



Ion beam induced interface mixing of Ni on PTFE bilayer system studied by quadrupole mass analysis and electron spectroscopy for chemical analysis

Jai Prakash^{a,*}, A. Tripathi^b, S.A. Khan^b, J.C. Pivin^c, F. Singh^b, Jalaj Tripathi^a, Sarvesh Kumar^d, D.K. Avasthi^b

^a Department of Chemistry, M.M.H (P.G) College, Ghaziabad-201001, India

^b Inter University Accelerator Centre, Aruna Asaf Ali Marg, New Delhi-110067, India

^c CSNSM, IN2P3-CNRS, Batiment 108, F-91405 Orsay Campus, France

^d Department of ASH (Physics), C. I. T. M., Aravali Hills, Sector-43, Faridabad 121 001, India

ARTICLE INFO

Article history:

Received 16 November 2009

Received in revised form

29 January 2010

Accepted 1 February 2010

Keywords:

Swift heavy ions (SHI)

Polytetrafluoroethylene (PTFE)

Ion beam mixing (IBM)

Ion track chemistry

ABSTRACT

We have investigated interfacial chemistry in a 100 nm Ni on PTFE (polytetrafluoroethylene) bilayer system induced by 120 MeV Au ions with fluences varying from 1×10^{12} to 5×10^{13} ions/cm². In-situ quadrupole mass analysis (QMA) shows emission of Fluorine (F) and different fluorocarbons (C_xF_y) such as CF, CF₃, C₂F₃ etc. during irradiation. Electron spectroscopy for chemical analysis (ESCA) studies show that Ni reacts with chemically reactive species such as F⁻/F* and C_xF_y ions or radicals emitted during irradiation forming NiF₂ and metal-polymer complexes (-CFNi-). Rutherford backscattering spectrometry (RBS) was used to analyze the atomic transport at the interface and strong interface mixing is observed at the ion fluence 5×10^{13} ions/cm². Atomic force microscopy (AFM) studies before and after irradiation show that surface roughness is increased from 6.9 to 12.4 nm with increasing fluence. Observed results have been explained on the basis of the chemical reactions taking place within molten ion tracks in the polymer and hot zones around the ion paths created in the Ni film. The studies show that swift heavy ion irradiation introduces strong chemical alteration in the system and induces chemical reactions within the ion track, which enhance ion beam mixing in Ni-PTFE bilayer systems.

© 2010 Elsevier Ltd. All rights reserved.

1. Introduction

Swift Heavy ions (SHI) when passing through a material, cause materials modification by inducing a high degree of localized electronic excitation. The magnitude of the effect on the target material depends mainly on the electronic energy loss of the ion and also on the material properties [1,2]. Materials under ion irradiation undergo significant atomic rearrangement which can be explained on the basis of either Coulomb explosion model [3] or thermal spike model [4]. In the Coulomb explosion model it is assumed that when ion passes through a material, it creates a cylindrical zone of positively charged ions. Strong repulsion takes place among the positively charged ions and they are pushed out of the track and a region of reduced atomic density is left behind, termed as the ion track. However, this state is not stable and it may

lead to atomic motion towards the centre of the cylindrical zone, resulting in a perturbed ion track of radius of few nm. Coulomb explosion mainly takes place in insulators and is not applicable for the metals due to the presence of free electrons which neutralize the ionized atoms very quickly. In the thermal spike model it is assumed that, at first, energy is transferred to the electronic subsystem within a few 10^{-15} s and then via electron-phonon (e-p) coupling to the lattice within a few 10^{-13} s. Subsequently, it leads to an increase in the lattice temperature ($\sim 10^4$ K) around the ion path which may exceed the melting point of the material. Thus a molten cylindrical region within a few nm from ion path is formed, followed by rapid quenching ($\sim 10^{14}$ K/s) and subsequently latent ion track is formed. The chemical changes induced by any kind of ionizing radiation in a polymer (e⁻, UV, ions) generate ions or free radicals that initiate the molecular fragmentations, chain scissioning, cross-linking and formation of unsaturated groups [5,6]. Avasthi et al. have reported that SHI produce a cylindrical molten zone termed as an ion track in polymers, leading to bond breaking and evolution of gases [7]. The bond breaking within the polymer chains and secondary reactions with the metal resulting in chemical bond formation during the irradiation, are responsible for the

* Corresponding author. Inter University Accelerator Centre (IUAC), Aruna Asaf Ali Marg, P.O. Box – 10502, New Delhi 110067, India. Fax: +91 11 26893666; mobile: +91 9910533582.

E-mail address: jai.gupta1983@gmail.com (J. Prakash).

ion beam mixing at the metal–polymer interface. In the case of the bilayer systems, atomic intermixing and alloying/chemical compound formation occurs at the interface during ion irradiation [8]. Mixing has been studied by the co-authors in different systems like metal/semiconductor systems [9,10] and metal/metal systems [11,12] where the mechanism is well understood. Metal–polymer systems have been studied for adhesion which is an important issue and several reports are available [13–16]. However, there exist only few reports on mixing in metal–polymer systems [8,17]

In the present paper, we have studied swift heavy ion induced mixing and chemical processes within the ion track in a Ni-PTFE bilayer system. The mechanism of metal–polymer mixing through SHI irradiation with emphasis on ion track chemistry will be discussed.

