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Surface Modification of Titanium-Titanium Boride (Ti-TiB) Composite using Low Traverse Speed Laser Beam

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Abstract — The Titanium-Titanium boride (Ti-TiB) composite was subjected to surface modification using laser surface treatment. A significant increase in surface hardness to 980 VHN, relative to 513 VHN for the untreated material occurred with a laser energy input of about 30 kJ/m, achieved with 20 and 30 mm/s traverse speed. This increase in hardness corresponds to increase in surface volume fraction of TiB whiskers to about 65 % at about 30 kJ/m and above.

Keywords : *Laser treatment, Metal matrix composites, X-ray diffraction and Scanning Electron Microscopy*

INTRODUCTION

Titanium and its alloys are being used to an increasing extent because of their low density and high mechanical strength. However, the tribological properties of Ti are relatively poor. The wear resistance can be improved by reinforcing Ti with ceramic particles like Carbon [1], Boron [2], etc. Panda et al. [3] have studied the mechanical properties of Ti-TiB composite prepared by hot sintering process introducing β-stabilizing elements like Fe and Mo. Similar work has been reported by Chandrasekar et al. [4] to improve surface hardness of Ti-TiB composite by using laser power with higher traverse speeds. The surface hardness of Ti-6Al-4V could be enhanced to 1700

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HV by alloying with BN by laser beam [5]. Surface modification with ceramic coatings could improve the surface properties. TiN, TiB and TiB_2 ceramic have an attractive combination of low density, high hardness, excellent wear and corrosion resistance [5, 6].

Surface Nitriding is done to improve the micro hardness of Titanium to about 1700 VHN [7]. Similar results have been reported with powders of Titanium carbide on Titanium surface [8].The micro structural formation and hardness of the laser melted zone were reported from the metallographic analysis. Such a hard zone was constituted with hard Titanium carbide and ductile metallic titanium. High hardness in the surface with good mechanical properties in the core has been achieved by functionally grading the materials[9,10]. Hardness value of around 1500 HV could be achieved in Ti-TiB composite prepared by this method. Several methods are employed to modify the surface of Titanium composite like Laser remelting, plasma, Physical vapour deposition and Chemical vapour deposition. The objective of the present work is to improve the hardness of the hot pressed Ti-TiB composite surface using lower traverse speed laser beam.

EXPERIMENTAL

The elemental composition (concentration %) as measured by XRF is Ti-69.898, B-15.757, Mo-8.51, Fe-5.094, Si-0.501, Al-0.217.

Surface melting of Titanium composite was carried out using 10 kW CO_2 laser system. The surface of specimens were polished and prepared for effective absorptivity of Laser power. The Laser power and traverse speed were varied for surface treatment, as shown in Table 1. The laser beam was transported by means of a beam

TABLE 1.

Laser surface treatment conditions

Power (kW)	Traverse speed (m/s)	Incident Energy/Distance traversed (Power/Traverse speed) **(kJ/m)**
1.5	0.02	75
1	0.02	50
0.6	0.02	30
0.75	0.03	25
0.6	0.03	20
0.3	0.03	10

delivery system and was focused with the help of ZnSe lens of 127 mm focal length housed in a water cooled conical nozzle. A laser spot size of 3 mm is achieved by adjusting the focal plane.

Argon gas was supplied through a nozzle to protect the melt pool from oxidation. The argon gas was purged after the samples attained room temperature. The samples were cut by Electro discharge machining (EDM) for scanning electron microscopy (SEM), X ray diffraction analysis (XRD) and Micro hardness studies.

A scanning electron microscope (Jeol JSWM 6360 model) operating at 25 kV was used to study the surface of the laser processed composite. The laser processed surface was deep etched with Krolls reagent (3 ml HF, 3 ml HNO_3 and 40 ml H_2O). The secondary electron imaging mode was used to study the micro structural modifications.

