DEVELOPMENT OF AN ION SOURCE FOR IMPLANTERS AT THE INSTITUTE OF APPLIED PHYSICS

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Based on the beryllium ion source developed at the Institute of Applied Physics of the NAS of Ukraine, the design of an ion source with a slit extraction geometry has been carried out to improve its operational characteristics, including operating life, optimization of working material consumption, and expansion of the spectrum of generated ions. This work presents a description of the design of an evaporative ion source for generating strip ion beams intended for use in a technological line for the production of semiconductors with narrow-band p-n junctions.

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1. INTRODUCTION

Ion implantation as a technological process is widely used for: doping, strengthening of materials, modification of material properties and synthesis of new phases. A modern production process for doping wafers in the semiconductor manufacturing process may require twenty or more implantations of different types of dopants and doping levels. To make this possible, the ion source must have smooth and relatively repeatable characteristics. There are different types of ion sources, which differ in the design of the arc chamber and the method of electron generation.

At the Institute of Applied Physics of the NAS of Ukraine, the modernized VESUVIUS-5 implanter is successfully operating, conducting ion implantation processes [1, 2], simulation studies on the effects of ion irradiation on reactor technology materials [3,4], and the development of zirconium and refractory metal ion sources [5, 6].

The defining element of any ion beam installation is the ion source, the operational properties of which significantly depend on the quality of its operation. Quite strict requirements are usually imposed on the ion source. With a relative simplicity of design, it must be distinguished by reliability and stability of operation, stability of beam parameters, ease of control, adjustment and maintenance and, most importantly, have a long resource of continuous operation.

In modern laboratory ion-beam installations, which are actively being developed worldwide, a wide variety of ion sources are used, differing in both operating principles and design. Although these sources collectively cover the needs of ion-beam technologies, an analysis of the operation of such installations shows that the ion source is typically their weakest component, limiting the duration of continuous operation.

Based on the analysis of modern ion sources used in ion implanters, it can be concluded that the best option currently available is the Bernas source with a heated cathode. However, it also has certain drawbacks, such as a complex and inconvenient evaporation system for the working substance, the presence of a system for evaporation of the working substance requiring a separate power source for heating, and, consequently, an additional control and monitoring system.

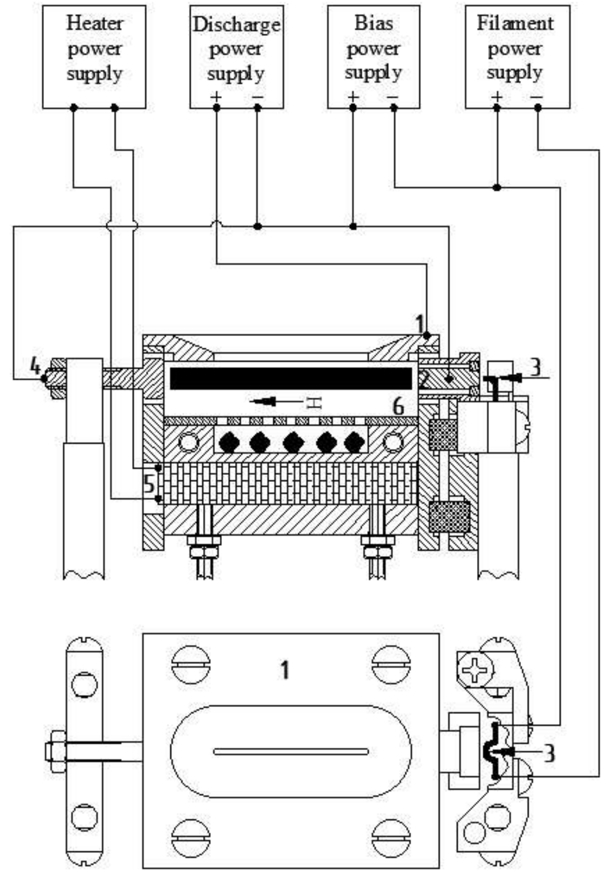
Additionally, its discharge chamber serves as the body of the ion source. When operating at high discharge currents, the inner walls of the chamber quickly become coated with a layer of sputtered cathode material, which needs to be periodically cleaned, which causes certain difficulties.

2. DESIGN OF THE IAP ION SOURCE

The task of this work was to create an ion source with a slit extraction geometry for generating ions of a wide mass spectrum, in the design of which we tried to avoid the above-mentioned drawbacks. Currently, there are several methods for obtaining ion beams of solid-state elements [7, 8]. The most widely used method is the formation of a working medium in an external evaporator with subsequent direction through a conduit into the ionization chamber of the ion source. The main drawback of this method is the condensation of vapor within the conduit when power is suddenly turned off. Additionally, it requires an extra heating element with a control and monitoring system, which must be electrically isolated at several hundred kilovolts.

The general view of the electrode system of the experimental IAP ion source with slit extraction geometry and a specially designed working material evaporation system is shown in Figure. The same figure also illustrates its power supply system.

The evaporated substance in this ion source is placed beneath a replaceable insert 6 in the discharge chamber. Vapors of this substance enter the discharge through openings in the chamber’s bottom, eliminating the need for a separate vapor conduit and its power supply. Heating of the working material is performed by an FCP ceramic heater 5, which is produced in standard sizes and power ratings. This heater is simply inserted into the discharge chamber housing and can be easily replaced if necessary. Ions from this source are extracted radially across the magnetic field through a 30 mm × 1 mm slit in the wall of the discharge chamber.



Ion source design: 1 – anode;
2 – heated cathode; 3 – cathode filament; 4 – anticathode; 5 – FCP ceramic heater;
6 – replaceable insert.

The plasma generator of the ion source consists of three main components: the electron source, the Penning cell, and the evaporator.

Electrons are generated using a heated cathode (2) and a filament (1), which is made of tungsten wire with a diameter of 1 mm. Within the Penning cell, the radial movement of electrons is restricted by a longitudinal magnetic field. The magnetic field induction at the center of the cell is approximately 0.05 T. In the axial direction, electron motion consists of multiple oscillations due to their reflection from the anticathode (4).

The heated cathode of the source is made of tungsten with a diameter of 4 mm and a length of 20 mm. The small diameter of the cathode allows it to be positioned as close as possible to the emission slit, enabling higher localization of ionization efficiency in the discharge plasma compared to other Bernas source designs. The increased length of the cathode extends its operational life time. The cathode filament is placed at its rear end, outside the discharge chamber volume, operating in a high-quality vacuum, which prevents damage from sputtering.

3. CONCLUSIONS

This ion source was designed for generating ions from solid-state materials whose vapors can be obtained by heating the materials themselves or their compounds. However, the source can also be integrated into a technology that creates the working medium by sputtering the material directly inside the discharge chamber.

Thus, the developed ion source design achieves an optimal balance between plasma properties in the discharge chamber, versatility, operational characteristics, and the desired properties of the ion beam.

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