Chiang Mai J. Sci. 2010; 37(2) : 206-212
www.science.cmu.ac.th/journal-science/josci.html
Contributed Paper

Fast Processing Technique for TiC Coatings on Titanium

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Received: 4 November 2009
Accepted: 12 February 2010

ABSTRACT

Coatings of TiC on titanium by current heating technique was studied. The titanium rod was cut into the disks with about 20 mm diameter and about 1.5 mm thick. The disks were ground with SiC papers and polished with 0.05 μm alumina slurry, and then they were cleaned with acetone. In the coating process, titanium disks were placed amidst 20 mm diameter graphite powders pressed against them in the glass tube. The electric current was applied across the graphite matrix with the fixed electric powers from 100 to 180 W for 20 min in argon atmosphere.The titanium disks were characterized using XRD, SEM, EDS and microhardness tester. The coating temperature, mass change, carbon concentration and hardness increased as the applied electric power increased. TiC was detected on the titanium coated at 120 to 180 W. The hardness of the titanium coated at 180 W is the highest at 6.53 GPa.

Keywords: titanium, current heating technique, coatings, carburization.

1. INTRODUCTION

Titanium and titanium alloys have been developed and they have raised interests in recent years. They have high strength, good corrosion resistance and low density, so that, they are used in aerospace structure, engine components and other applications [1,2]. However, they have an important disadvantage which is a poor surface property at high temperature. Surface coating of high hardness, wear resistance and corrosion resistance materials can improve surface property of titanium and titanium alloys. TiC is widely used as a coating material due to its high hardness [3,4], high strength, high rigidity [5-7], good wear resistance, low friction coefficient [5-11], high melting point and high chemical stability [9].

There are many techniques for TiC synthesis such as chemical vapor deposition [10], plasma enhance chemical vapor deposition [3], sputtering [12], plasma based ion implantation [13], ion beam-assisted deposition [11] and pulsed laser deposition [5]. The current heating technique [14] is a new technique for TiC synthesis. The direct current is applied across the work piece placed in graphite matrix resulting in an increase in the temperature. When the temperature is high enough, free carbon diffuses into the work piece and reacts with titanium to form TiC on the surfaces. The process could be completed within 10 to 30 min. This study aim to synthesis TiC coating on titanium using the current heating technique. The samples

were characterized using X-ray diffraction (XRD), scanning electron microscopy (SEM), energy dispersive X-ray spectroscopy (EDS) and Knoop microhardness test.

2. MATERIALS AND METHODS

Samples were prepared from titanium rod (99.7%) with the impurities as follow : Fe 0.05at%; C 0.05at%; N 0.05at%; H 0.015at%; O 0.05at%. The rod was cut into the disks with about 20 mm diameter and 1.5 mm thick. The disks were ground with SiC papers and polished with 0.05 μm alumina slurry, and then they were cleaned with acetone. In the coating process, samples were placed amidst 20 mm diameter graphite powders pressed against them with 10.3 kPa pressure in the 26.0 mm inner-diameter glass tube as shown in Figure 1. The graphite matrix was placed on the lower electrode, and then the chamber cover was closed allowed the upper electrode to contact to the top surface of the graphite matrix. The air in the chamber was removed by a rotary pump in order to decrease the pressure to 73.3 kPa, and then the chamber was purged with the 99.99% purity argon gas. Pressure in the chamber was maintained at an atmospheric pressure with the argon flow rate of about 3 ml/min. An electric current was applied across the graphite matrix in order to increase the temperature of the sample measured by a type K thermocouple. The electric powers were kept constant at 100 to 180 W for 20 min. The current was ceased as the coating processes were completed, and then samples were removed from the chamber. Samples were characterized using XRD operated at 40 kV accelerating voltage, SEM and EDS operated at 15 kV accelerating voltage and Knoop microhardness test performed at 100 gf load and 10 s loading time.

