BEAM ENERGY SCALING OF ION-INDUCED ELECTRON YIELD FROM K+ IONS IMPACT ON STAINLESS STEEL SURFACES*

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Abstract

The cost of accelerators for heavy-ion inertial fusion energy (HIF) can be reduced by using the smallest possible clearance between the beam and the wall from the beamline. This increases beam loss to the walls, generating ion-induced electrons that could be trapped by beam space charge potential into an "electron cloud", which can cause degradation or loss of the ion beam. In order to test the physical mechanism model of ion-induced electrons production we have measured the impact of K+ ions with energies up to 400 KeV on stainless steel surfaces near grazing incidence, using the ion source test stand (STS-500) at LLNL. The electron yield will be discussed and compared with experimental measurements from 1 MeV K+ ions in the High-Current Experiment at LBNL.

INTRODUCTION

The cost of accelerators for High Energy Density Physics and Heavy Ion Fusion can be drastically reduced by increasing the fill factor. At the range of interest (beyond 60%), the beam halo is expected to produce electrons and desorbed gas, which could move to the beam path and be ionized. The electrons produced may be trapped by the space charge beam potential. If sufficient electrons are trapped, we could lose control of the beam transport, resulting in more beam hitting the wall producing more electrons and desorbed gas. This is the beginning of the "electron cloud effect", a recognized problem in positive-charged-particle accelerator rings (see e.g. ECloud2004 [1] & PAC2003 [2] conferences) and in the low energy (1 MeV) region of linacs for heavy ion fusion.

DESCRIPTION OF EXPERIMENT

In order to test the physical mechanism model of ion-induced electrons production we have measured the electron yield by placing the Gas-Electron Source Diagnostics experiment (GESD) [3] at the end of a 500 kilovolt ion source test stand (STS-500) [4], which can generate a 17 microsecond duration, up to 500 KeV and 1A pulse every few seconds.

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The GESD, which is shown in Fig. 1, consists of several electrodes that are independently biased. It is designed to measure ion-induced electron emission and gas desorption from heavy-ion beams impacting a surface. The beam current passing through a small aperture hits the stainless steel target. The target is treated using LBNL ultrahigh vacuum cleaning procedures [5] and is adjustable between angles of incidence from 82 to 89.5 degrees from normal to the surface, which corresponds to θ in the Fig. 1. Between the aperture and the target a suppressor electrode prevents electrons from entering or leaving the GESD. At the end of the target a catcher is placed to capture the reflected ions. Around the target we have a grid and under the target we have a Faraday Cup (FC). If we apply correct bias to each electrode, we can measure the electron yield. The procedure consists of first placing the FC in the beam to measure the ion current entering the GESD, after that we move the target to a desired angle and measure the electron current leaving. The electron yield coefficient is the number of electrons produced by each ion.

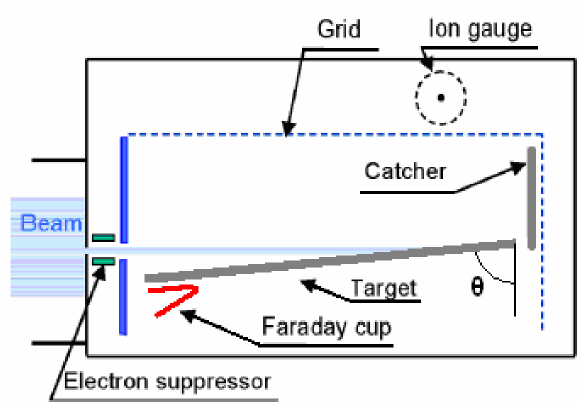

Figure 1: Gas-electron source diagnostic (GESD).

RESULTS

The energy range covered in this work is represented in Fig. 2 with gray color. At low energies (below 250 KeV for K+ ions) the nuclear stopping power is larger than the electronic, at higher energies the electronic component dominates. Our goal here is to check our understanding of the mechanism of ion-stimulated electron production. For that we acquire data with the GESD device using the STS

500 facility that can operate from ~50 KeV to 500 KeV, where the nuclear stopping power begins dominating and we transition to the electronic stopping power dominance. Those data will be compared with data collected previously with the HCX at 1 MeV, where the electronic stopping power dominates.

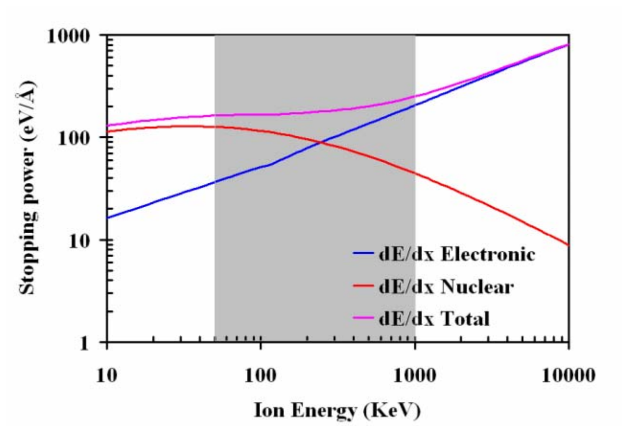

Figure 2: Stopping power for K+ ions hitting Stainless Steel target.

Sternglass [6] developed an ion-induced electron model and derived a simple expression in which the electron yield is proportional to the electronic stopping power, as represented in Eq. 1.

$$\gamma = K\left(\frac{dE}{dx}\right)_e \tag{1}$$

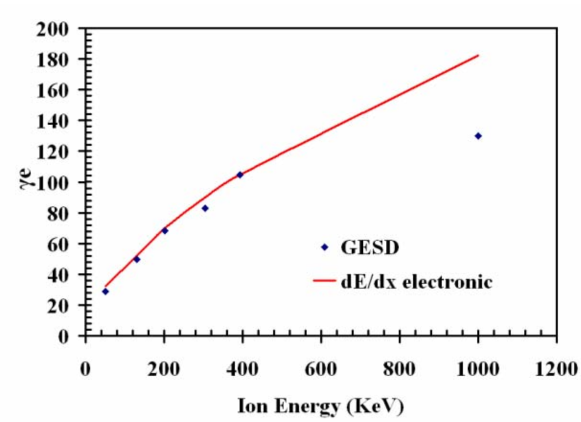

Figure 3: Electron Yield obtained with Gas-Electron Source Diagnostic at 88 degrees compared with the electronic stopping power normalized to 392.8 KeV.

Fig. 3 compares electron yield (γe) acquired with GESD at 88 degrees with the electronic stopping power from SRIM 2003 software [7] normalized to 392.8 KeV. Our result is in good agreement with the theory at lower energies, but there is a difference of 40% at higher energies, where the electronic stopping power prevails.

CONCLUSIONS

The literature has a variety of studies of ion-induced electron emission [8,9,10], but they are mainly done at low or high energies, where either electronic or nuclear stopping power dominate.

Data for heavy ions over the range of medium energies where there is a transition from the predominance of nuclear to electronic stopping power is scarce. The general tendency is to extrapolate the data from light ions, applying a different correction factor K given in Eq. 1.

The electron yield proportionality with ion energy is confirmed for low energies, but a difference of 40% is observed at 1 MeV. We plan to extend the analysis of the data in a further article to better explain the difference obtained. The model being developed will consider more parameters, such as the fact that almost 70% of the incident ions are backscattered and therefore do not excite the same amount of electrons.

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