IMPROVEMENT OF EFFICIENCY ON CO_2 LASER WORKING OF ALUMINUM ALLOYS BY SURFACE TREATMENT.

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ABSTRACT As transparent absorbent for laser beam, perhydropolysilazane (PHPS) films were prepared on aluminum alloys by dip-coating technique. PHPS films obtained as transparent films, and the FTIR spectra of the films showed a absorption peak at wavelength of CO_2 laser due to Si-N bond. For A1050 alloys, by irradiating CO_2 laser at the power of 1 kW, 0.04mm depth of melting zone was obtained for the 0.7 μ m thick PHPS coated workpiece, but melting zone was not observed for untreated workpieces at the laser power of 3kW. Same effects of PHPS coating on absorption of laser beam were recognized for another workpieces, A2017 and A5052.

Keywords ; *CO_2 laser, transparent absorbent, aluminum alloy, perhydropolysilazane, metalworking*

1.INTRODUCTION

Because it can generate high power beam under continuous output and shows high efficiency of energy conversion into laser beam, CO_2 laser is used for metalworking, such as cutting, heat treatment and surface finishing. However various metals show inherent low absorption for the wavelength of CO_2 laser (10.6 μ m). Especially aluminum absorb only few % of laser beam, and is well known as hard processing material for laser. And reflecting beam causes the lens damage. For efficient utilization of the laser energy, coating by the absorbent for laser beam to metal surface have been employed. Chemical coatings, such as manganese phosphate and paints of graphite, silicon, and carbon, have been used.[1] But these treatment are colored coating, therefore it must be removed after laser working. And it is difficult to coat the workpiece surface uniformly with these paints. Furthermore optical system is damaged by reflecting laser beam.

To solve the above mentioned problems, we tried to coat the surface of aluminum alloys with the material, which is transparency and shows good absorbability at the wavelength of CO_2 laser . In this study, as such transparency absorbent , Perhydropolysilazane (PHPS) was coated on aluminum alloys. And then, the influences of PHPS coating on improvement of absorbability of CO_2 laser beam were investigated.

2.EXPERIMENTAL PROCEDURE

Commercial aluminum alloys (JIS A1050, A2017 and A5052), sized 50 × 200 × 4mm were used as the workpieces. The chemical composition of these alloys are given in Table 1. The workpieces were ultra-sonic washed in acetone, and then PHPS films were prepared on the workpieces by dip-coating from the 20% PHPS - xylene solution at a constant withdrawing speed (2.5mm/sec). After dip-coating, in order to remove the xylene, workpieces were dried at 423K for 1800sec. Film thickness was varied by repeating dip-dry process, and was measured by observing the cross section of the coated workpiece using optical microscopy. The IR absorption spectra and the visible transmission spectra of the film were measured by FTIR and visible spectroscopy respectively.

The CO_2 laser was irradiated onto the treated and untreated workpieces under the conditions: laser power were ranged 0.5 ~ 3.0kW, traverse speed was 33mm/sec and shield gas was Ar. The focusing lens was made of zinc selenide , and it's focal length was 254mm. And laser beam focused on the workpieace surface. PHPS coating effect on absorption of laser beam was evaluated by measuring the width and the depth of melting zone from the cross section of laser irradiated workpieces using optical microscope. Compositional change in the PHPS film after laser irradiating was observed by Electron probe microanalyser (EPMA) .

Table 1 Chemical compositions of materials used (wt%)

	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti
A1050	0.07	0.32	-	0.01	0.02	-	-	0.01
A2017	0.48	0.34	3.84	0.64	0.57	0.02	0.13	0.04
A5052	0.12	0.26	-	0.05	2.40	0.21	0.02	0.01

3.RESULTS AND DISCUSSION

3.1 Properties of PHPS film

Constitutional formula of PHPS is shown in Figure 1.[2] Firing in an oxygen-containing atmosphere PHPS change into silicon dioxide, and well known as the material for forming thick planarization layer of integrated circuit device. Under the present experimental conditions, about 0.7 μ m thick PHPS layer was obtained by a dip-dry process. Figure 2 shows FTIR spectra of the PHPS film. The absorption peak at about 1000cm^{-1}, which includes wavelength of the CO_2 laser beam, is

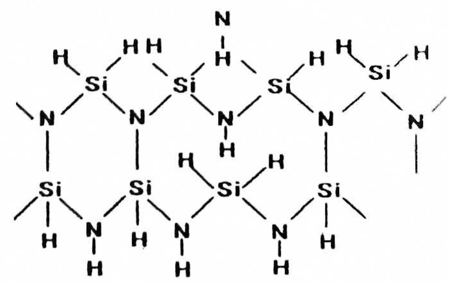

Fig.1 Constitutional formula of perhydropolysilazane

due to Si-N bond. On the other hand, over the visible region, spectral transmissivity of the films were almost 100%. In this way, PHPS film was obtained as transparent film, and the external appearance of workpiece hardly changed.