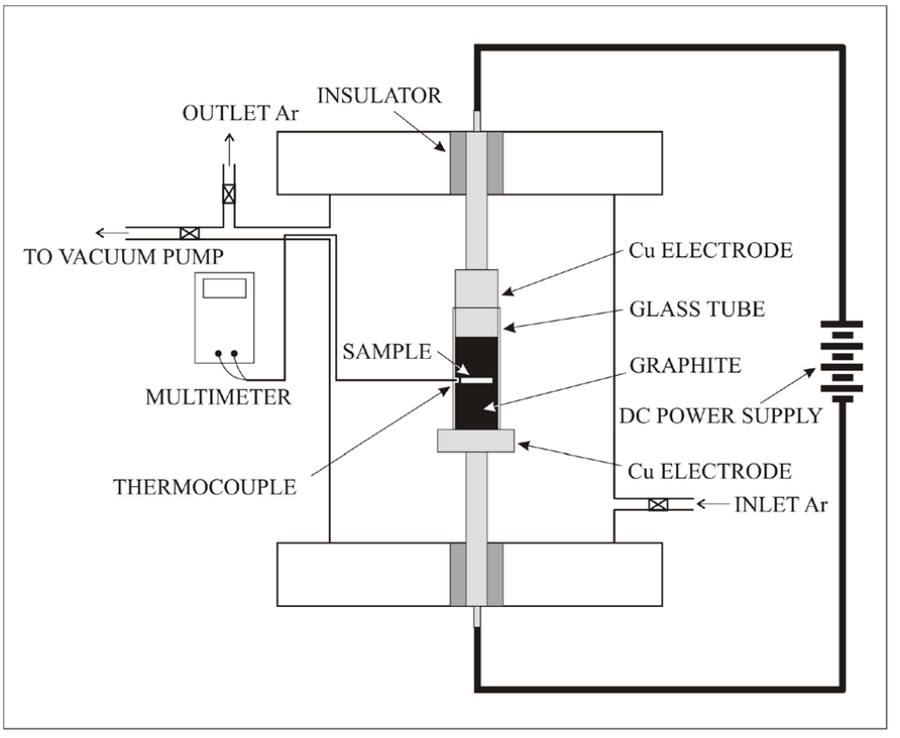

Figure 1. Schematic diagram of the apparatus used for coating process.

3. RESULTS AND DISCUSSION

The temperatures of the samples coated at 100 to 180 W are shown in Figure 2. In the coating process, the electric power was applied across the graphite matrix. Electric energy was changed into thermal energy transferred to the sample and graphite resulting in an increase in temperature. The temperature increased in a high rate at the initial period of the coating process and the rate decreased as the time increased. It shows that the temperature increased as the applied electric power increased.

According to diffusion theory, diffusion

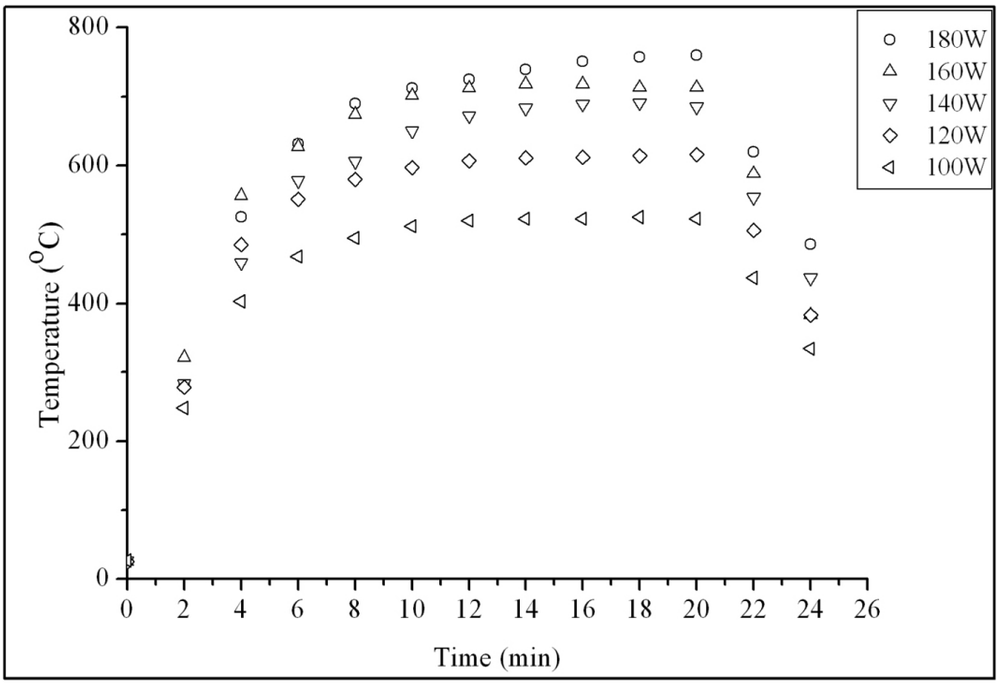

Figure 2. Temperature as a function of processing time for the titanium coated at 100, 120, 140, 160 and 180 W.

