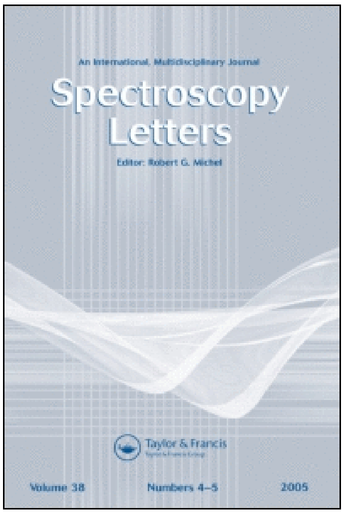

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OPTOGALVANIC PROPERTIES OF THE ION GUIDE SOURCE IN THE RECOIL NUCLEUS SELECTIVE PHOTOIONIZATION

Key words: Selective Laser Ionization, Ion Guide Source, Corpuscular Quasi Resonant Plasma, Optogalvanic Effect, Electron Energy Distribution Function

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INTRODUCTION

The advancement to β-stability boundary demands new experimental methods in studying of the nucleus. The *Ion-Guide Source (IGS)* is a fast and efficient technique for the fulfilment of this task. However it requires additional interatom selection to reduce the background created by other isotopes. This reduction is of essential importance for studying of low yield isotopes.

Abstract

This consideration is a conjunction of two processes: generation of recoil products and selective detection. A new type of plasma is carried out. The electron energy function distribution of the ion-guide source plasma is calculated and discussed. The properties of a laser ionization scheme detecting recoil atoms are analyzed using an optogalvanic approach.

The *Resonant Laser Ionization (RLI)* in low temperature currentless plasma, formed by accelerated particle beam propagating through gas, will be used for the above mentioned separation. A tuned dye laser excites the studied atoms and the fast electrons ionize them. This process exceeds in cross-section the ionization from ground state which provides selectivity of IGS. The latter produces ions of almost all chemical elements. It can be used for investigating processes flowing in low temperature currentless plasma which presents a specific interest. These functions impart to the IGS the role of an *Optogalvanic (OG)* element, to be precise, of hollow cathode discharge used as an *OG* detector [1].

In this paper the IGS is analyzed as an OG detector in a *quasi OG scheme.* The investigation is a step simulating the *IGS* properties. The *Electron Energy Distribution Function (EEDF)* and the most important processes are analyzed and discussed as a first step in this field. The results obtained contribute to the efficiency of the *RLI* method.

1. IGS IN THE GENERAL MEASURING OPTOGALVANIC SCHEME

The arrangement in FIG.1 illustrates the scheme of measuring nucleus products. We analyze the case when an uninterrupted beam of accelerated cyclotron ions (35 *MeV*) bombards a suitable foil stimulating a

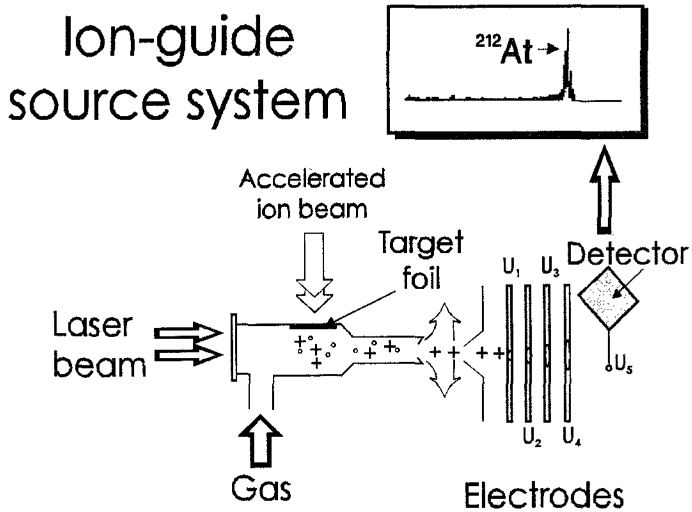

FIG. 1: Measuring scheme - general view.

chain reaction in IGS. A continuous dye laser tuned at suitable optical transition excites selectively the recombined atoms of interest. As a result of this selective ionization the IGS medium is enriched with pairs electron-recoil ions. Simultaneously all particles, including light-created ions, move outside *IGS* due to the buffer gas flow. Subsequently the photoselected ions reach the detecting part by means of the transporting system [2].

Hence, the laser produced ions form a channel of conductivity between *IGS* space and the *ion detector*. This channel includes, in addition, the $U_{1\text{-}4}$ transporting system and in fact represents an OG measuring circuit. The essence and succession of the above mentioned processes give reason to consider flowing in an equivalent OG-like scheme.

The OG effect is known [1] as light-induced change Δj in the plasma conductivity j: the absorbed laser power irradiation causes an initial transfer of population between the two levels, excited usually by free electrons; this resonant excitation of the atoms results in an electron-ion pair Δn_e being produced and/or rarely in variation Δv_e of the electron velocity. Both changes Δn_e and Δv_e appear due to collisions of *light-excited atom - free electrons.* Then $\Delta j/j = \Delta n_e / n_e + \Delta v_e / v_e$ applies due to their higher mobility the electrons determine the values j and Δj.

Thus, the light-induced conductivity in the scheme (FIG.1) may be considered as an OG response to both the appearance of a certain nucleus product and its ion light selection. However, in our case, the processes of selective excitation (ionization) and Δi measuring are spaced by the transporting system $U_{1\div4}$. It separates (extracts) the ions and they only determine the light-induced yield on the detector. In this way the signal-to-noise ratio may be improved by suitable adjusting of the transporting system, which may be considered as the measuring resistor in a typical OG scheme. These are the peculiarities of our IGS OG-like scheme in contrast to the conventional OG arrangement. First of all, the efficiency of an OG scheme depends on its OG detector. In our case this is the IGS which also transforms the absorbed laser light to electron-ion pairs. Therefore, the physical characteristics of IGS are of exceptional importance.

