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ENERGY SPREAD OF ION BEAMS GENERATED IN MULTICUSP ION SOURCES *

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For the production of future microelectronics devices, various alternate methods are currently being considered to replace the presently used method of lithography with ion beam lithography. One of these methods is the Ion Projection Lithography (IPL), which aims at the possibility of projecting sub-0.25 μm patterns of a stencil mask onto a wafer substrate. In order to keep the chromatic aberrations below 25 nm, an ion source which delivers a beam with energy spread of less than 3 eV is desired. For this application, multicusp ion sources are being considered. We measure the longitudinal energy spread of the plasma ions by using a two-grid electrostatic energy analyzer. The energy spread of the extracted beam is measured by a high-voltage retarding-field energy analyzer. In order to obtain the transverse ion temperature, a parallel-plate scanner is being set up to study the beam emittance. In this paper, comparisons are made for different ion source configurations.

I. INTRODUCTION

For the production of microelectronics devices, lithography, i. e. the projection of structures onto a wafer substrate, plays an important role. However, since the devices are getting smaller, it is foreseeable that the wavelength of light will be too large for future structures.

An alternative method for projecting the structures onto the wafer is Ion Beam Lithography [1], where, instead of light, particle beams are used. The wavelength of the particles depends on their momentum and can be much smaller than in the case of light. The particles can be guided by the well known techniques of electrostatic and magnetic lens systems, which also make their use preferable to that of x-rays.

One of the approaches for Ion Beam Lithography is the Ion Projection Lithography (IPL) [2], which presently is being developed by the Advanced Lithography Group (ALG). According to a design by Ion Microfabrication Systems (IMS), a 10 keV hydrogen or helium ion beam is extracted from an ion source and expanded by a specially designed triode extraction system. With a ±3° emission angle, an area of homogeneity of 60×60 mm^2 is achieved. A condenser lens behind the extraction system allows an additional correction of the overall homogeneity in the beam as well as a mass separation. The beam then falls onto a stencil mask containing the structure that is to be projected onto the wafer. After that an optical column is used to reduce the ion beam before it impinges onto the photoresist surface. Thus, a 5x reduction of the mask pattern can be achieved at the image plane.

This lens system is highly demanding in regard to the ion optical qualities of the beam generated in the source. A high energy spread in the beam would disturb the ion optical qualities of the system and thus also the precision of the projected structures.

The beam is generated in an ion source, consisting of a plasma chamber and a triode extraction system. As plasma generator a multicusp source is considered. A permanent magnet can be installed in the plasma chamber for modification of the plasma potential distribution and for the enhancement of atomic hydrogen ion species [3, 4].

To determine the energy spread generated by the source plasma and the energy spread that is obtained in the process of beam formation, electrostatic energy analyzers are used. The influence of the filter magnets on the energy spread is investigated.

II. EXPERIMENTAL SET-UP

In this experimental investigation, a filament-driven multicusp ion source was used. The source chamber has a diameter and a length of 10 cm and can, in the longitudinal direction, be divided into two sections by the use of a magnetic filter. This filter was originally used to enhance the atomic H^+ in the beam [3] by trapping the cold plasma electrons in the extraction region. However, the filter magnets also influence the potential distribution inside the plasma [4].

In order to determine the influence of the filter magnets on the energy spread, the filters are removable. Additionally, the end-flange of the source is exchangeable, so that later on the plasma can be driven by an rf- discharge as well.

For measurement of the energy spread the transverse and longitudinal components have to be determined separately. For the measurement of the transverse energy spread, a parallel plate slit-slit emittance scanner will be employed. For analyzing the longitudinal energy spread two versions of energy

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analyzers can be used. A small, two-grid energy analyzer allows the measurement of the energy distribution of the emitted plasma ions. This analyzer can be attached directly to the first electrode of the source. The measurement of the energy distribution of the accelerated beam can be performed by a high-voltage, retarding-field analyzer, which was built by IMS. This analyzer was used in the measurements described below.

Fig. 1 shows a schematic of the experimental arrangement. The triode extraction system (ES) is mounted to the multicusp ion source (IS). The IMS energy analyzer is placed in 50 cm distance from the extraction system . The beam is collimated and only the central part of the extracted beam contributes to the measurement. Behind the entrance of the energy analyzer a grid for electron suppression is installed. A column of electrodes, connected by a resistor chain, then retards the ion beam. The analyzer plate is tied to source potential. A battery allows a voltage variation on this plate of ± 90 V.

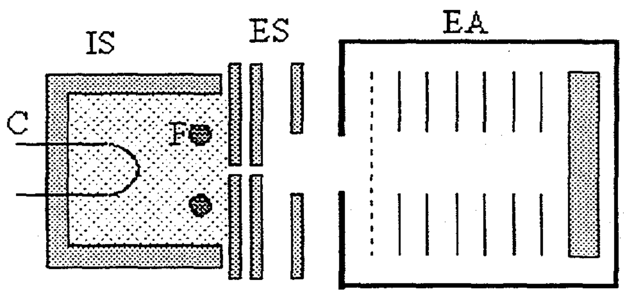

Figure 1: Schematic of the experimental arrangement. A multicusp ion source (IS) with filter magnets (F) is used for filament-driven plasma generation (C). Attached to the source body is the triode extraction system (ES). The high-voltage, retarding-field analyzer (EA) is placed 50 cm behind the extraction system. It consists of an electron suppression grid at the entrance, a column of electrodes for deceleration and an analyzer plate for collection of the ions.

