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Fibre laser joining of highly dissimilar materials: Commercially pure Ti and PET hybrid joint for medical device applications

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ABSTRACT

Laser transmission joining (LTJ) is growing in importance, and has the potential to become a niche technique for the fabrication of hybrid plastic-metal joints for medical device applications. The possibility of directly joining plastics to metals by LTJ has been demonstrated by a number of recent studies. However, a reliable and quantitative method for defining the contact area between the plastic and metal, facilitating calculation of the mechanical shear stress of the hybrid joints, is still lacking. A new method, based on image analysis using ImageJ, is proposed here to quantify the contact area at the joint interface. The effect of discolouration on the mechanical performance of the hybrid joints is also reported for the first time. Biocompatible polyethylene terephthalate (PET) and commercially pure titanium (Ti) were selected as materials for laser joining using a 200 W CW fibre laser system. The effect of laser power, scanning speed and stand-off distance between the nozzle tip and top surface of the plastic were studied and analysed by Taguchi L9 orthogonal array and ANOVA respectively. The surface morphology, structure and elemental composition on the PET and Ti surfaces after shearing/peeling apart were characterized by SEM, EDX, XRD and XPS.

1. Introduction

Because of improved access to healthcare facilities and consequently increased life expectancy, the demand for medical implant devices has increased significantly in the past two decades. One of the biggest obstacles hindering the development of innovative medical devices is the ability to join dissimilar materials. Difficulties arise due to chemical incompatibility and different physical characteristics, for example melting point, coefficient of thermal expansion, thermal diffusivity, etc. The joining of dissimilar materials for medical device applications has recently been the subject of much recent research. In particular, successful implementation of hybrid plastic-metal joints would allow complementary structural and non-structural needs of medical devices to be realised in a single customized solution [1] with the plastic parts offering flexibility and the metal parts providing the mechanical strength. Traditionally, joining of plastic to metal parts in medical devices has been achieved by using medical adhesives, such as polyurethanes, silicones, and epoxies. For example, pacemakers, defibrillators and neurological stimulators are designed using silicone adhesive to seal the joint between the polyurethane connector module and the titanium can [2,3]. However, there are a number of drawbacks associated with the use of adhesives, such as slow processing time, lack of long term stability and design flexibility, as well as a high tendency to produce leachable/extractable products. Consequently, there is an urgent demand for a fast, safe, flexible, reliable and adhesive-free method to directly join the plastic component to the metal body.

Laser transmission joining (LTJ) is growing in importance, and has the potential to become a niche technique in the fabrication of hybrid plastic-metal joints for medical device applications. Key advantages of laser transmission joining over the traditional adhesive method include a clean and non-contact process, fast joining cycles (usually less than few seconds), highly flexible and automated, the absence of particulate generation, and no vibration of the parts during joining. Successful laser joining of metals to plastics has been demonstrated for a range of material combinations. Examples include CFRP-zinc coated steel [4], CFRP-SS304 [5], HDPE-SS304 [6], PA6-SS304 [1], PA66-SS304 [7], PET-A5052 [8,9], PET-AZ91D [10], PET-Cu [9], PET-SS304 [9,11–12], PET-SS316L [13], PET-Ti [14,15], PMMA-SS304 [16] and PI-Ti [17]. Katayama et al. [11] applied continuous wave (CW) diode laser to join SS304 and PET and reported that high strength plastics and metal joints can be fabricated by laser heating due to the formation of mechanical, physical and chemical bonds (e.g. Cr-O) between the plastics and metal surfaces. Cenigaonaindia et al. [1] used a high power CW diode laser to join SS304 and PA6. They reported that good quality joints can be obtained by carefully optimising the process parameters, such as laser power, processing speed, joining trajectory, and clamping pressure. Process monitoring and control systems were used in their study to inspect the joint quality during the joining process. Fortunato et al. [7] applied CW diode laser to fabricate joints between SS304 and a group of PA materials, e.g. PA66,