2. CORPUSCULAR QUASI RESONANT CURRENTLESS PLASMA AND MAIN PROCESSES IN IGS

The cyclotron charged particle beam bombards the foil placed on the inside surface of the IGS. In reality, all ions penetrate into *IGS*, ionizing the buffer gas atoms *B,* creating a medium which we named *Corpuscular Quasi-Resonant Currentless Plasma (CQRCP*). There are few data about this kind of medium. CQRCP distinguishes the known types of plasma because of a wide variety of originating particles and their mass and energy; its main distinction are the recoil products. However, the destination of *CQRCP* is to provide recoil ions selectively.

In the beginning, the IGS medium consists of the buffer neutrals and buffer ions, electrons, recoil - products and bombarding heavy particles losing their initial energy. The latter redistributes from high energetic cyclotron ions to the other particles. The main part of this loss is the process of buffer gas atoms ionization. Thus, generally, the characteristics and behavior of *CQRCP* follow those of particles B and B^+, i.e. their ionization and recombination. The experiments in He, Ar and Ne showed Ar as the most suitable buffer gas for recoil - nucleus ion neutralization. The main part of losses are transferred to the lighter particles, i.e., the electrons. Their energetic state is of importance for the step like ionization as well as in describing the IGS medium.

2.1. ELECTRON ENERGY DISTRIBUTION FUNCTION (EEDF)

The knowledge of the *EEDF* is important to evaluate several plasma characteristics (electron density, mean energy etc.) and to estimate the role of different elementary processes. The *EEDF* has been obtained by solving the time independent and spatially averaged electron Boltzmann equation using two-term expansion in Legendre polynomials [3]. The following processes have been accounted for: elastic scattering, excitation and ionization from the ground state of the buffer gas, diffusion, recombination (dissociative and three-body), and a source term describing the appearance of secondary electrons due to ionization with the fast ion beam. The solution method and the terms appearing in the electron Boltzmann equation are similar to electron beam plasmas, described in details elsewhere [3]. Only the ionization differential cross section in the source term is different (since it describes ionization with ion beam), for which an analytical formula derived in [4] has been used.

The *EEDF f(U)* is calculated for He^+ bombarding ions of energy *E=35 MeV*, *Ar (80 Torr and 150 Torr)* and *He (50 Torr)* buffer gases and He^+ - ions beam intensity $I=5\ x10^{14-16}$ *part./s.cm*^{2}. At these conditions the production and loss of electrons in the *IGS* due to electron (*e*)-atom (*A*) interaction have been calculated: *i) the ionization by the ion beam* (A + *ion-beam* $\Rightarrow A^+ + e$); *ii) the ionization by electrons* ($A + e \Rightarrow A^+ + 2e$); *iii) dissociate recombination* ($A_2^+ + e \Rightarrow A + A$); *iv) three body-recombination* ($A_2^+ + e + e \Rightarrow 2A^* + e$); *v) three body-recombination with the atom as a third particle* ($A_2^+ + A + e \Rightarrow 3A^*$); *and vi) electron diffusion to the wall.*

The corresponding *EEDFs* are calculated by solving the Boltzmann equation under energy up to *100 eV*. For higher energy the solution is not correct but these energies do not contribute to the rate constants value. The calculated *EEDFs* have a long tail and extend up to energy about 10^2 *eV* (FIG.2). Nevertheless, the ionization with plasma electrons account for about 20% of the total needed number for ionization (with the ion beam and the plasma electrons). A very small electron mean energy of about 0.12 eV has been obtained. In spite of its low mean energy, the plasma produced contains electrons whose energy is sufficient to ionize atoms from most of the chemical elements.

CONCLUSIONS

i) The origin, interaction and detection of the recoil products near the β *–stability boundary are analyzed and discussed within the frame of a quasi optogalvanic scheme; here the IGS is considered as an OG element;*

ii) A new kind of optogalvanic medium, i.e. CQRCP is analyzed. It appears in IGS due to bombardment by cyclotron accelerated ions beam;

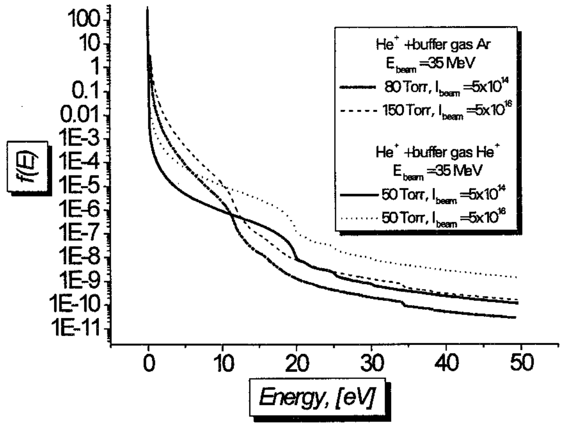

FIG. 2: The Electron Energy Distribution Function (EEDF) *f(E)* in different conditions.

iii) The electron energy distribution function in CQRCP is calculated. The distribution is not Maxwellian. It has a long tail extending up to energies about 10^2 *eV. However, the Maxwellian is an acceptable approximation. When a mean electron energy is introduced; it is found to be rather low, i.e. about 0.12 eV. The accelerated ion beam intensity manifests itself as the main parameter for EEDF. The electron density calculated is of the order* 10^{10} *-* 10^{12} cm^{-3}.

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