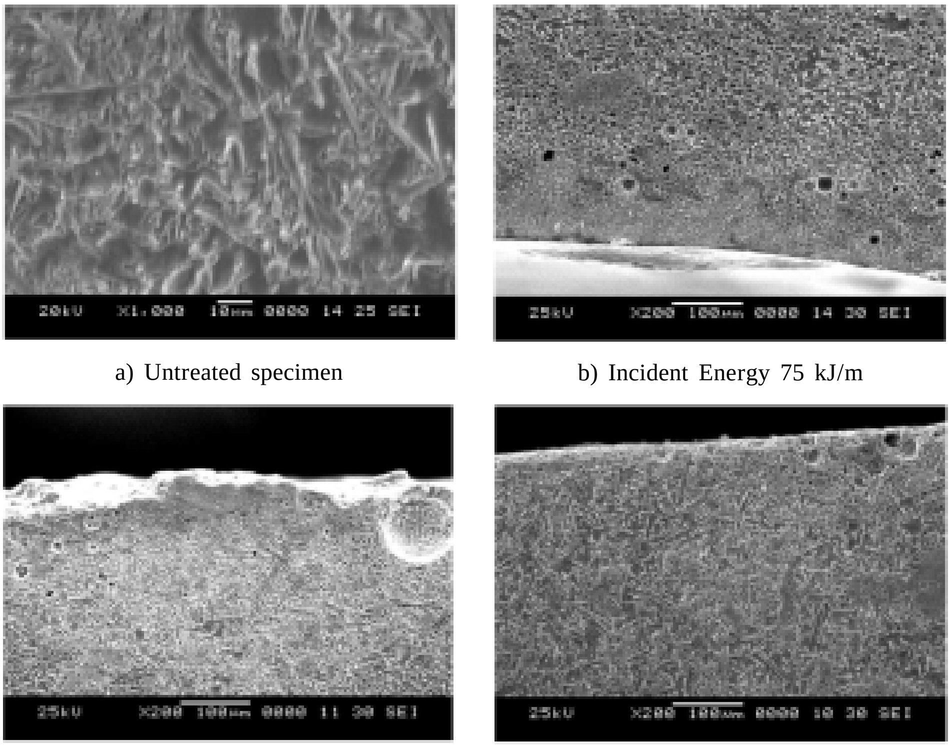
Mitutyo Microhardness tester with diamond intendor was used with 200 gm load to study the hardness values of sample from surface to interior.

RESULTS AND DISCUSSION

Microstructures

Scanning Electron Microscopy

Fig. 1 shows the SEM micrographs of TiB whisker surface on surface laser treated materials with different heat inputs (Table 1). The high magnification micrographs were taken in the SEI mode after deep etching of the sample surface to reveal the distribution of TiB whiskers. Generally, due to nucleation and growth of TiB whiskers in the laser melted pool, the diameter of TiB whiskers remains in the nano range. From SEM picture, the grain refinement is evident for 75 kJ/m treated specimen than 25 and 10 kJ/m treated specimens. Also the depth of grain refinement is more for high energy treated specimen. The SEM micrographs show a large amount of boride needles inter connected and relatively smaller TiB whiskers appearing as clusters in maximum incident energy. The samples processed with low incident energies (20 and 10 kJ/m) show considerable amount of borides on the surface, but the amounts of these borides are small compared to that in the sample treated with high incident energy. The SEM pictures were taken on the surface after polishing and etching. This is done to reveal the amount and the distribution of borides as a function of depth. This is done to confirm the boride enrichment on the surface which would contribute for the increase in the hardness of the surface. The phase contrast observed in the Ti matrix may be due to phases formed because of the contamination of C, N and O picked up during the laser processing. This is possible since the shielding gas Argon probably had traces of oxygen and nitrogen.



a) Untreated specimen b) Incident Energy 75 kJ/m

c) Incident Energy 20 kJ/m d) Incident Energy 10 kJ/m

Fig. 1. SEM micrographs of microstructures of Ti–TiB composite laser treated at power input levels indicated in the figure.

X ray diffraction analysis

Fig. 2 illustrates the X-ray diffraction patterns of the untreated Ti-TiB composite and that of the laser treated composite.

The strong peaks in the treated surfaces correspond to β-Ti phase and the TiB whiskers. For the untreated surface, the dominant β-Ti peak present is (110) β-Ti and those of TiB are $(102)_{TiB}$, $(200)_{TiB}$ and $(112)_{TiB}$. The laser treated specimens showed very pronounced $(200)_{TiB}$ at $2\theta = 29.5°$, whereas for the specimens treated with energy level above 30 kJ/m, $(102)_{TiB}$ at $2\theta = 42.5°$ becomes more predominant next to $(200)_{TiB}$ at $2\theta = 29.5°$. This $(102)_{TiB}$ is relatively less pronounced at lower incident energies (< 30 kJ/m). In the earlier work by Chandrasekar et al. [4], the specimens treated with incident energy greater than 60 kJ/m, enrichment of TiB had taken place, whereas in the present study, the enrichment is evident above 30 kJ/m. Even though both the studies are reported in terms of incident energy, the reduction in incident energy level for similar TiB enrichment in the composite surface is attributed due to variation in traverse speed. A heat transfer analysis may reveal more details on TiB enrichment for various traverse speeds.

