Surface & Coatings Technology 302 (2016) 107–116

Contents lists available at ScienceDirect

Surface & Coatings Technology

journal homepage: www.elsevier.com/locate/surfcoat

Effect of deposition parameters on the microstructure and deposition rate of germanium-carbon coatings prepared by plasma enhanced chemical vapor deposition

H. Jamali *, R. Mozafarinia, A. Eshaghi

Department of Materials Engineering, Malek-Ashtar University of Technology, Isfahan, Iran

ARTICLE INFO

Article history:
Received 3 April 2016
Revised 28 May 2016
Accepted in revised form 29 May 2016
Available online 31 May 2016

Keywords:
Germanium-carbon coating
Microstructure characterization
Surface topography
Deposition rate

ABSTRACT

Germanium-carbon ($Ge_{1-x}C_x$) coatings have been prepared by plasma enhanced chemical vapor deposition (PECVD). The effects of different deposition parameters, including flow rate ratios of GeH_4:CH_4 precursors, RF power and deposition pressure, on the microstructure and deposition rate were investigated. Microscopic investigation and surface topographic evaluation of coatings were performed using field emission scanning electron microscopy (FESEM) and atomic force microscopy (AFM), respectively. Based on the results, the germanium-carbon coatings exhibit a completely dense structure without any pores, cracks and non-uniformity. The results indicated that the deposition rate of coatings had a direct proportion to deposition pressure and GeH_4:CH_4 flow ratio. Whereas, with increasing the RF power, the deposition rate firstly increased and then decreased. The surface topographic investigation revealed that the surface roughness of coatings was remarkably dependent on the deposition rate and plasma etching effects.

1. Introduction

In the recent years, germanium-carbon (Ge_{1-x}-C_x) coatings have been received with high interest because of their numerous extraordinary optical, electrical, and structural properties. The refractive index of germanium-carbon coatings can be varied over a very wide range (2–4) with the ratio varying of C and Ge, thereby making germanium-carbon coatings potential candidates for the design and preparation of multilayer protective antireflective coatings in infrared windows [1–3]. In addition, germanium-carbon coatings may provide the apparent tunability of the band gap in a wide range. This important characteristic can be used for next generation photovoltaic applications [4–7].

Although up to now, some properties of germanium-carbon coatings prepared by the different method such as plasma enhanced chemical vapor deposition (PECVD) [8–11], X-ray chemical vapor deposition [12,13], RF co-sputtering [14–16], and RF reactive sputtering [17–20] have been studied, but such limited investigations are not enough for development of these coatings. Moreover, most researches have been conducted on structural and bonding characteristics of germanium-carbon coatings, but microscopic characterization of these coatings have not been fully investigated so far. Therefore, in the current work, a systematic study with focus on the effect of deposition parameters, including gas precursors flow ratio, RF power and deposition pressure, on the microstructure and deposition rate of germanium-carbon coatings was performed. For this intention, germanium-carbon coatings have been prepared by PECVD and characterized by field emission scanning electron microscopy (FESEM) and atomic force microscopy (AFM). This can provide some substructure for the development of germanium-carbon coatings deposited by PECVD.

2. Experimental procedures

2.1. Preparation of coatings

Germanium-carbon coatings were deposited on glass substrates by PECVD technique with mixture of germane (GeH_4, 99.999%, Foshan Huate Gas, China) and methane (CH_4, 99.995%, Technical Gas Services, China) gases as the precursor. To this end, a parallel plate RF glow discharge stainless steel reactor (13.56 MHz) was employed. The substrates were ultrasonically cleaned in the deionized water and OP-120 solution for 10 min and in the deionized water for 10 min consecutively. Finally, the substrates were dried by a blow dryer. In order to perform

Table 1
Plasma etching parameters.

RF power (W)	100
Background vacuum (Torr)	9×10^{-5}
Flow rate of Ar (sccm*)	30
Work pressure (Torr)	0.1
Time (min)	15

* standard cubic centimeter per minute.

* Corresponding author.
E-mail address: h.jamali@mut-es.ac.ir (H. Jamali).

http://dx.doi.org/10.1016/j.surfcoat.2016.05.081

Table 2
Deposition parameters of germanium-carbon films.

Experiments	RF power (W)	Deposition pressure (Torr)	Flow rate of GeH_4 (sccm)	Flow rate of CH_4 (sccm)	Flow rate ratio of GeH_4:CH_4
A1	120	0.04	0.06	0.6	1:10
A2	120	0.05	0.08	0.8	1:10
A3	120	0.12	0.30	3.0	1:10
A4	120	0.20	0.70	7.0	1:10
B1	60	0.05	0.08	0.8	1:10
B2	100	0.05	0.08	0.8	1:10
B3	120	0.05	0.08	0.8	1:10
B4	160	0.05	0.08	0.8	1:10
C1	120	0.05	0.15	0.00	1:0
C2	120	0.05	0.10	0.4	1:4
C3	120	0.05	0.08	0.8	1:10
C4	120	0.05	0.06	1.2	1:20

the deposition process, after placing the samples in the reactor, the chamber was evacuated by rotary and diffusion pumps to 9×10^{-5} Torr. Then, for the activation of substrate surface and consequently, the improvement of the coating adhesion, plasma etching process was done in the argon plasma environment. The details of plasma etching are listed in Table 1. Afterwards, the background vacuum (9×10^{-5} Torr) provided again and at a given RF power and based on the deposition pressure and precursors flow rate ratio, germane and methane gases were fed into the deposition chamber under the precise control of digital mass flowmeters. In order to investigate the influences of the deposition parameters, including RF power (A), flow rate ratio of GeH_4:CH_4 precursors (B) and deposition pressure (C) on the microstructure and deposition rate of germanium-carbon coatings, the coatings were deposited under different conditions in three experiments groups presented in Table 2. In each experiments group, only one parameter was varied with the other parameters kept constant.