2. Experimental

A commercially-available film of PTFE (polytetrafluoroethylene) [Good fellow, Cambridge Ltd., England] with thickness ~ 1 mm was used as a substrate in the experiment. The substrates were cleaned with ethanol to remove the contaminations. 100 nm thin film of Ni was deposited on smooth Teflon (PTFE) substrates (1×1 cm² sheet) using e-beam evaporation in ultra high vacuum ($\sim 10^{-5}$ Pa chamber base pressure). High-energy ion beam irradiation was carried out using the 15 UD Pelletron accelerator at Inter-University Accelerator Centre (IUAC), New Delhi. 120 MeV Au ions were used at fluences varying from 1×10^{12} to 5×10^{13} ions/cm² for irradiation. The energy of the ion is chosen in such a way that it can pass through the interface. The projected range of the ions in Ni and PTFE is 6.6 and 16.9 μm , respectively. Electronic energy loss (S_e) and nuclear energy loss (S_n) values of projectiles, calculated by SRIM-2006 in both Ni and PTFE are summarized in Table 1. Rutherford backscattering spectrometry (RBS) was done using 2 MeV He⁺ ions at the scattering angle of 160°.

Atomic force microscopy (AFM) was performed using the Digital Instrument Nanoscope IIIa. In-situ quadrupole mass analysis (QMA) was performed with a quadrupole mass analyzer (model HAL 2/201 from Hiden, UK). Electron spectroscopy for chemical analysis (ESCA) measurement was done using an Mg K₂ source (1253.6 eV).

3. Results and discussion

3.1. Gas evolution measurement by in-situ QMA

Evolution of the various gases from the Ni-PTFE system during irradiation was monitored on-line by a quadrupole mass analyzer. Fig. 1 shows the major gaseous molecules present in the irradiation chamber (a) before irradiation and (b) during ion irradiation. Spectra recorded during the ion irradiation show a number of additional peaks related to different C_xF_y fragments and fluorine as expected, since the PTFE linear chain has structural repeat units [–(CF₂–CF₂)–]. The prominent residual gases observed were CF, CF₂, CF₃, C₂F₃ etc. Fig. 2 shows the variation of evolution of prominent fluorocarbons with time. It was observed that the evolution of fluorocarbon gases from the polymer increases with the increasing irradiation time due to higher electronic excitation energy deposition. However the gas evolution saturates at mass specific values

Table 1

S_e and S_n values of 120 MeV Au ions in Ni and PTFE.

Materials	S_e (10^3 eV/Å)	S_n (10^1 eV/Å)
Ni	3.6	7.3
Teflon (PTFE)	1.5	1.9

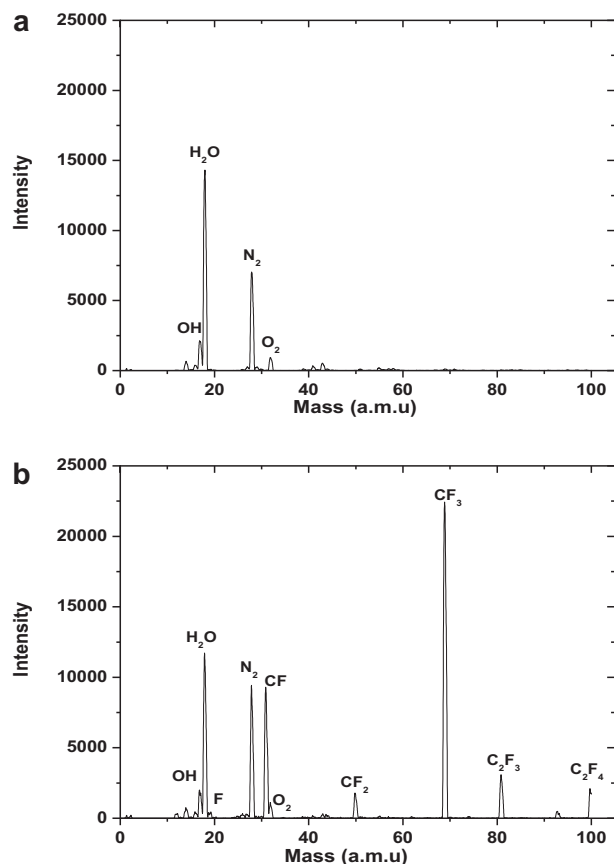


Fig. 1. Mass spectrum showing the gaseous molecules in the irradiation chamber (a) before irradiation (b) during ion irradiation.

with the exception of C₂F₃ which shows a pronounced maximum and nearly disappears after few hundred seconds.

3.2. Formation of chemical compounds

Reactions within the polymer have been observed by QMA. Furthermore, reactions between metal and polymer were

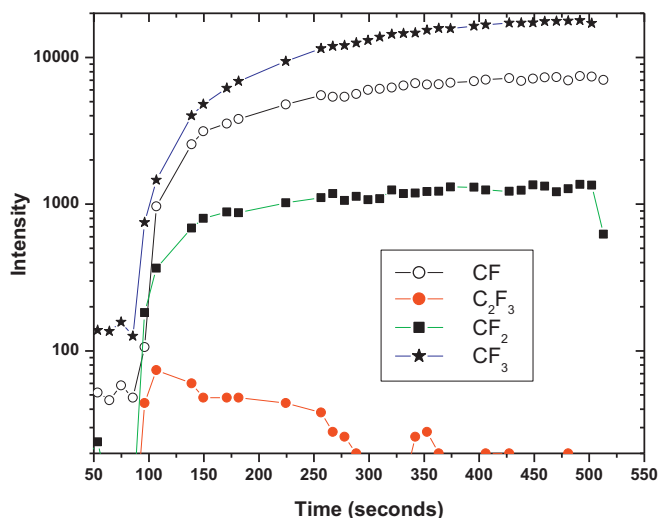


Fig. 2. Variation of evolution of fluorocarbon gases with time. Evolution of prominent fluorocarbons increases with the irradiation time (or fluence).

Download English Version:

<https://daneshyari.com/en/article/1689008>

Download Persian Version:

<https://daneshyari.com/article/1689008>

[Daneshyari.com](https://daneshyari.com)