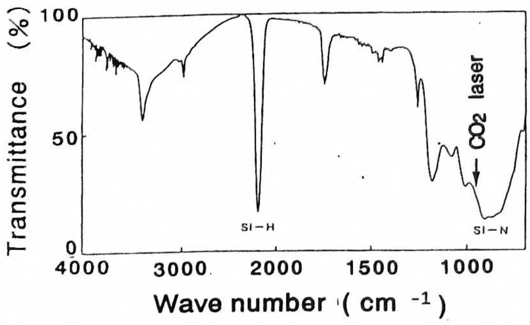

Fig.2 FTIR spectra of the PHPS film

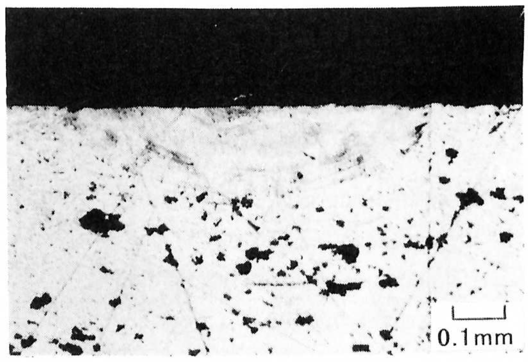

Fig..3 Optical micrograph of cross section of the LMZ (A1050)

3.2 PHPS coating effects on laser melting of aluminum alloys

Figure 3 shows a optical micrograph obtained from cross section of the laser irradiated A1050 alloy, and it can be observed typical heat-conduction type melting zone. The effects of laser power on depth and width of the laser melting zone (LMZ) in A1050 alloys with various thickness PHPS films are shown in Figure 4. For the 0.7 μ m thick PHPS coated workpiece 0.04 mm depth of LMZ was obtained by irradiating CO_2 laser at the power of 1 kW. And depth and width of the LMZ increased as the beam power was increased. On the other hand , melting zone was not observed for the untreated workpiece even at laser power of 3kW. Among the coated workpieces, the 0.7 μ m thick PHPS coated workpiece showed smaller size LMZ at the power of 0.5 ~ 2 kW than the other thick film coated workpieces. The 2.2 and 3.4 μ m thick PHPS coated workpieces showed similar relation between sizes of the LMZ and laser power.

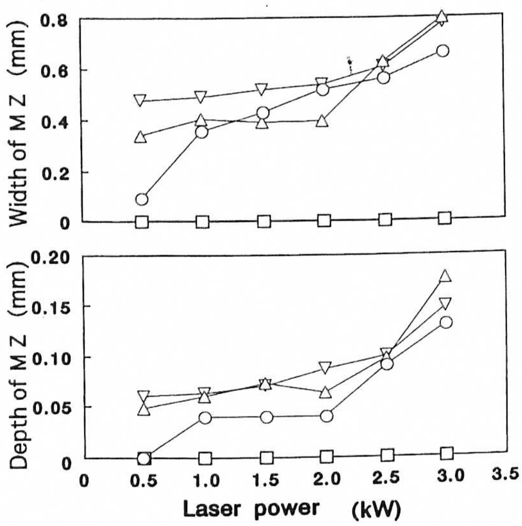

Fig.4 Relationship between depth,width of the MZ in A1050 and laser power.(□ non-treatment, PHPS coating; ○ 0.7 μ m , △ 2.2 μ m,▽ 3.4 μ m)

Figure 5 shows the relationship between width, depth of the LMZ and laser power in

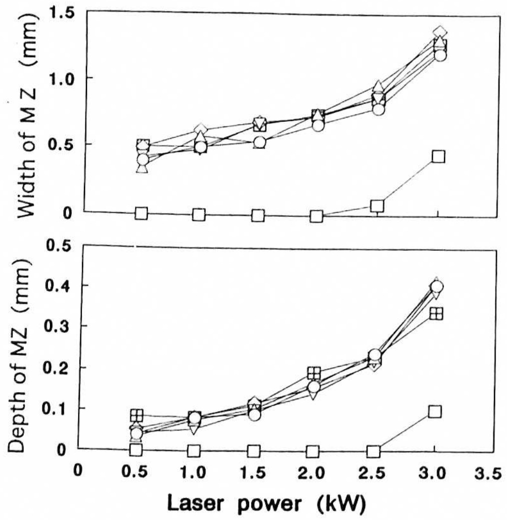

Fig.5 Relationship between depth,width of the melting zone(MZ) in A2017 and laser power (□ non- treatment, PHPS coating; ○ 0.7 μ m, △ 1.6 μ m,▽ 2.8 μ m, ◇ 3.4 μ m, ⊞ 5.0 μ m)