2.2. Characterization of coatings

The microscopic characteristics of the coatings were investigated by a field emission scanning electron microscope (FESEM; MIRA3-TESCAN, Czech Republic). A thin gold coating was evaporated onto the surface of specimens for electrical conductivity before microscopic observations.

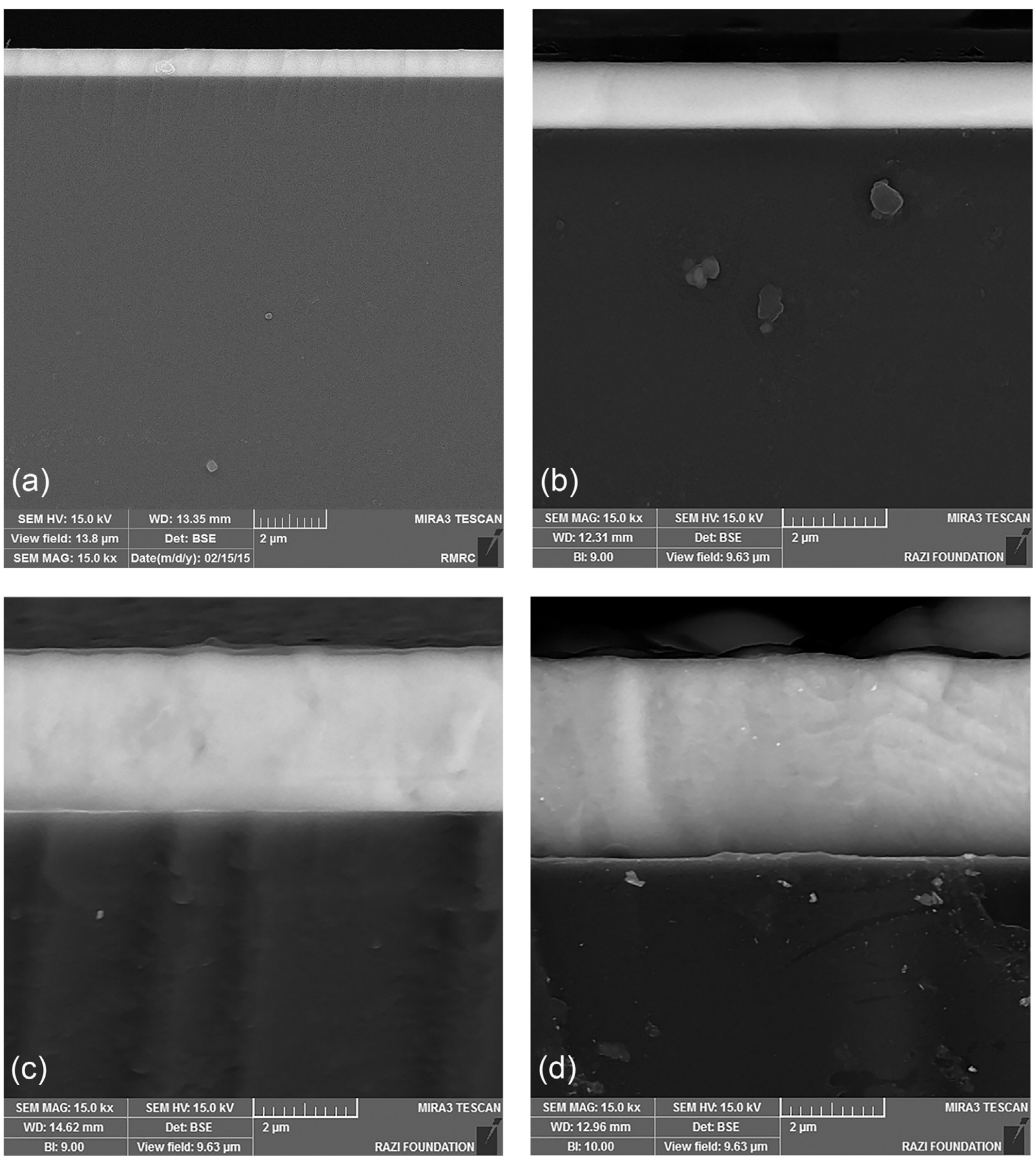

Fig. 1. FESEM micrographs of the fractured cross-section of germanium-carbon coatings deposited at different deposition pressures; a) 0.04 Torr, b) 0.05 Torr, c) 0.12 Torr and d) 0.20 Torr.