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Short Communication

Towards Next Generation Of Boron Ion Implantation Devices

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Abstract

There is an overall need for small size user friendly implanters. The challenge is to find technology that allows to use pure Boron ion sources instead of its chemical compounds that create difficulties in the beam forming process and in most cases are poisonous. We offer game changing approach to use hollow cathode discharge combined with RF-ICP plasma to produce Boron ions and to form beam of Boron ions for implantation in crystals accordingly.

Keywords: Ion Implantation; Boron Ion Source; "State-Of-The-Art" Boron Ion Implantation Equipment; Search In Breakthrough Towards More Handy Implanting Apparatus

Introduction

Currently, besides semiconductor manufacturing, ion implantation is used for many other purposes, e.g., sensor manufacturing, hardening of metal surfaces, friction modification, chemical resistance alteration, painting and many others. Most of turnover in the industry (about 70% is made by research driven MEs), thus the new generation of implanters ought to be user friendly to highly flexible and small-scale production in small size enterprises. The development history of ion sources in detail can be found in [1]. The [2] discusses advantages and weakness between ion sources. Due to extremely low volatility with melting point at 2076°C and boiling point at 3927°C [3] the development of Boron ion source is a technological challenge. Since early 1960's various boron containing molecules were investigated until boron rifluoride gas (BF3, extremely toxic molecule) was chosen as one of the best options. It was used in Sidenius torch which is based on hollow cathode discharge (HC) and also in Freeman torch, but incandescent cathode of the source corrodes in the aggressive gas.

State-of-The-Art Of Pure Boron Ion Beam Forming Approaches

The development of ion sources using hardly volatile elements accelerated after 1990 and comprehensive review [4] describe the possibility of usage of HC discharge for various needs, particularly, allowing to atomize hardly volatile elements. Further relevant research exposed that it effectiveness may be increased substantially if HC discharge is combined with radio-frequency (RF) glow discharge (capacitive coupled plasma - CCP) or RF inductively coupled plasma sources (ICP). Similar review concerning the progress in the development of ICP is [5]. The diversity in applications of ICP plasma is described in several rewievs in 2005-2018: [6-8]. At 2012 the coupling of ICP or CCP actuator with the HC was reported by [9-11]. Well known hollow cathode technologies are in high demand in analytical spectroscopy, along with ICP. In contrast, the HC (or glow discharge) exhibits a specific electron energy distribution function which includes a small part of high energy electrons able to atomize the surface material of hollow cathode and to bring in the volume and to excite resonance spectra of atoms as well as ions of a large number of elements (including hardly volatile). During the last decade HC technologies has come into space micropropulsion thruster industry, evidenced by [9,12]. RF-ICP can reach electron temperatures up to 10 000 K, giving the complete atomization of the sample elements. The ICP works as virtually ideal linear atomizer and ionizer as well. After detailed studies we found out that application of hybrid of HC discharge and RF-ICP plasma possibly leads to game changing solution in the design and manufacturing of new generation of ion implanters. The approach for the first time mentioned and used for spectroscopy by [13], comprehensively described in [14] and used recently on sputtering of solid metals by [15]. The key of the emerging disruptive innovation is in the development of a sophisticated hybrid geometry (based on glass, silica glass technology) of ICP –HC- ICP plasma coupling/conjunction, that is conceptually different from the existing commercial devices dedicated for Boron implantation shows [16,17].

RF-ICP coil possitioned before HC will increase plasma density. Another RF-ICP coil after HC will raise ionization ratio in plasma volume before the beam extraction/forming. Further challenge is linked to magnetic mass filter necessary to select ions with the mass of choice. We studied different sector magnet geometries, Wien filter and QMS filter (Quadrupole mass selector). QMS seems to be a realistic and preferable filter yet not used for implantation until now for single reason, beam transparency. The choice is based on the following considerations: it is cheaper and mechanically simpler than solenoidal sector magnet, has higher selectivity, less weight, less power demand. QMS consists of cylindrical rods extra-accurate parallel to each other and fed by DC and RF voltage superposition. QMS is filtering ions by (m/z) ratio. The ion-transparency of QMS is sharp dependent on mechanical accuracy having critical jump at 0,1 to 10 μm of position accuracy and shape geometry [18]. Currently the best available QMS in the markets have accuracy of 0.25 μm [19] yet most are sold within 2 to 4 μm. QMS needs specific software and hardware. Currently advanced and simple solution for this is technology called DDS (Direct Digital Synthesis) [20,21]. Ion beam technologies need high vacuum for the beam. We are offering to build the equipment on glass silica technologies and glass to metal seals based on kovar (iron-nickel-cobalt alloy), having thermal expansion similar to borosilicate glass. Graded seals quartz-borosilicate glass may be applied in several cases. In comparison with thick-metal molybdenum vacuum vessel being industry standard, we deduct from available data-tables, the quartz-wall vacuum chamber allows to ensure an order of magnitude higher vacuum. Basing on further studies we foresee some possibilities for further improvements:

a. Application of laser ablation technique to intensify the atomization in HC by laser ablation, described by [22]. Specific advantage there is pulsing laser resulting in pulsing beam.

b. Several articles indicate another promising ion source: [23] report boron cathodic arc source. Decade later [24] show in detail the generation of boron ions for ion-beam using this approach. Beforehand [25] and [26] described this technology development step by step.

c. Another principle of ion source giving excellent ion beam current of 75 mA is reported in detail by [27] where the LaB6 tablet was used (which is a conductor).

Discussion/Conclusions

The performed study confirmed the potential to respond to the current and future needs for miniaturized cost-effective boron ion implantation device. The key to the success is Boron ion source based on hybrid plasma source coupling HC discharge and RF-ICP. Use of QMS filter instead of magnetic provides better size, weight, price, and selectivity. Use of quartz in vacuum tract alter the ion-beam purity, what industry may say be crucial. Recently published research articles provided knowledge base needed to face and resolve emerging challenges.

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