of 8 mm inner diameter, 6 mm above the Ti alloy component and at about 75° to its surface, was used to minimise atmospheric contamination.

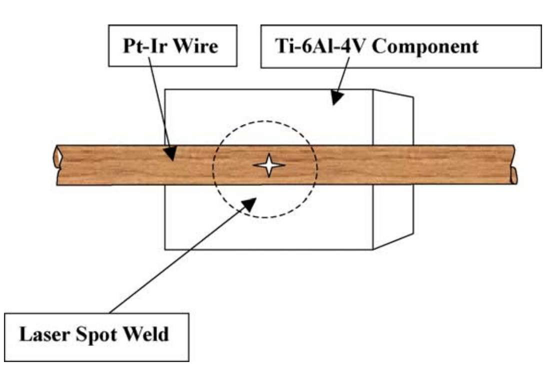

Fig. 2. Geometry of Pt alloy wire and Ti alloy component prior to welding.

After welding, the surface of each spot weld was examined for possible cracks, and quantitatively analyzed for compositional variations using energy dispersive spectroscopy (EDS) in a scanning electron microscope (SEM). Analysis of the microstructures was performed on a LEO 1530 field emission scanning electron microscope (FESEM) equipped with EDAX Genesis 2000. The quantitative data was collected at 20 or 21 KV accelerating voltage selecting L peaks to resolve and quantify Pt and Ir contents and K peaks to quantify Al, V and Ti contents. It should be noted that the compositions given are always in atomic proportions, unless otherwise mentioned and the microstructural constituents were predicted based solely on their Pt and Ti contents.

The welds were then cold mounted and metallographically polished for further observations of the microstructure and possible cracks in the weld cross-sections. Microhardness indenting (load of 50 gf, time of 15 s) was performed on a Shimadzu hardness tester after which diagonals of the indentations were measured in an optical microscope and Vickers hardness numbers (VHN) were obtained using Image Pro (Version 4.5) software.

3. Results and discussion

3.1. Microstructural evolution

Increases in laser pulse energy not only resulted in larger Pt–Ti alloy welds, but also higher dilution by the Ti alloy base metal giving rise to an evolution of the fusion zone microstructure. Weld cross-sections in Fig. 3 are examples showing the effect of pulse energy on the dilution of the fusion zone by the Ti alloy base metal. The cross-section of the weld produced with 6 J pulse energy in the back scattered electron image of Fig. 3(a) shows extensive regions of bright contrast in the fusion zone and hence, has minimal dilution by the Ti alloy. The increase in regions of grey contrast evident in the back scattered electron images of the fusion zones in Fig. 3(b) and (c) of 8 and 10 J welds, respectively, indicates that higher laser pulse energy increases the dilution by the Ti alloy base metal.

Fig. 4(a) and (b) shows the variation of Ti content (% Ti/(Ti + Pt)) from the Pt alloy base metal side to the Ti alloy base metal end of the fusion zones produced at 8 and 10 J pulse energies, respectively. Fig. 4(a) also shows that about two-thirds of the regions analyzed by the line scan across the 8 J weld cross-section consist of 38–50% Ti, while the rest of the regions on the line scan, which are near the Ti alloy, consist of 50–75% Ti. However, the line scan across the 10 J weld cross-section in Fig. 4(b) shows that most of the regions analyzed consist of 50–75% Ti. The length of line scans on