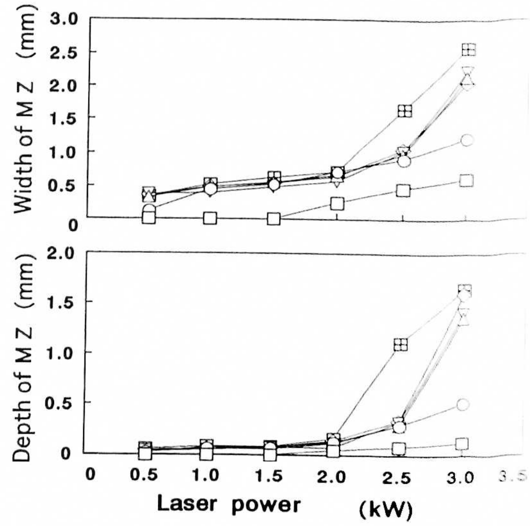

Fig.6 Relationship between depth,width of the LMZ in A5052 and laser power □ non-treatment, PHPS coating; ○ 0.7 μ m, △ 1.6 μ m,▽ 2.6 μ m, ◇ 3.5 μ m, ⊞ 4.6 μ m)

the A2017 alloys. Both the depth and the width of the LMZ obtained in the PHPS film coat A2017 workpieces were about twice these of the A1050 workpieces. Moreover laser meltin were occurred in untreated A2017 workpieces at laser power of 2.5 and 3.0kW. It is considere that increase in the sizes of the LMZ of A2017 compared to A1050 is due to the effects of al element. And the relation between the depth,the width of LMZ in the PHPS coated A20 workpieces and laser power scarcely depended on film thickness within the limits of th experiment. Though exact solution to the cause could not obtained, it is assumed that surfa oxide layer promotes absorbing the laser beam.

As for the PHPS coated A5052 workpieces, the depth and the width of the LMZ obtained the both the untreated and the coated workpieces increased to a great extent compared w A1050 and A2017 at the same laser power (Figure 6). Among the coated workpieces, the 0.7 m thick PHPS coated workpiece showed smaller size melting zone at the power of 0.5 and 3 k than the other thick film coated workpieces. Whereas the 4.6 μ m thick PHPS coated workpie showed considerable increase in depth of LMZ compared with the other workpieces at the hig laser power of 2.5kW and 3.0kW.

Figure 7 shows the ratio of depth to width (D/W) of the LMZ obtained in 3.4 ~ 3.5 μ thick PHPS coated aluminum alloys. D/W values of the A1050 and the A2017 alloys gradua increased from about 1 to 3 with the laser power increased from 0.5kW to 3.0kW. However th A5052 alloy showed sudden change in D/W value at the laser power of 3.0kW. Before and af

