Available online at www.sciencedirect.com
SCIENCE DIRECT®
Vacuum 78 (2005) 423–426
VACUUM
SURFACE ENGINEERING, SURFACE INSTRUMENTATION & VACUUM TECHNOLOGY
www.elsevier.com/locate/vacuum

Phase structure of the Fe–Ti layers produced by the IPD method

Katarzyna Nowakowska-Langier[a,*], Krzysztof Zdunek[a], Michał Kopcewicz[b]

[a]*Faculty of Materials Science and Engineering, Warsaw University of Technology, Wołoska 141, 02-507 Warsaw, Poland*
[b]*Institute of Electronic Materials Technology, Wólczyńska 133, 01-919 Warsaw, Poland*

Abstract

This paper is concerned with the synthesis of Fe–Ti layers under the impulse mass and energy transport. The synthesis method employed in the present study was impulse plasma deposition. The synthesis processes were conducted in an apparatus equipped with two independent impulse plasma accelerators operated alternately. The material was an Fe–Ti alloy. The sources of Fe and Ti were the internal electrodes of the impulse plasma accelerators, made of titanium and iron. The phase structure of the Fe–Ti layers was studied using X-ray diffraction and conversion electron Mössbauer spectroscopy (CEMS). The phases identified were α-Fe, α-Ti, β-Ti bcc-Fe(Ti), crystalline intermetallic FeTi, amorphous FeTi and amorphous Fe–Ti–C.

Keywords: IPD method; Fe–Ti alloy; CEMS; XRD

1. Introduction

As is known, the IPD method utilizes the impulse plasma [1] generated and accelerated in a coaxial generator by the Ampere force [2]. The consecutive plasma packs with a lifetime of about 100 μs are generated at a specified frequency and ejected in the form of ion packs from the accelerator toward the substrate at a velocity of about 10^4 m/s. The structure and dynamics of the impulse plasma has already been described in our earlier publications [3,4].

Characteristically, the layer growth mechanism in the IPD method consists of the uncompleted coalescence of the clusters formed in the plasma itself and delivered onto the cold surface of the substrate [5].

2. Experiment

A schematic view of the multi-accelerator apparatus for the fabrication of the Fe–Ti layers

*Corresponding author. Tel.: +48 22 660 85 49; fax: +48 22 660 87 05.
E-mail address: kaha@inmat.pw.edu.pl (K. Nowakowska-Langier).

0042-207X/$ - see front matter © 2005 Elsevier Ltd. All rights reserved.
doi:10.1016/j.vacuum.2005.01.060

by the IPD method is shown in Fig. 1. The internal electrodes of each of the two impulse plasma coaxial accelerators installed in this apparatus were made of iron and titanium, respectively. The outer electrodes were made of ARMCO iron. The plasma processes were carried out in a hydrogen atmosphere under a dynamic pressure of 20 Pa. The layers were produced on tantalum substrates. The substrates were installed perpendicular to the axis of the accelerator electrodes. The plasma generation rate was 0.2 Hz. The chemical composition of the layer expressed as the Fe/Ti ratio was: 5/1, 2/1, 1/1 and 1/2. To achieve, for example, the Fe/Ti ratio = 5/1, each 5 plasma impulses generated from the accelerator equipped with an iron electrode were followed by 1 plasma impulse generated from the other accelerator equipped with a titanium electrode. The successive portions of Fe and Ti were deposited independently and separately, according to the schedule that specified the number and proportion of the impulses generated by each accelerator. The work of the accelerators was controlled by a microprocessor system. The layers were produced using 3000 plasma impulses.

The structural properties of the thin Fe–Ti layers were determined as functions of the Fe/Ti ratio (5/1, 2/1, 1/1 and 1/2).

The microstructure of the Fe–Ti layers was characterized by Fe^{57} conversion electron Mössbauer spectroscopy (CEMS) and X-ray diffraction (XRD).

The CEMS measurements were performed at room temperature. A computer-controlled spectrometer with a ^{57}Co-in-Rh source was used. The isomer shifts were determined with respect to the α-Fe standard. The Mössbauer spectral parameters (hyperfine fields, H_{hf}, quadrupole splitting, QS and isomer shifts, IS) were obtained by fitting the Lorentzian line shapes to the experimental data by the least squares method using the NORMOS program [6]. The XRD measurements were carried out in the Bragg–Brentano geometry by using Cu–K_α radiation.

3. Results and discussion

Fig. 2 shows the CEM spectra recorded for the Fe–Ti layers with the Fe/Ti ratios 5/1, 2/1, 1/1 and 1/2. As seen from the variation of the shape of the Mössbauer spectra, the phase structures strongly depend on this ratio. For the layers with the Fe/Ti ratios: 5/1, 2/1 and 1/1 (Fig. 2a–c), the CEM spectra consist of three magnetically split components (i) one due to the α-Fe phase ($H_{hf} = 32.92$ T, IS = 0.00 mm/s), and (ii) two sextets due to the Ti atoms in the bcc structure (bcc-Fe(Ti)) with hyperfine fields of about 30 T and 26 T and isomer shifts 0.008 and 0.04 mm/s, respectively.

According to Vincze [7], the Ti atoms are located in the first and second coordination spheres, and thus, the hyperfine field at the iron sites is reduced. Due to the Ti impurities in the first

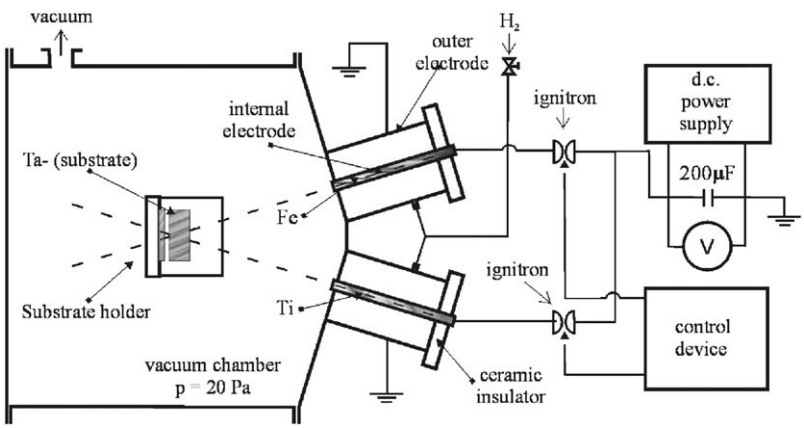

Fig. 1. Schematic view of the multi-accelerator apparatus for the fabrication of the Fe–Ti layers.