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COMMUNICATION

Paul Ion Trap as a Diagnostic for Plasma Focus

S. M. Sadat Kiai · S. Adlparvar · A. Zirak · Samira Alhooie · M. Elahi · S. Sheibani · A. Safarien · S. Farhangi · A. A. Dabirzadeh · M. M. Khalaj · M. S. Mahlooji · S. KaKaei · A. Talaei · A. Kashani · H. Tajik Ahmadi · F. Zahedi

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Abstract The plasma discharge contamination by high and low Z Impurities affect the rate of nuclear fusion reaction products, specially when light particles have to be confined. These impurities should be analyzed and can be fairly controlled. This paper reports on the development of a Paul ion trap with ion sources by impact electron ionization as a diagnostic for the 10 kJ Iranian sunshine plasma focus device. Preliminary results of the residual gas are analyzed and presented.

Keywords Plasma focus device · Ion source · Paul ion trap · Impurity ions

Introduction

Plasma focus devices are the most powerful source of neutrons, accelerated charge particles, and electromagnetic radiations. Recent applications of plasma focus for the production of short-lived radioisotopes require a high performance of the device [1–3]. To this task, although the design and operational parameters are crucial for high quality performance, nevertheless, the roll played by the impurity ions in the confined hot and dense plasma is very important and is becoming the subject of the research activities in controlled nuclear fusion [4–7].

S. M. Sadat Kiai (✉) · S. Adlparvar · A. Zirak · S. Alhooie · M. Elahi · S. Sheibani · A. Safarien · S. Farhangi · A. A. Dabirzadeh · M. M. Khalaj · M. S. Mahlooji · S. KaKaei · A. Talaei · A. Kashani · H. Tajik Ahmadi · F. Zahedi
Nuclear Science Research School, AEOI, Nuclear Science & Technology Research Institute (NSTR), 14155-1339 Tehran, Iran
e-mail: sadatkiai@yahoo.com

The origin of the impurity ions is either from the plasma interaction with the wall or the impurity molecules in the mother gas [8–11]. The material surface in contact with the plasma will produce low Z (Be, C, O, etc.) and high Z (Fe, Ni, Mo, etc.) material impurities. Impurity materials can be analyzed by different ways such as activation methods, magnetic and time of flight ion spectrometers, optical or qaudrupole mass spectrometry. The qaudrupole Paul ion trap is an efficient method for evaluating the types, rates, density, etc., of impurity ions in the plasma focus devices. In this article, we describe a Paul ion trap designed for 10 kJ Mather type plasma focus under construction. Preliminary results obtained for the residual gas are presented.

Experimental Set Up and the Results

The schematic of the Paul ion trap connected to the plasma focus device is depicted in Fig. 1. The plasma focus is a Mather type and has six cathodes with the anode in the centre and all those contained in a chamber. The chamber has 25 cm diameter and 35 cm long with some special ports designed in the chamber for the purpose of handling material in and out of the chamber without validating too much the pressure inside the chamber. These facilities are preview for the production of short-lived isotopes. At the bottom of the chamber there is an orifice which is connected to the analyzer system.

The Paul ion trap has a hyperbolic geometry; two end-caps and one ring electrodes made stainless steel have $Z_0 = 1$ cm (distance from centre to the end-cap electrode) and $r_0 = 2^{0.5} \times Z_0$ cm (radius of the ring electrode). The down end cup of the Paul ion trap hold the anode electrode which has six small holes of 0.1 mm in diameter for the electrons which get through the ionization area and the

