Journal of New Technology and Materials
JNTM
Vol. 03, N°02 (2013)29 - 31

OEB Univ. Publish. Co.

Nd:Yag Laser Ablation of Recuperated and Industrial Aluminum Alloys. Study of Threshold Ablation

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Received: 29 September 2013, accepted: 27 December 2013

Abstract

In this work, we used a nanosecond Nd: Yag laser (λ=532 nm) with a pulse duration of 15 ns, and an energy of 50 mJ and, therefore, we studied the threshold ablation of industrial aluminum alloy. The composition of the recuperated aluminum (% mass) is (72.02 Al, Si 13.05, 6.34 Zn, 4.28 O, 2.08 Mg, 1.75 Cu, 0.48 Ni) and the industrial aluminum is (83.10 Al, 1.66 Si, 4.12 Fe 2.17 O, 1.20 Mg, 5.47 Cu, 1.74 Mn, 1.79 Pb). For nanosecond lasers, the primary energy is lost by thermal diffusion in the irradiated target, because there is enough time to convert optical energy into thermal energy and heat spread. Fusion and / or evaporation may take place if the surface temperature exceeds the critical point when the energy of radiation is above the ablation threshold. The results shows that the threshold ablation of the recuperated aluminum is lower than that of the aluminum industry, it is about 5 $J.cm^{-2}$ for the recovered aluminum and 10 $J.cm^{-2}$ for the industrial aluminum. The threshold ablation is shifted towards the low values when the number of pulses increases.

Keywords: laser-matter interaction; Laser ablation; Aluminum Alloys

Introduction

Nanosecond laser pulses may produce both thermal melting (as femtosecond and picosecond pulses) or ultrafast nonthermal melting depending on the pulse fluence. This was demonstrated experimentally by Sokolowski-Tinten et al. [1], who found that the transformation of GaAs into its liquid state occurs within several tens of picoseconds at fluences close to the melt threshold due to thermal melting under highly superheated conditions [1] or within several hundred femtoseconds via carrier excitation[1, 2] for very high fluences. The processes occurring under high energetic fs pulse irradiation could be described more precisely with the help of the theoretical work of Stampfli and Bennemann [3]. The joining of very small metallic workpieces (10– 200 mm) causes problems that often cannot be solved by conventional methods. In this case, soft soldering by means of laser radiation is sufficient. During soldering, laser light is used to melt an additional material with a considerably lower melting temperature than that of the material of the component to be joined. In order to understand this phenomenon, metallic alloys (Al, Cu, Zn, ...) are irradiated by a Nd:Yag pulsed laser. The chemical distribution of elements can be influenced, in particular the oxygen [4] as well as the microhardness [5]. The irradiated area is studied by the profilometer instrument in order to measure the ablation depth.

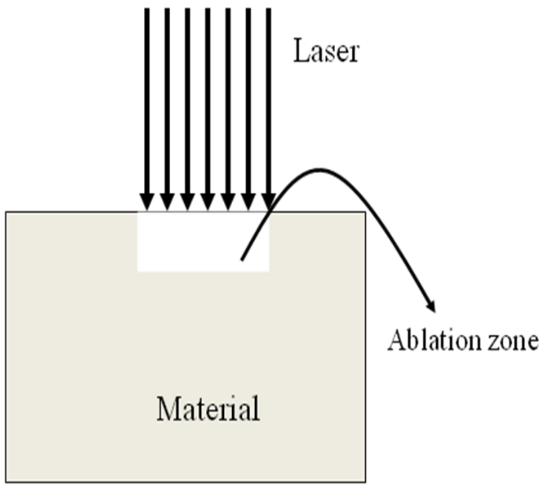

Fig.1. Schematic representation of ablation procedure

Experimental

The samples studied are two materials, industrial and recuperated aluminum alloys. They were polished mechanically and cleaned. The chemical composition of each type is obtained by X-ray analysis[4]. The chemical composition of recycled aluminum alloy is Al(72.02 wt %), Si(13.05 wt %), Zn(6.34 wt %), O(4.28 wt %), Mg(2.08 wt %), Cu(1.75 wt %), and Ni(0.48 wt %). The chemical composition of industrial aluminum alloy is Al(83.10 wt %), Cu(5.47 wt %), Fe(4.12 wt %), O(2.71 wt %), Mn(1.74 wt %), Si(1.66 wt %), and Mg(1.20 wt %). A

nanosecond pulsed laser (Nd:Yag) is used to irradiate an aluminum alloy sample (fig.1). The instrument used in this experiment is the Spectrum laser system. The pulse duration, wavelength, and pulse energy are 15 ns, 532 nm, and 50 mJ, respectively. All irradiation experiments are performed in air at room temperature. The analysis of irradiated area is realized by the profilometer instrument in order to measure the ablation depth.
The properties of material studied are reported in the table 1.