coefficient of carbon in titanium increased as temperature increased. Therefore, the quantity of carbon diffused into titanium increased and it was reflected in the mass change of the samples shown in Figure 3. It is evident that mass change of the samples increased as the applied electric power increased. The carbon diffused into the titanium could be detected by EDS. The EDS spectra for the sample coated at 100 W and 140 W are shown in Figutr 4. The intensity of carbon for the sample coated at 100 W is lower than that of 140 W. There are the Au peaks appeared in the EDS spectra due to the coating of gold on the samples required for the EDS operation. Figure 5 shows the carbon concentration analyzed by EDS. The trend shows that carbon concentration increased as the applied electric power increased. The analysis is in accord to the result of mass change. Some dissolved carbon reacted with titanium and formed titanium carbide as the reaction : $Ti + C \rightarrow TiC$. Some carbon which did not form with titanium were left as graphite and amorphous carbon appeared in the sample. TiC and graphite could be detected by XRD.

XRD patterns in Figure 6 show the detection of Ti, graphite and TiC in the samples coated at 120 to 180 W. There was no detection of TiC in the sample coated at 100 W, only Ti and graphite were detected. The formation of TiC depended on the carbon concentration in the sample. The results show that the carbon concentration in the samples coated at 120 to 180 W, which is about 28 at% and above, was adequate for the formation of TiC. The trend shows that the intensity of TiC peaks increased and those of Ti decreased as the applied electric power increased. SEM micrographs for uncoated titanium and the titanium coated at 120 W are shown in Figure 7. The micrographs show the difference between a plain surface of the uncoated titanium and a rough surface of the titanium coated at 120 W resulting from the formation of the new phase, which could be TiC, on the surface. The results reflect the formation of TiC as a coating layer on the titanium.

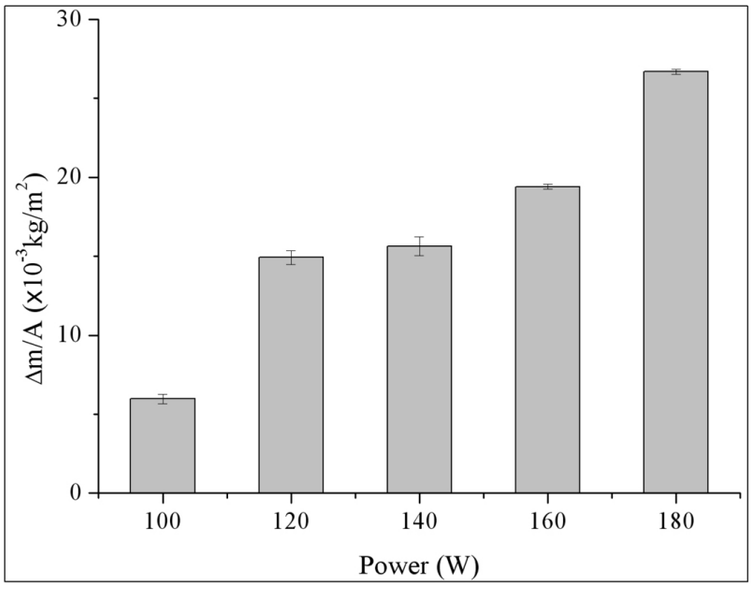

Figure 3. Mass change of coated titanium as a function of applied electric power.

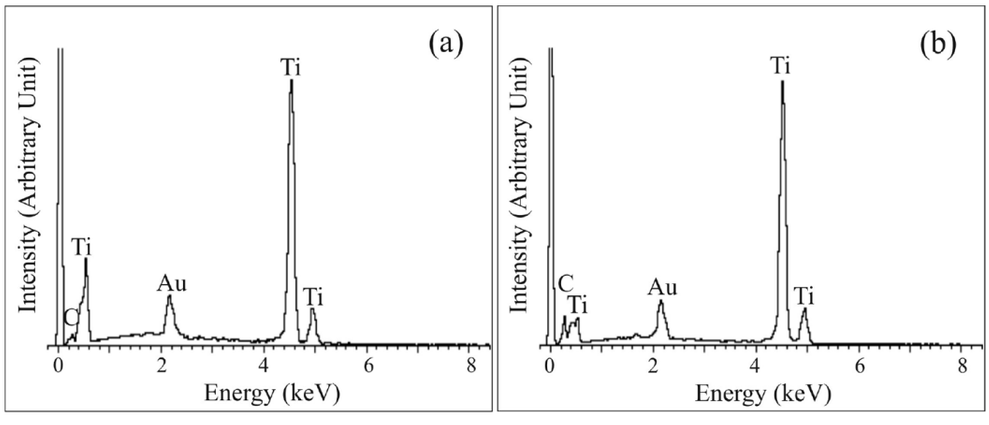

Figure 4. EDS spectra for titanium coated at (a) 100 W and (b) 140 W.

