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The desorption of condensed noble gases and gas mixtures from cryogenic surfaces

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Abstract

In accelerators, operating at liquid-helium temperature, cold surfaces are exposed to intense synchrotron radiation and bombardment by energetic electrons and ions. Molecular desorption yield and secondary electron yield can strongly influence the performance of the accelerator. In order to predict the gas density during the operation, the knowledge of electron-induced desorption yields of condensed gases and of its variation with the gas coverage is necessary. Desorption yields under electron impact of various noble gases and gas mixtures condensed on a copper surface cooled at 4.2 K have been measured.

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1. Introduction

The large hadron collider (LHC) under construction at CERN near Geneva is a proton storage ring with a circumference of about 27 km. In this ring, protons will be accelerated up to an energy of 7 TeV and heavy ions up to 2.76 TeV per nucleon. To keep the high-energy particles on their path, super-conducting magnets are needed to provide the required intense magnetic field. In these superconducting magnets, operating at 1.9 K, two proton beams circulate in separate beam pipes held at 1.9 K, inside a beam screen kept at a temperature between 5 and 20 K. A more accurate description of the LHC vacuum system can be found in Ref. [1]. At these low temperatures, most molecules condense on the surface of the beam screen. This condensed gas layer is exposed to the bombardment of various energetic particles: photons radiated by the high-energy proton beam, ions produced by the ionisation of the residual gas by the proton beam and accelerated by its space charge, electrons emitted from the beam screen surface and attracted by the circulating beam. These electrons submitted to a high-frequency electromagnetic field generated by the bunched proton beam can multiply leading to a detrimental effect called "electron cloud" [2]. This phenomenon can limit, at least temporarily, the performance of the LHC by inducing an increased heat load to the cryogenic system, a large desorption from the beam screen copper surface and possible parasitic oscillations in the high-energy proton beams [3,4]. The gas produced by the photon [5] and electron bombardment of the beam screen (primary desorption) re-condenses, building up a condensed gas layer of increasing thickness. During these processes, the pressure in the LHC vacuum system and the equilibrium-condensed gas coverage is partly determined by the condensed gas layer desorption yield [6]. The measurements of the electron-stimulated desorption yields from gas mixtures and from condensed noble gases is hence needed to predict the vacuum behaviour in the LHC, and to understand the mechanism of electron induced desorption from thin condensed gas layers.

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2. Experimental set-up

The experimental system is shown in Fig. 1. The cold condensing surface is a hollow cylinder connected to a liquid helium vessel and electrically insulated by a glass transition. In order to limit large uncertainties due to an uncontrolled re-adsorption of the desorbed molecules between the sample and the detection system, the cold sample is surrounded by room temperature surfaces by which pumping speed can be neglected. The use of bellows between room temperature and liquid nitrogen temperature and between liquid nitrogen and liquid helium temperature allows reducing the area of the surfaces at intermediate temperature while keeping the cryogens consumption reasonable. This results in a reduced uncertainty on the condensing area and hence on the condensed gas coverage.

A heated thorium-coated tungsten filament providing the electrons is placed 5 cm in front of the sample surface. The filament is biased to a positive potential with respect to ground to avoid spurious electron bombardment of the surrounding vacuum chamber. Switching the sample to a positive potential (between 40 and 1 keV) with respect to the filament generates the electron bombardment of the cold sample at an angle of 90°. The intensity of the electron beam is measured using an electrometer connected to the filament.

The gases are introduced through a known conductance. The pressure difference across this conductance is measured using calibrated Bayard–Alpert gauges to calculate the pumping speed and the amount of gas injected. The condensed gas thickness is obtained by dividing the amount of gas by the condensing area.

The pumping system consists of a turbo molecular pump and a rotary pump. Before cool-down, the system is baked to 300 °C during 24 h and reaches a base pressure of 10^{-8} Pa.

3. Experimental procedure

A typical cycle for a desorption experiment is the following:

- Injection of the gas quantity corresponding to the required coverage.
- Bombardment of the condensed layer with the following operating parameters:
  - Filament bias: +9 V.
  - Filament power: 4–9 W.
  - Initial pressure (room temperature): $\sim 1 \times 10^{-8}$ Pa.

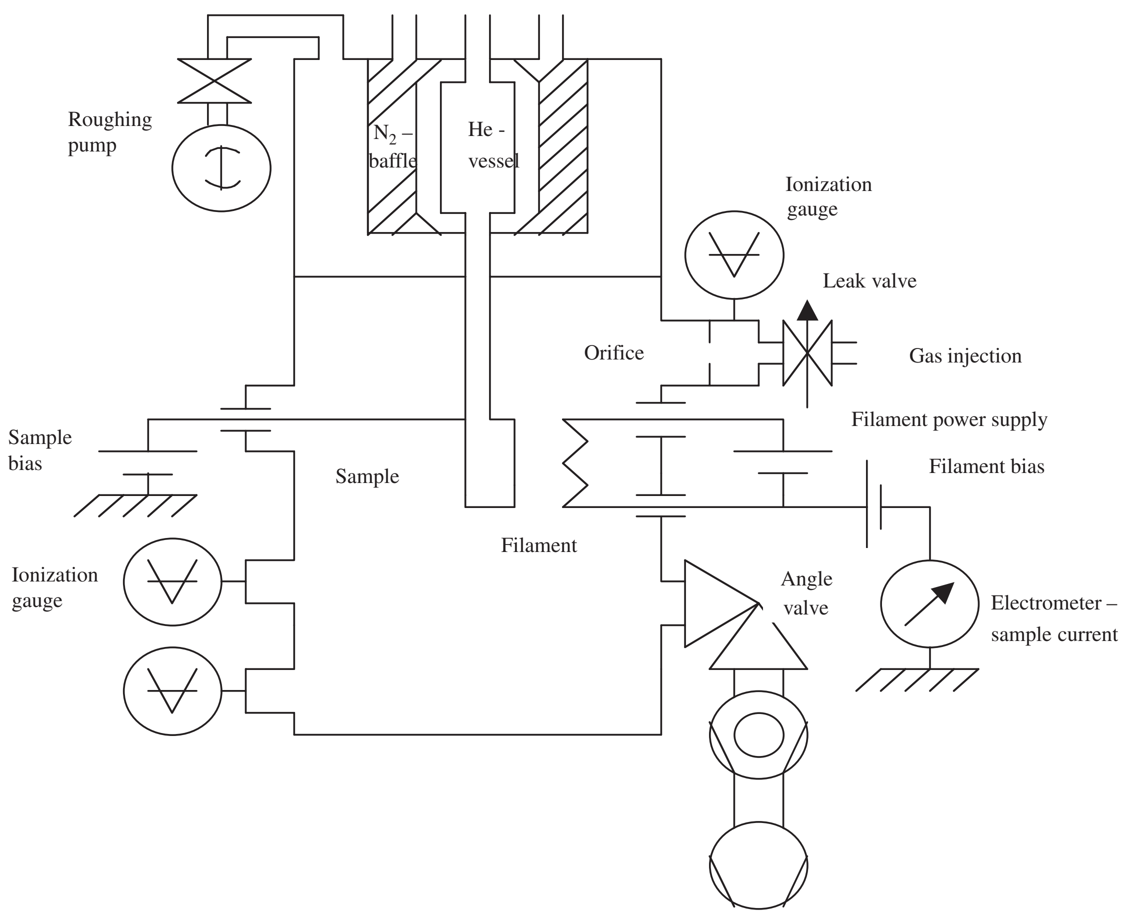

Fig. 1. The experimental set-up.