Table1: Main properties of the two alloys studied (compared with pure Aluminum)

	recuperated aluminum	industrial aluminum	pure Aluminum
Density	2816	2614	2700
Microhardness (kg F/mm^2)	118	125	2.75
Thermal conductivity (W/m.K)	128	160	237

Results

The fluence threshold ablation (Fs), by definition, is the influence filed in the material from which a significant removal is achieved [1, 2]. The fluence threshold depends on the material and laser parameters[1]. The fluence threshold ablation may be shortened to one critical temperature to be reached for a regime ablation [3]. It is measured experimentally by extrapolating the quasi-linear evolution of the ablation depth (or the quantity of material ejected) depending on the fluence; for the low fluences until the zero, the ablation depth is nil. Figure 2 (a) and (b) show the ablation depth as a function of fluence for the two studied alloys, recuperated and industrial aluminum respectively. The threshold ablation is around 7 J.cm^{-2} for recuperated aluminum and 10 J.cm^{-2} for the industrial aluminum. That depends on the number of pulses. The ablation threshold tends toward low values when the number of pulses increases (see fig.2 (a) and (b)) the tow cases, 80 and 40 pulses).

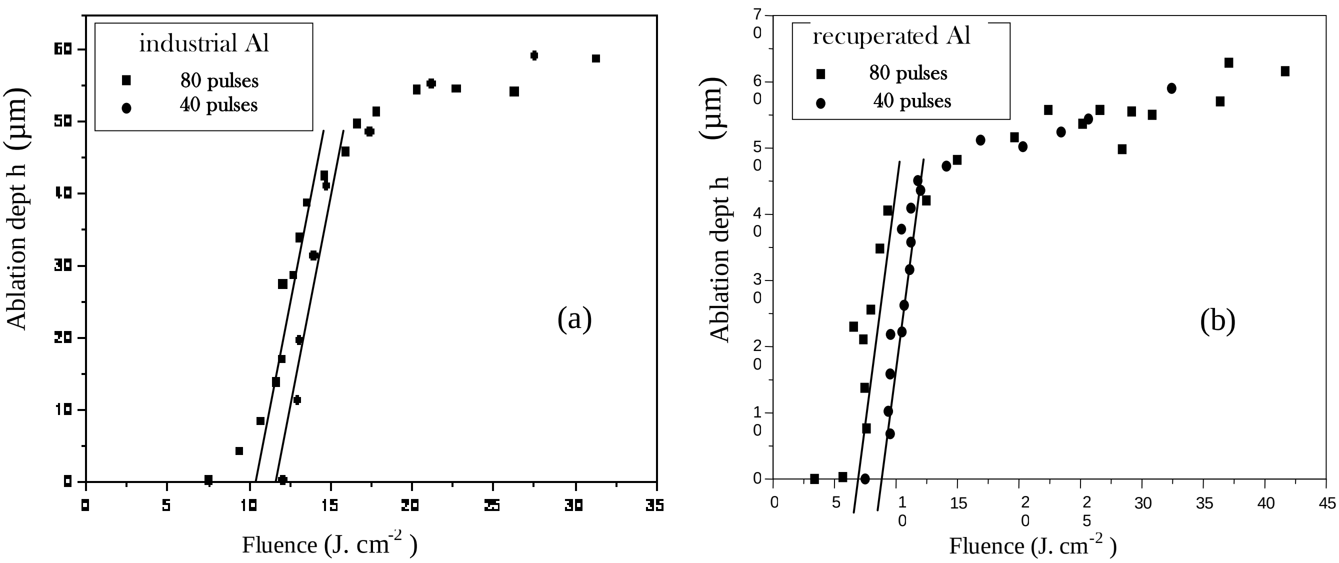

Fig.2. Dependence of ablation depth on fluence for industrial (a) and recuperated aluminum(b)

The threshold ablation in the industrial aluminum is greater than that one of the recuperated aluminum; this is may be due to the low thermal conductivity of the recuperated aluminum in comparison with that of the industrial aluminum. So, when the metal has a high thermal conductivity, thermal energy will be transported quickly within the sample, so it does not accumulate in the irradiated zone, leading to a ablation depth.

The quantity of ablated matter tends to saturation for high fluencies because the crater is very deep and because a quantity of laser energy is absorbed by plasma created near to the ablation zone.

Conclusion

The two studied alloys (industrial and recuperated aluminum) contain several chemical elements; each alloy is composed of more than six elements. So it is a complex material, and its interaction with a laser pulse of high intensity causes strange and very complex mechanisms. However, the behavior of these alloys in the ablation procedure is similar to that for simple alloys (binary or ternary). The threshold ablation is about 10 $J.cm^{-2}$.

Références

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