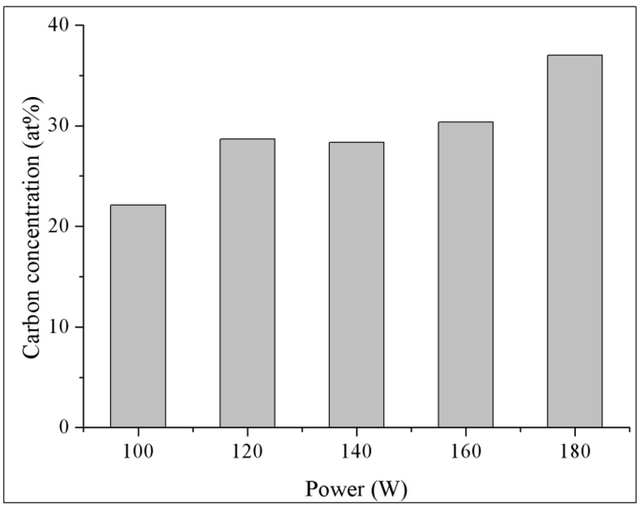

Figure 5. Concentration of carbon in the coated titanium as a function of applied electric power.

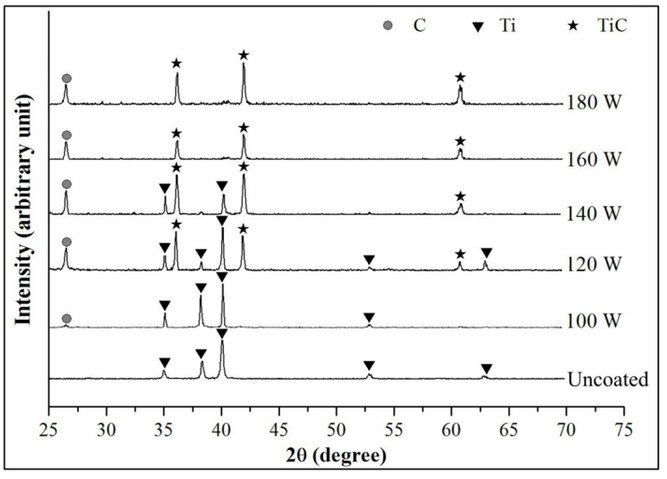

Figure 6. XRD patterns for uncoated titanium and the titanium coated at 100, 120, 140, 160 and 180 W.

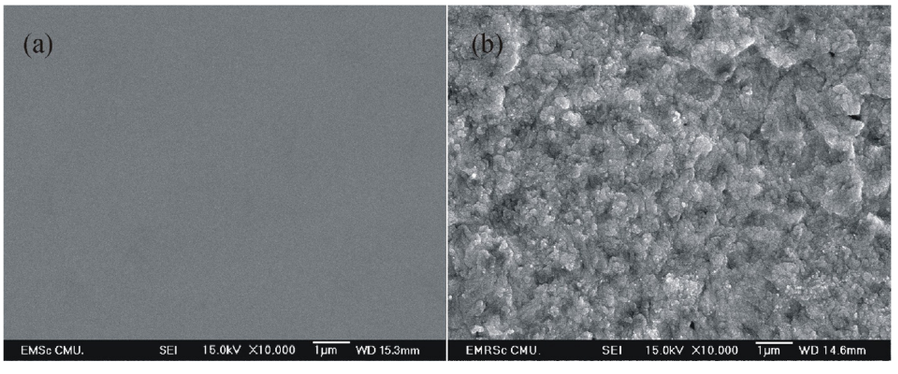

Figure 7. SEM micrographs for uncoated titanium and the titanium coated at 120 W.

Hardness of the uncoated sample and the samples coated at 100, 120, 140, 160 and 180 W are shown in Figure 8. Hardness of the sample is influenced by the hardness of TiC forming on the surface of titanium and by the hardness of titanium substrate. The hardness of TiC is about 26 to 35 GPa [3-4] and the hardness of titanium substrate measured from the uncoated sample was about 1.63 GPa. The hardness of samples which have high content of TiC would be influenced by TiC formed on the surface more than by the titanium substrate. Therefore, the hardness of the samples increased as the applied electric power increased. The hardness of the sample coated at 180 W is the highest at 6.53 GPa.