III. EXPERIMENTAL RESULTS

The measurement of the longitudinal energy spread in the accelerated beam was performed on a 5 keV He^+ beam. The beam was formed in a triode extraction system, which was designed by IMS. The beam exits from the extraction system divergent with a very good uniformity.

With the energy analyzer, by applying the retarding field, the integral energy distribution was measured, and from this, by differentiation of the curve, the energy spread (FWHM of the curve) was determined. Figs. 2 and 3 give an example of the measured and calculated data. In this case an arc voltage of 60 V was applied. The first electrode of the extraction system was tied to source potential. No filter magnets were installed in the plasma chamber. An energy spread of 10.4 eV was determined.

We measured the energy spread for different settings of the arc voltage in the source. Also the influence of the potential of the first electrode of the extraction system (source potential vs. floating potential) was tested. In all these cases the energy spread was approximately 10 eV.

The same measurements were then repeated with the filter magnets installed in the plasma chamber. The energy spread of the beam ions was determined to be approximately 8.7 eV (Fig. 4), which is slightly lower than in the case without the magnetic filter.

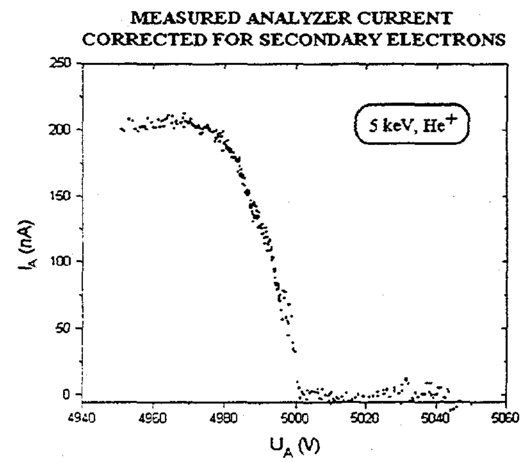

Figure 2: Integral distribution of the energy spread for a 5 keV He^+ beam generated in the filament driven multicusp source with no filter magnets in the source chamber.

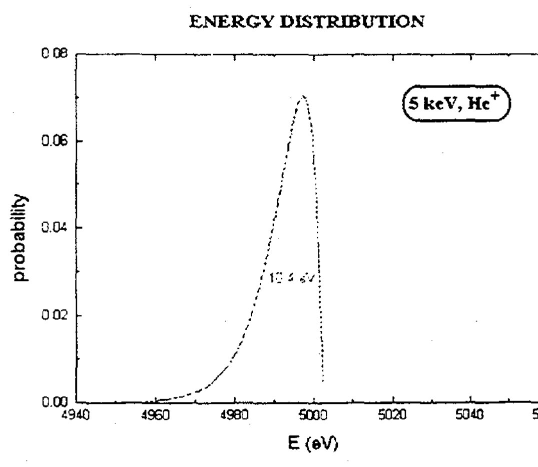

Figure 3: Differentiation of the curve shown in Fig. 2. The energy spread was determined to be in the order of 10 eV.

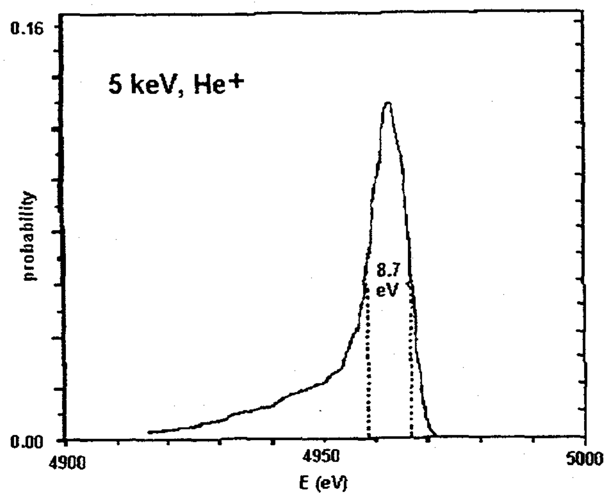

Figure 4: Energy spread in a 5 keV He^{+} beam, when the magnetic filters are installed in the ion source.

IV. DISCUSSION

The measurements described above showed an energy spread of the beam ions of 8 to 9 eV with, and 10 to 11 eV without applying the magnetic filter in the plasma chamber of the ion source. This difference can be explained by the change of the axial potential distribution inside the source. As was shown in [4] the introduction of the magnetic filters yields in a region with a relatively flat plasma potential profile in axial direction. The voltage drop in this case is only 1.5 eV, whereas without the filters a potential difference of 3.5 eV could be observed.

The lower energy spread in the case with the magnetic filters can be explained by these former observations. However, there is still a high energy spread in the beam (8 to 10 eV). The cause for this high energy spread is not yet understood. Further investigations are in progress. To obtain information about the energy spread of the ions as they exit from the plasma, at present we are planning to install the two-grid energy analyzer at the first plasma electrode. The transverse energy spread will be determined by means of emittance measurements. Experimental investigation is in progress, results will be presented in the near future.

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