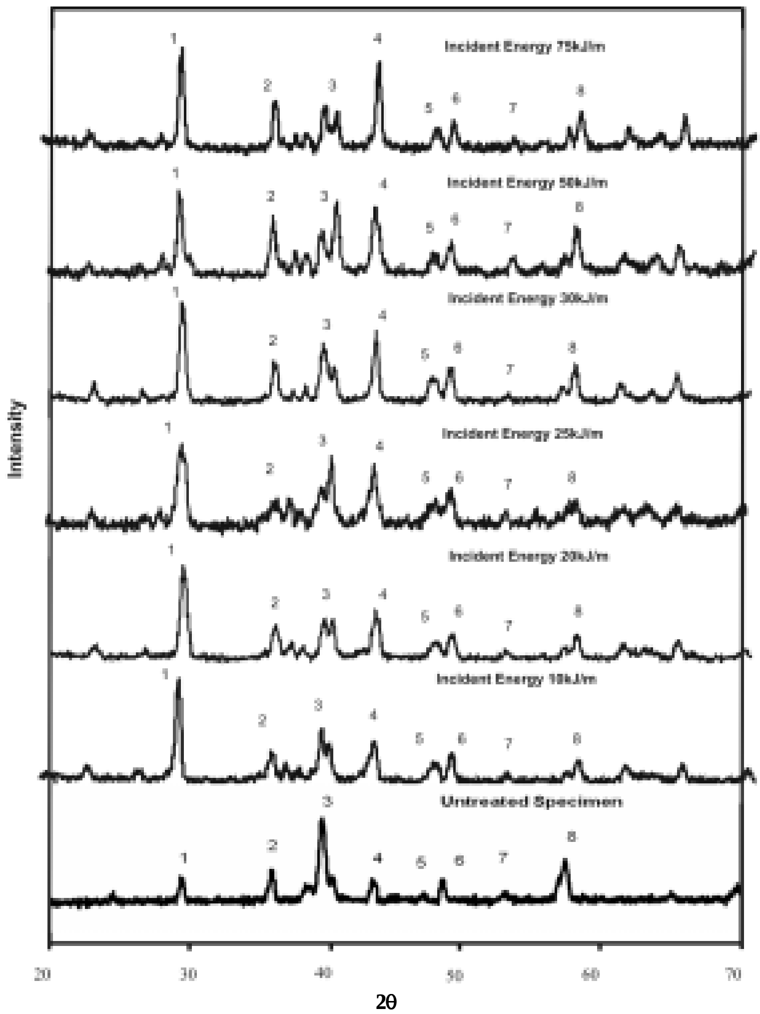


Fig. 2. X-ray diffraction patterns of the surfaces of laser treated Ti-TiB composites. X-ray peaks : 1–TiB (200), 2–TiB (201), 3–βTi (110), 4–TiB (102), 5–TiB (211), 6–TiB (301), 7–TiB (112), 8–βTi (200).

The ratio of the integrated intensity of $(200)_{TiB}$ peak to the $(110)_{\beta-Ti}$ is a measure of the relative volume fraction of TiB and β-Ti phases, as shown in a separate study[9] of Ti-TiB functionally graded materials of varying TiB volume fractions. This ratio for the surfaces laser treated at energies = 30 kJ/m is significantly larger compared to either the untreated composite or the surface treated at energies < 30 kJ/m suggesting that the amount of TiB in laser treated surfaces is substantially higher than that in the untreated bulk. The integrated intensity values are plotted against incident energies in Fig. 3 which reveals that the integrated intensity factor values are directly proportional to that of surface hardness.

Micro hardness Measurements

Fig. 3 illustrates the variation of hardness as a function of depth from the surface for all the laser treatment conditions.

In general the laser treatment has improved the hardness of specimens for all incident energies. For specimens treated with energy levels ≥ 30 kJ/m, the surface hardness has improved appreciably to around 975 VHN and the surface hardening up to a depth of about 0.7 mm could be achieved. This value is quite comparable to those achieved with carbon and boron atmospheres [1, 2]. For specimens treated with incident energy less than 30 kJ/m, the surface hardness has improved to around 800 VHN, but the depth of hardening is not appreciable.

