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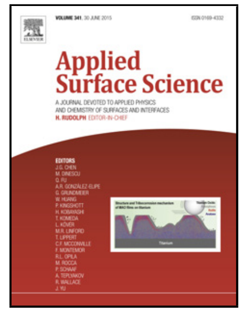

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PII: S0169-4332(15)01608-6
DOI: http://dx.doi.org/doi:10.1016/j.apsusc.2015.07.043
Reference: APSUSC 30768

To appear in: *APSUSC*

Received date: 4-5-2015
Revised date: 23-6-2015
Accepted date: 8-7-2015

Please cite this article as: O.G. Lenivtseva, I.A. Bataev, M.G. Golkovskii, A.A. Bataev, V.V. Samoilenko, N.V. Plotnikova, Structure and properties of titanium surface layers after electron beam alloying with powder mixtures containing carbon, *Applied Surface Science* (2015), http://dx.doi.org/10.1016/j.apsusc.2015.07.043

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Structure and properties of titanium surface layers after electron beam alloying with powder mixtures containing carbon

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Abstract

The structure and tribological properties of commercially pure titanium (cp-Ti) samples after non-vacuum electron beam surface alloying with carbon were studied. Two types of powders were used to introduce carbon in surface layer of cp-Ti: titanium carbide (TiC) and mixture of pure titanium and graphite ("Ti + C"). Single layer and multilayer coatings were studied. Application of electron beam for alloying provided cladding rate of 4.5 m^2/h. The thickness of the clad coatings was 1.6 - 2.0 mm. The main phases received after "Ti + C" powder cladding were α-titanium, TiC, and retained graphite. In the samples obtained by cladding of TiC, graphite was not observed. A factor determining the microhardness and tribological properties of the cladded layer was the volume fraction of TiC. Maximum coating microhardness of 8 GPa was obtained by cladding of single layer of TiC powder or two layers of the "Ti + C" mixture. Two types of tests were carried out to evaluate the wear resistance of the samples. In friction tests against loose abrasive particles, the wear rate of the best samples was 9.3 times lower than that of cp-Ti. In wear tests using fixed abrasive particles, the relative wear resistance of the best samples was 2.3 times higher than that of cp-Ti.

Keywords: titanium; electron beam cladding; metallography; wear resistance

1. Introduction

One method of increasing the hardness and wear resistance of titanium and titanium alloys is surface alloying using high-concentration energy sources. Laser [1-7] and electron beam processing [8-16] are the most widely used methods for this purpose. Many studies have proved the effectiveness of surface alloying of titanium alloys with carbon [1, 12, 16]. Even small amounts of carbon when combined with titanium led to the formation of extremely hard carbides. Laser cladding of TC4 titanium alloy (6.5 % Al, 4.26 % V, and Ti) with a powder mixture of titanium carbide (TiC) and titanium (Ti) resulted in a hardness of 1400 HV in the surface layer, which is 4.5 times the hardness of the substrate (300 HV) [17]. The starting material for surface alloying with carbon is typically a graphite powder [1, 12, 16, 18] or a TiC powder [7, 9, 10, 17, 19, 20].

The main parameter determining the microhardness and wear resistance of surface alloyed layers is the volume fraction of TiC particles. According to the data of [21], the tribological properties of surface alloyed layers were significantly improved with the formation of more than 24 % TiC in the surface layer. However, even at 8 % TiC, the ductility of the material was drastically reduced.

The properties of a surface titanium layer reinforced with TiC particles depend on their morphology. The smaller the size of the TiC dendrites used, the higher the hardness of the

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