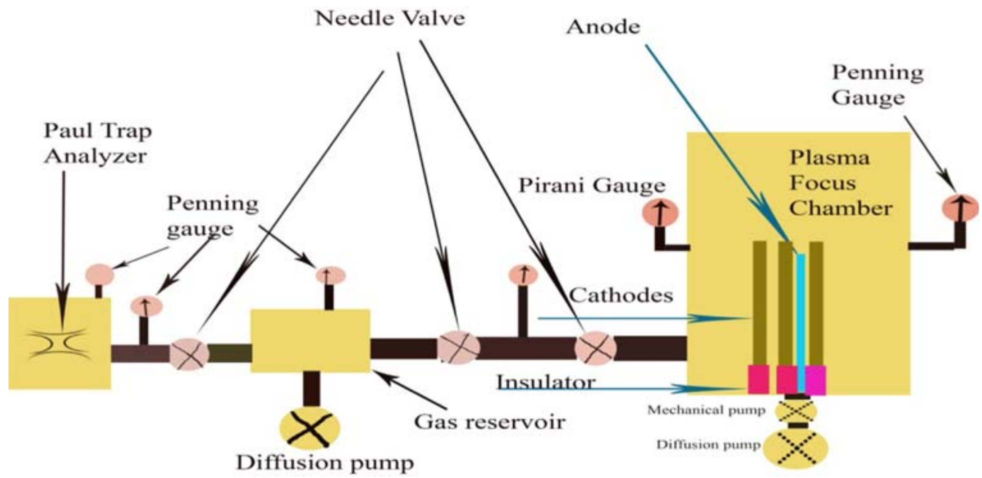

Fig. 1 Schematic of the plasma focus set up

upper end-cap has the same holes as one for the ions which get through for the detection. Moreover, the ring electrode has some holes round (for each 120°) for the purpose of better entering the filling gas into the ionization area without perturbing the homogenous electric field inside the trap. The end-caps are connected to the ring electrode through Al_2O_3 insulators. For the analyzer system and for ionizing the gas molecules inside the Paul ion trap, a low-energy electron gun is designed and used for the energy range 0–110 eV. Also the electron gun is situated behind the down end-cap electrode in which the beam of electron covers effectively the whole ionization area inside the trap.

Electrons are provided by a coiled cheap tungsten filament wire coated with Re–O (2–4 A and 2–5 V), with six coils and 0.0127 ± 0.0008 cm in diameter and 10.5 ± 0.2 cm lengths mounted on Mo and isolated by Al_2O_3 with the rest of materials. The filament is surrounded coaxially by a cylindrical stainless steel grid (Wehnelt) which has an aperture located below the filament tip. The grid is biased by a negative voltage with respect to the filament to suppress all unwanted electrons emitted from the filament except those electrons emitted at the filament tip. Just after the grid, at some distances, there is a stainless steel anode, depending on the electron gun operational conditions for the crossover point.

The partial pressure for the experiment test is kept at 10^{-5} torr, before introducing any gases. A Farady cup is positioned behind the upper end-cap electrode as a detector and biased with the anode. It is important that the filament is properly centered in relation to the opening of the Wehnelt cap for better focusing some micro ampere electron beam locating at the suitable distance from the opening. The Wehnelt cap acts as a convergent electrostatic lens and serves to focus the cloud of the electrons. Otherwise, an off center beam that is either weak/condensed or bright/diffuse will be produced.

Paul trap analyzer is excited with a rf sinusoidal voltage form (pick to pick 1,000 V and 1 MHz frequency) and connected to the plasma focus chamber through an orifice, needle valves and reservoir using pirani and penning gauges because the pressure must be drop from plasma focus chamber (nearly few torr) to the level in Paul trap analyzer (10^{-5} to torr).The vacuum systems for Paul trap and plasma focus chambers are provided by diffusions and mechanical *References* pumps.

Preliminarily result is obtained by scanning residual gas (air) in a plasma focus chamber. The result provides nitrogen atom (^{14}N), water molecule ($^{18}H_2O$), high intensity of nitrogen molecule ($^{28}N2$) and oxygen molecule ($^{32}O_2$). Two week picks of ^{40}Ar and $^{44}Co_2$ have also been observed.

Comment

The Paul ion trap mass spectrometer is a useful device to determine the percentage of impurities in plasma focus device. Although we have detected the residual gas impurities, nevertheless, as the plasma focus is in operation, impurities such as Cu, C, etc., will also affect the plasma environment, resulted in plasma cooling by plasma resistivity through Z_{eff}.

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