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Properties of TiN and TiZrV thin film as a remedy against electron cloud ☆

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Abstract

In many accelerators running positively charged beams, ionization of residual gas and secondary electron emission in the beam pipe will give rise to an electron cloud which can cause beam blow-up or the loss of the circulating beam. One solution to avoid the electron cloud is to ensure that the vacuum wall has low secondary emission yield (SEY). The SEY of thin films of TiN and sputter-deposited non-evaporable getter were measured for a variety of conditions, including the effect of recontamination in an ultra high vacuum environment.

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1. Introduction

Beam-induced multipacting, which is driven by the electric field of successive positively charged bunches, arises from a resonant motion of electrons that have been initially generated by photons, by gas ionization, or by secondary electron emission (SEE) from the vacuum chamber wall. These electrons move resonantly along the wall, occasionally getting "kicked" by the circulating beam to the opposite wall. The "electron cloud" (EC) density depends on characteristics of the positively charged circulating beam (bunch length, charge and spacing) and the secondary electron yield of the wall from which the electrons are generated. The electron cloud effect, started by multipacting, has been observed or is expected at many storage rings [1]. The space charge from the cloud, if sufficiently dense, can lead to a loss of the beam or, at least, to a drastic reduction in beam luminosity.

The SEY of technical surfaces, needed to mitigate multipactor, EC or space charges, has

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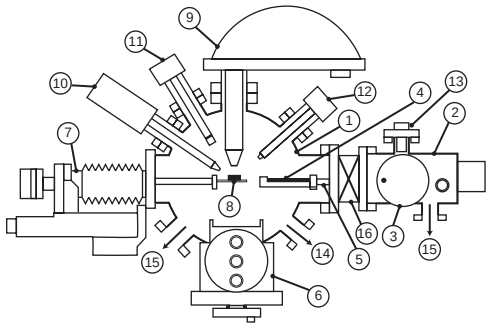
been measured in the past at SLAC [2–4], at CERN [5–7] and in other labs [8–12]. The term "technical surface" refers to a mill-finish surface which is commercially available and then chemically cleaned for ultra high vacuum (UHV) use. Technical surfaces have, generally, an SEY higher than the pure material because they are oxidized.

2. Experiment description and methodology

The system used to measure SEY, shown schematically in Fig. 1 and thoroughly described in Ref. [13], is composed of two coupled stainless steel UHV chambers in which the pressure is in the low 10^{-10} Torr range in the measurement chamber and high 10^{-9} Torr range in the load lock chamber. Samples individually screwed to a carrier plate, are loaded first onto an Al transfer plate in the load lock chamber, evacuated to a low 10^{-8} Torr range, and then transferred to the measurement chamber. Pressures are in Torr equivalent N_2.

The measurement chamber has two electron guns and a soft (1.49 keV) X-ray source. One electron gun (energy, 1–3 keV) is used for SEY and SEM, and the other is a "flood" gun for electron



(1) Analysis chamber
(2) Load lock chamber
(3) Sample plate entry
(4) Sample transfer plate
(5) Rack and pinion travel
(6) Sample plate stage
(7) XYZ θ Omniax^{TM} manipulator
(8) Sample on XYZ θ
(9) Electrostatic energy analyzer
(10) X-ray source
(11) SEY/SEM electron gun
(12) Microfocus ion gun
(13) Sputter ion gun
(14) To pressure gauges and RGA
(15) To vacuum pumps
(16) Gate valve

Fig. 1. Experimental setup.

conditioning. The X-ray source is used to excite photoelectrons for surface chemical valence and stoichiometry analysis, called Electron Spectroscopy for Chemical Analysis (ESCA), also called X-ray photoelectron spectroscopy (XPS). Principles of surface analysis techniques can be found in Ref. [14]. The information depth for XPS is <5 nm, much less than the film thickness of the samples in this study.

After all samples (up to 10 or so) are transferred into the measurement chamber, one sample at a time is loaded, on its individual carrier plate, onto an XYZ θ manipulator arm (Vacuum Generators Omniax®). Two thermocouples are available to measure the temperature near the sample, during irradiation or during a sample bake. The back of the samples are heated by electron bombardment, achieved by biasing a tungsten filament negatively with a grounded sample [13].

A good way to monitor the activation process of the TiZrV non-evaporable getter (NEG) is to record the decrease of the surface oxygen concentration with XPS. During the NEG activation, the surface goes from an oxidized state to a partially metallic state. During XPS measurement the X-ray generated photoelectron current leaving the surface of the sample is measured to be ~27 nA, over an area of 16 mm^2. It should be noted that hot Zr is pyrophoric. This is also true for other Zr-based alloyed getters such as St707^{TM} ($Zr_{70}V_{24.6}Fe_{5.4}$). However, a sample of our $Ti_{27}Zr_{31}V_{42}$ getter, prepared by SAES Getters®, of about 1 μm thickness, did not ignite in air when heated up to 350 °C.

The electronic circuit for SEY measurement is presented in Fig. 2 [4]. The energy of the computer-controlled electron beam coming from the gun is decoupled from the target measurement circuitry. However, the ground is common to both. The target is attached to a Keithley 6487, a high resolution electrometer with internal variable ±505 V supply and IEEE-488 interface. Filter modes of the K6487 were turned off for our measurements. The integration time for each current reading was 167 μs, which is the minimum value for the instrument. The current was sampled 100 times; the mean and standard deviation were returned from the K6487 to the computer.