PRAMANA
—journal of
physics

Vol. 50, No. 6,
June 1998
pp. 653–668

Metal-ion implantation in glasses: Physical and chemical aspects

F CACCAVALE
Istituto Nazionale per la Fisica della Materia (INFM) and University of Padova, Physics Department, via Marzolo 8, 35131 Padova, Italy
E-mail: caccavale@padova.infm.it

Abstract. A review of the state-of the-art of the research in the field of chemical interactions in silica and silicate glasses implanted with metal ions (e.g., Si, Ti, W, Ag, Cu, Cr) and N is presented in terms of new compounds formation. Moreover, under certain circumstances, the formation of nanometer-radius metal colloidal particles in a thin surface layer is observed. The chemical state of the implanted atoms is determined by X-ray photoelectron (XPS) and X-ray excited Auger-electron spectroscopies (XE-AES). Rutherford backscattering spectrometry (RBS) and secondary-ion mass spectrometry (SIMS) are used to determine the in-depth elemental distributions. Optical absorption measurements and transmission electron microscopy (TEM) are used to detect the presence of metallic clusters, as well as to determine their mean size and size distribution. A thermodynamics approach is used to explain the interaction between the implanted ion and the separate atomic species of the target glass and/or between the implanted ion and the target molecular species.

Keywords. Ion implantation; glass; chemical interaction; compound formation; metal nanoclusters.

PACS No. 34.50; 61.43; 61.46; 61.72

1. Introduction

Because of its unique features, research on ion implantation in insulators grew independently from works in the field of metals and semiconductors since the first years of 1970. Ion implantation in glasses attracted a large interest being one of the most attractive methods to incorporate virtually any element in a substrate and for the possibility to overcome the doping solubility limits.

The interaction of energetic ions with an insulating glass target determines effects directly connected to radiation damage, such as mechanical stresses, density and composition modifications, and consequent mechanical, optical and chemical durability property changes [1, 2]. In addition to these, depending on the choice of element and dielectric host, chemical interactions with the formation of particular compounds are possible [3–5].

The chemical role in determining the final properties of the implanted layers was first observed in experiments employing the double implantation of nitrogen and silicon in silica glasses [6–9]. Implantation of metal ions into glass is of particular interest since, depending on their reactivity with the substrate, they cause the synthesis of new compounds [10–13], and/or the formation of metallic nanoclusters [5, 11, 12, 14, 15].

The group of Padova is active in the study of the chemical interactions in SiO_2 and silicate glasses implanted with metal ions with the aim of giving a contribution to the