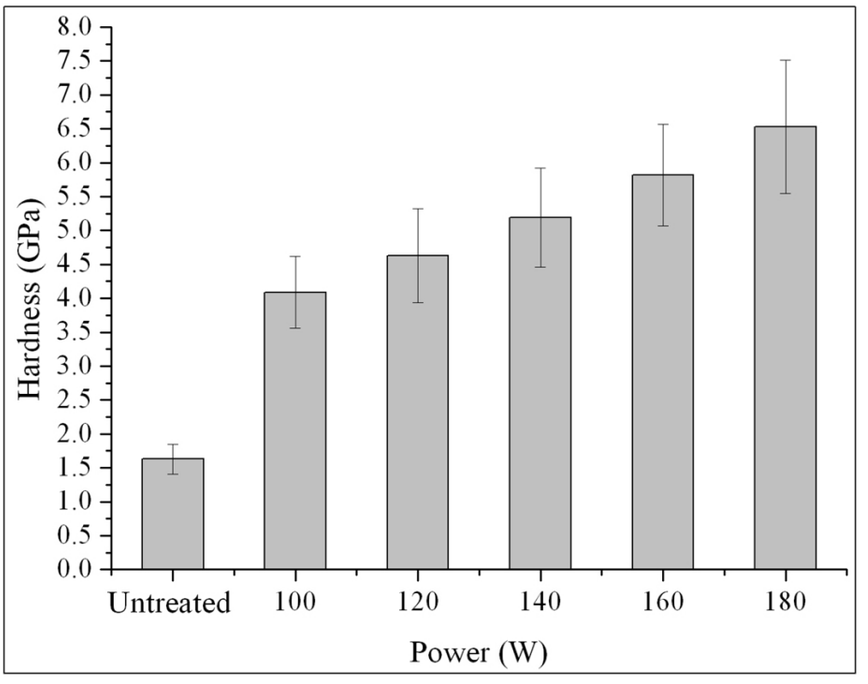

Figure 8. Hardness of uncoated titanium and the titanium coated at 100, 120, 140, 160 and 180 W.

4. CONCLUSIONS

Coating of TiC on titanium was succeeded using the current heating technique operated at 120 to 180 W for 20 min. The coating temperature increased as the applied electric power increased resulting in an increase in the mass change and the carbon concentration. The carbon concentration in the titanium coated at 120 to 180 W, which is about 28 at% and above, was adequate for the formation of TiC. The hardness of the coated titanium increased as the applied electric power increased. The hardness of the titanium coated at 180 W is the highest at 6.53 GPa.

ACKNOWLEDGEMENTS

This study was supported by the Faculty of Science, Chiang Mai University, Thailand.

REFERENCES

[1] ASM International Handbook Committee, Introduction to titanium and titanium alloys; in *ASM Handbook, Metals Handbook, Volume 2 Properties and Selection: Nonferrous Alloys and Special-Purpose Materials*, Formerly 10th ed., ASM International, U.S.A., 1998: 587-590.

[2] Boonruang C., Thongtem T., McNallan M. and Thongtem S., *Mater. Lett.*, 2004; **58**: 3175-3181.

[3] Kusano E., Satoh A., Kitagawa M., Nanto H. and Kinbara A., *Thin Solid Films*, 1999; **343-344**: 254-256.

[4] Pancielejko M., Precht W. and Czyzniewski A., *Vacuum*, 1999; **53**: 57-60.

[5] Soto G., *Appl. Surf. Sci.*, 2004; **230**: 254-259.

[6] Rawat R.S., Lee P., White T., Ying L. and Lee S., *Surf. Coat. Technol.*, 2001; **138**: 159-165.

[7] Santerre F., El Khakani M.A., Chaker M. and Dodelet J.P., *Appl. Surf. Sci.*, 1999; **148**: 24-33.

[8] Fang T.H., Jian S.R. and Chuu D.S., *Appl. Surf. Sci.*, 2004; **228**: 365-372.

[9] Suda Y., Kawasaki H., Doi K., Nanba J. and Ohshima T., *Mater. Charact.*, 2002; **48**: 221-228.

[10] Li G. and Xia L.F., *Thin Solid Films*, 2001; **396**: 16-22.

[11] López J.M., Gordillo-Vázquez F.J., Fernández M., Albella J.M., Cáceres D. and Vergara I., *Appl. Surf. Sci.*, 2001; **172**: 110-116.

[12] Kusano E., Sato A., Kikuchi N., Nanto H. and Kinbara A., *Surf. Coat. Technol.*, 1999; **120-121**: 378-382.

[13] Ma X., Sun Y., Wu P., Xia L. and Yukimura K., *Surf. Coat. Technol.*, 2003; **169-170**: 375-378.

[14] Singjai P., Wongjamras A., Yu L.D. and Tunkasiri T., *Chem. Phys. Lett.*, 2002; **366**: 51-55.