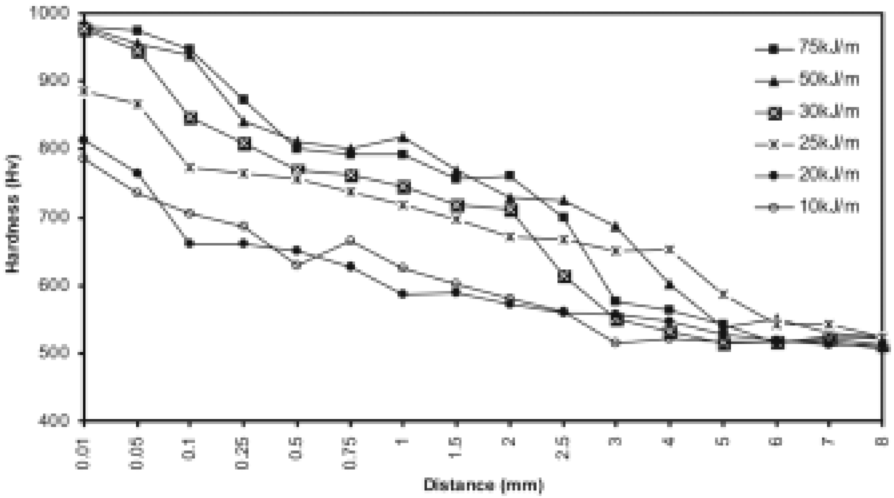


Fig. 3. Hardness as a function of depth from the laser treated surfaces

While comparing these results with the earlier reported work [4], the increase in depth of hardening to around 0.7 mm as against 0.5 mm in earlier study, the reason may be attributed to the variation in traverse speed as discussed in X-ray diffraction results. A change in nature of hardening would have taken place at incident energy ≥ 30 kJ/m, which has resulted in stabilized hardening value of around 980 VHN (Fig. 4).

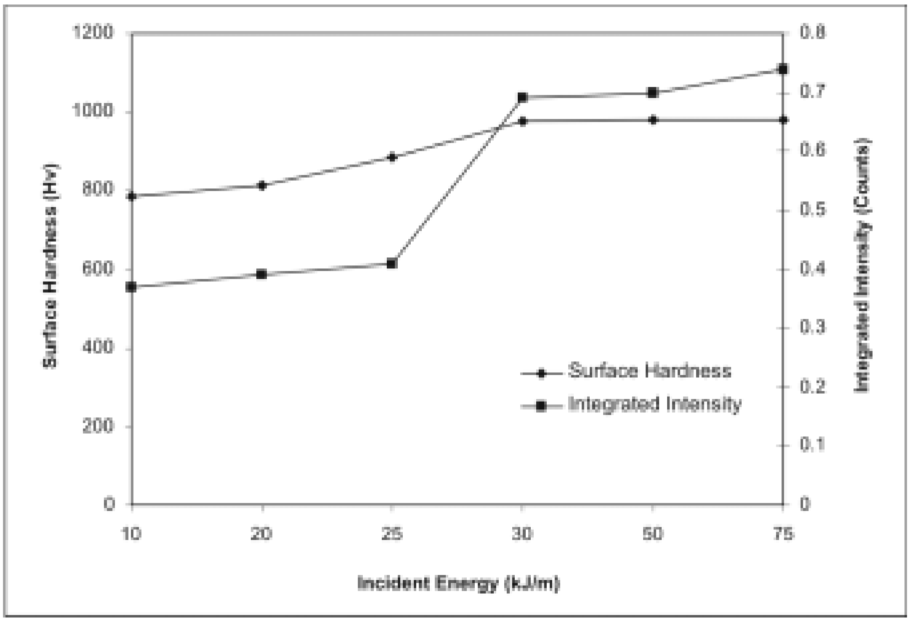


Fig. 4. Maximum surface hardness and integrated intensity of TiB/Ti as a function of laser incident energy.

The high hardness levels at and above 30 kJ/m, is clearly consistent with the intensity ratios observed in X-ray diffraction patterns- the integrated intensity ratio of the 200(TiB) peak to the (110) $_{\beta\text{-Ti}}$ peak. The higher intensity ratio means that a greater amount of TiB is formed, and this corroborates the higher hardness values (980 VHN) found at incident energies ≥ 30 kJ/m. The hardness level of 980 VHN corresponds to a Ti-TiB composite with about 65 % TiB by interpolation of hardness data of functionally graded material [9].

CONCLUSION

Laser surface treatment of Ti-34%TiB metal matrix composite leads to a substantial increase in hardness to 980 VHN at the surface, for incident energy ≥ 30 kJ/m. There appears to be a pronounced increase in concentration of TiB whiskers (estimated to be about 65 vol %) at the surface at incident energies ≥ 30 kJ/m. This lower incident energy achieved with 20 and 30 mm/s traverse speed has contributed greater B diffusion from subsurface regions to the laser melted regions. In the previously reported work [4] similar condition has been achieved for incident energies ≥ 70 kJ/m which was arrived out of 40 and 50 mm/s traverse speeds.

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