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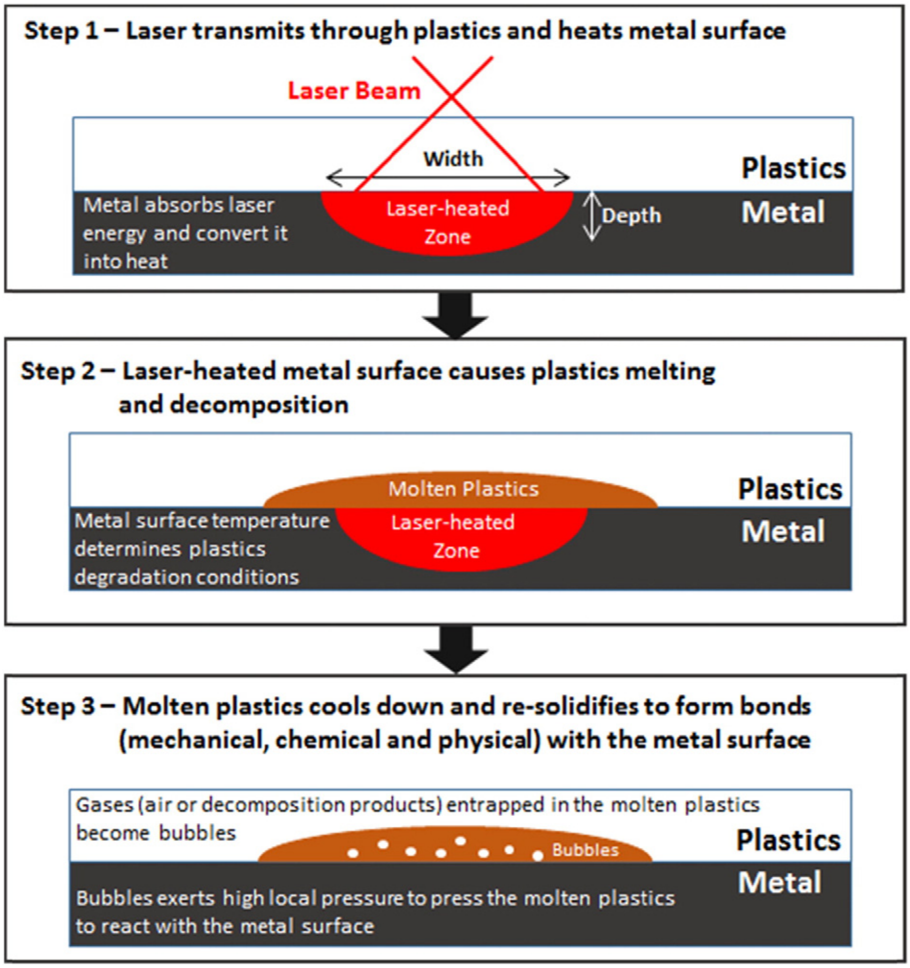

Fig. 1. Schematic diagram to illustrate the laser joining process of PET (plastics) to Ti (metal).

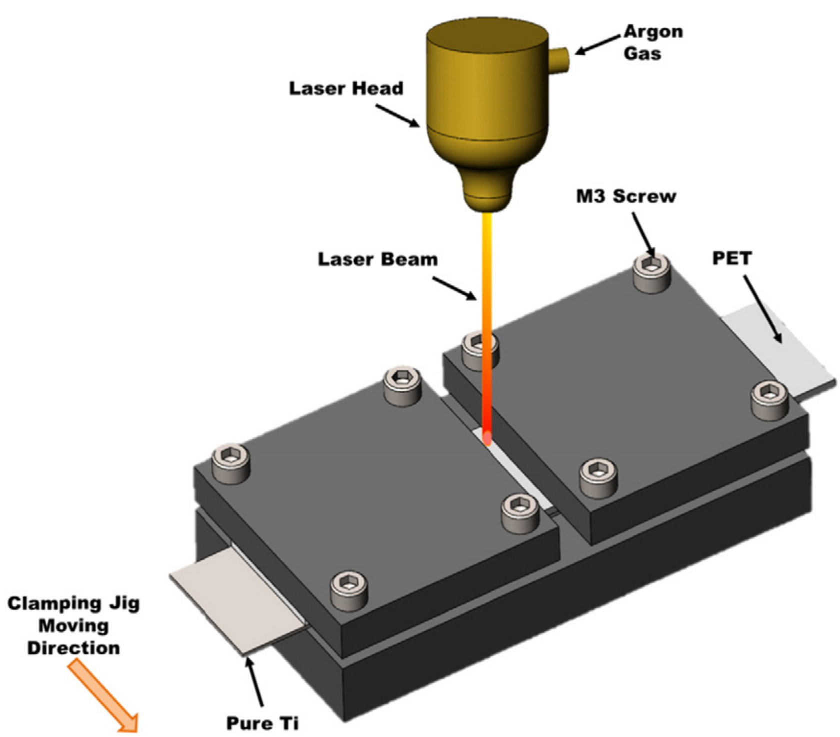

Fig. 2. Schematic of joining rig assembly.