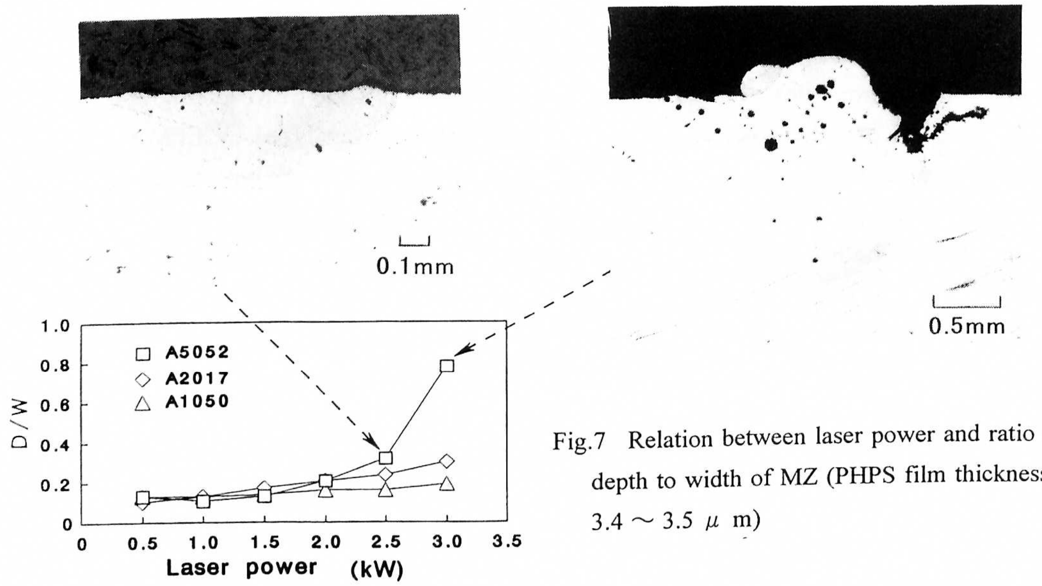

Fig.7 Relation between laser power and ratio of depth to width of MZ (PHPS film thickness= 3.4 ～ 3.5 μ m)

the sudden increase in D/W value, as shown in figure 8, micro-structure of the cross section of the LMZ changed from heat-conduction type melting to deep-penetration melting. It is considered that the deep-penetration melting is closely connected with the alloying elements such as magnesium. And the results revealed that the laser power required for deep-penetration melting was lowered by coating the PHPS film.

The above-mentioned experimental results indicated the possibility of PHPS film for transparency laser absorbent.

3.3 Change in PHPS film after laser irradiation

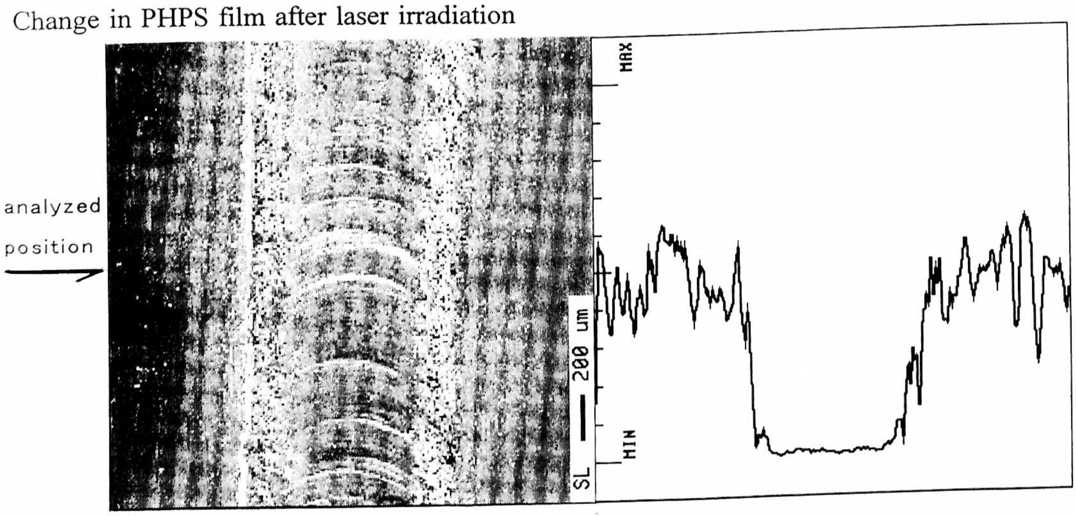

Fig.8 SEM micrograph and Si distribution obtained from LMZ of A5052

There is a possibility that the constituent of the PHPS film, especially Si element, leave on the workpiece surface after laser irradiation, or diffuse into melting zone, and thus affect bad influence on the properties of aluminum alloy. Figure 8 shows the SEM micrograph of LMZ and the line analysis of silicon perpendicular to traverse direction analyzed by EPMA over the laser irradiated area, and indicates that silicon was not recognized in the melting zone. It is considered that PHPS film was moved to both end of LMZ by surface tension of molten metal, or was scattered during the laser irradiating.

4.CONCLUSION

For efficient use of energy for laser metalworking, PHPS films were prepared on commercial aluminum alloys (A1050, A2017, A5052) by dip-coating technique. PHPS film was obtained as transparent films, and showed infrared absorption at the wavelength of the CO_2 laser. The width and the depth of melting zone made by CO_2 laser irradiation were remarkably increased when the PHPS film were coated on workpiece surface. The film thickness required for sufficient laser absorption to melt the aluminum alloys was about 1 μ m. After laser irradiation the PHPS film did not leave the residue on the melting zone.

REFERENCES

[1]ASM Handbook,vol.6 Welding,Blazingand Solderling;ASM International(1993)
[2]Tonen Polysilazane Technical Report :Tonen Corporation(1997)