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Studies on sputtering process of multicomponent Zr–Ti–Cu–Ni–Be alloy thin films

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Abstract

Sputter deposition process of a multicomponent Zr–Ti–Cu–Ni–Be metallic alloy has been studied experimentally and by numerical simulations. Monte-Carlo simulations were performed using a model based on thermalization and diffusion of sputtered atoms. Incident energy and angle of sputtered atoms on substrate were obtained from simulations. The incident angular distribution was observed to be a normal distribution at all sputtering pressures. Average incident kinetic energy of the condensing atoms on the substrate was observed to be 0.2–0.3 eV indicating most of them are thermalized. Simulations were extended to predict compositional variations in films prepared at various process conditions. These results were compared with composition of films determined experimentally using Rutherford Backscattering Spectrometry (RBS). Contents of Zr, Ti, Cu and Ni quantified using RBS were in moderate agreement with the simulated composition. Be could not be quantified accurately by RBS largely due to very low energy peak of Be in the spectrum. These studies are shown to be useful in understanding the complexities in multicomponent sputtering. © 2005 Elsevier Ltd. All rights reserved.

Keywords: Monte-Carlo simulations; Multicomponent thin films; Sputtering

1. Introduction

Micro electro mechanical systems (MEMS) have been the subject of intense research activity in the

last two decades due to their technological potential and wide applications. MEMS devices with superior performance including increased functioning, reliability, robustness, long life and high safety are required. However, failure of MEMS devices due to wear of micromechanical components has been a common problem. Several methods [1–4] have been proposed to overcome wear of MEMS components. We propose to use

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high strength, flexible amorphous metallic alloy thin films for fabricating MEMS structures. Thin film metallic glasses exhibit high yield strength, a large elastic limit and a low Young's modulus in addition to good wear and corrosion resistance [2]. These materials also possess mechanical isotropy, structural homogeneity and absence of crystalline defects such as lattice defects, grain boundary, segregation, etc. making them suitable for MEMS fabrication. We have developed processes to make metallic glass thin films from a Zr–Ti–Cu–Ni–Be alloy by sputtering.

Sputter deposition of a multicomponent material such as Zr–Ti–Cu–Ni–Be alloy is complex due to their inhomogeneous distribution of plasma density, angular ejection of sputtered atom, differential sputtering yield of individual elements, differential transport of sputtered atoms and selective condensation at the substrate, all of which affect composition and hence properties. A detailed study on effect of process parameters is necessary to predict the properties and tailor-make the films. To better understand the sputtering process and predict compositional profiles, Monte-Carlo simulations have been made initially to estimate the compositions in a diode-sputtering configuration. Simulations based on the ejection and transport of sputtered atoms, have been carried out in the present study. The sputtering process can be described well as having three aspects namely, physical sputtering, gas phase transport and the resulting thin film growth. In the first process, important quantities for atoms ejected from the target are sputtering yield, their energy and angular distribution. The initial energy and angular distribution are well described by Sigmund–Thomson distribution [5]. Gas phase transport of sputtered atoms has been dealt both analytically (by Valles-Abarca et al. [6]), and numerically (e.g., by Yamazaki et al. [7]). Analytical models based on continuous energy loss approximation were used to derive expressions for the average kinetic energy of the non-thermalized part of the sputtered flux as a function of distance from the target. However, such approximation neglects the scattering of sputtered atoms and hence, detailed information on the energy and angular distribution of incident atoms on substrate

cannot be obtained. We have used a model based on thermalization and diffusion of sputtered atoms based on Motohiro et al.'s work [8]. Under an assumption of energy-dependant collision cross-section, the model includes scattering due to collisions and is able to calculate the parameters of sputtered atoms on the substrate in detail. Simulation of sputter deposition process has been reported recently for single elemental targets [9,10]. However, no detailed study has been reported earlier on the processes involved in sputtering complex, five elemental target such as Zr–Ti–Cu–Ni–Be.

The present study is concerned with sputter deposition of a multielemental Zr–Ti–Cu–Ni–Be target. Information on energy, angle of impact on the substrate and subsequently the composition of the films have been evaluated by Monte-Carlo simulations at different processing conditions. To compare the simulated results with the experimentally obtained composition data, careful experiments were designed and performed to extract the composition by Rutherford Backscattering Spectrometry (RBS), in particular, the contents of Be. These results will be discussed in detail.

2. Experimental details

In this study, a home built DC/RF magnetron sputtering system was utilized to fabricate the Zr–Ti–Cu–Ni–Be thin films. The arc-melted target 3 in in diameter and 0.25 in in thickness, was obtained from Liquidmetal Technologies [11]. The vacuum chamber was pumped down to 1.5×10^{-5} mbar using a cryopump and argon flow at 30 sccm was controlled by adjusting a throttle valve to produce the required pressure. Argon gas pressure was varied between 6×10^{-3} and 1.33×10^{-1} mbar and the RF power varied between 100 and 300 W. Pre-sputtering was carried out for 10 min. The thickness of the deposited thin films ranged between 5000 and 7000 Å as determined by surface profilometric measurements. The structure of the thin films was analyzed by X-ray diffraction (Philips model X'pert Pro) and composition by RBS (model Ionix 1.7 MU Tandetron).

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