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Measurement of internal electric field in coated grounded quartz irradiated by an electron beam

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Abstract

Physical mechanisms involved in insulators submitted to electron irradiation inside a scanning electron microscope (SEM) are investigated by combining some simple considerations of electron trapping mechanisms with basic equation of electrostatics. To understand such mechanisms, only widely irradiated samples having a uniform trapping sites distribution are considered. This hypothesis leads to develop simple models for the trapped charge distributions and subsequently for the distribution of the electric field build-up in ground coated specimens as investigated in electron probe microanalysis (EPMA). This enables us to study the distortion of the $\Phi(\rho z)$ function (the depth distribution of characteristic X-ray production) as well as the modification of the specimen's local composition. In this paper, an experimental method, using a series of quartz samples, is described for evaluating the magnitude of the electric field build-up within specimens; thus allowing to establish clearly the electric field influence on the measured $\Phi(\rho z)$ function.

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Keywords: Insulating materials; Charge effect; Internal electric field; X-ray spectrometry; Monte Carlo simulation

1. Introduction

Difficulties to apply standard quantification procedures of EPMA to insulating materials are getting well known [1–4]. Even when an insulator is covered with a grounded coating, a part of the

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incident electrons being trapped below the surface may induce very large internal electric fields which, in turn, change the trajectories of the «new» arriving electrons in the bulk of materials and then the generation function of the X-ray quanta will be modified.

Whatever the stress faced by a dielectric, either electrical or mechanical, it induces polarization due to dipole orientation, electrical charge migration or lattice distortion. The consequence of this polarization is the increase in the effective mass of the particle, which leads to a formation of quasiparticles called polarons. In fact, initially incident electrons will be either trapped at the defect sites in the specimen or end up as self-trapped electrons [5,6]. Gradually, the trapped charge forms a space charge distribution. In the case of a negative trapped charge, the generated potential may slow down the incoming electrons and increase the current resulting of secondary emission [7,8]. The internal field arising from the space charge distribution might also reach a strength able to detrap an electron from a trapped site. The setting up space charge distribution could be accompanied by trapping, detrapping and diffusion of charge carriers.

To investigate these changes, the use of Monte Carlo simulations seems very convenient as it has been demonstrated for the generation of the characteristic photons in various oxides [9].

This paper evokes results of Jbara et al. studies [10] however is related to experimental investigations which consist in measuring the trapped charge in the specimen, and then deducing the corresponding internal field.

In this work, only ground-coated quartz being widely irradiated is considered. The study of uncoated quartz seems to us more criticizable because of its complexity. This choice leads to take an electric field model suggested recently by Cazaux [11]. Different electric field strengths are postulated, and their influences on the amplitude and on the shape of the depth distribution function of characteristic X-ray production, $\Phi(\rho z)$, are investigated. The experimental and theoretical results are analyzed and the basic mechanism involved in charging–discharging of the electron-irradiated crystalline quartz is discussed.

2. Experimental methods

Experiments were carried out in a SEM Philips 505 equipped with a PGT SiLi energy dispersive spectrometer (EDS) in order to acquire the X-ray spectra. The experimental setup is shown in Fig. 1. Insulator's plane sample is fixed under the hole of a cylindrical metallic enclosure connected to the ground through a picoammeter. To measure the displacement current produced from the charge trapping process [12], a metallic disk placed inside the enclosure under the sample of about 200 μm on a Teflon disk is connected to another picoammeter.

The use of such an arrangement, allows that electrons emitted from the SEM chamber-wall or electrons lacked from the insulator to be collected by the surface of the metallic enclosure, and next to be flowed to the ground. Thus, it is important to point out that the current flowing from the probe (the metallic disk) through the picoammeter to ground corresponds to a net displacement current I_d.

Samples used in this study are series of parallelipipedic pure single crystals of quartz pieces (with dimensions 1 cm × 1 cm and a thickness of 1 mm) which contain some impurities in the parts per million range such as Al^{3+} and alkali ions (Li^+

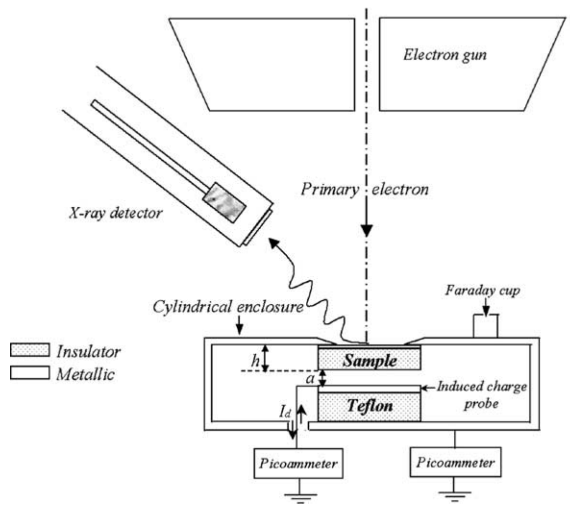

Fig. 1. Schematic illustration of the experimental arrangement using for the influence current measurements in insulators.