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# Ion Source with Radiofrequency Mass Filter for Sputtering Purposes[1]

Źródło jonów z filtrem mas o częstości radiowej do rozpylania jonowego

**Abstract.** The Kaufman ion source with radiofrequency mass filter is described. The construction as well as operating characteristics of ion source are presented. The arrangement is suitable for range distribution measurements of implanted layers, where the sputtering rate has to be constant over the wide range of sputtering time.

## 1. INTRODUCTION

Considerable interest has been shown during the last ten years in the use of ion beams for surface analysis, thinning specimens for transmission scanning-electron microscopy, cleaning of specimen surfaces, removal of superficial layers, sputter deposition of thin films and so on [1-10]. The work of many investigators has shown that there are areas where special advantages are gained using ion beams in preference to other techniques.

To remove atoms from the surface of a solid material at a useful rate, usually the beam of low energy ions (0.1÷5 keV) is used. There are many different ion sources developed for various ion milling — techniques applications. A description of different kinds of ion sources with their operating characteristics and a listing of applications to which the sources

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were designed has been published by E. G. Spencer and P. H. Schmidt [11] and L. Valyi [12].

In this paper the characteristics of Kaufman ion source additionally equipped with radiofrequency mass filter are described. The arrangement is suitable for range distribution measurements of implanted layers, where sputtering rate has to be constant over the wide range of sputtering time.

## 2. GENERAL DESIGN

In the Figure 1a and b the setup of the ion source and its photograph are shown. This is a low-voltage arc ion gun utilizing a hot filament as the source of electrons to ionize the gas. The ions are extracted from the plasma by the two molibden grids which have matching arrays of 150 holes, each of which has 0,3 mm in diameter. This results in 150 collimated ion beams over 4 cm diameter area. Each beam is capable to produce a current of about 100 $\mu$A, that is the total beam current of about 15 mA for 1000 V acceleration voltage.

The source described above Kaufman is usually used for cleaning of specimen surfaces, removal of superficial layers and microcircuit etching. The ion beam falls directly on the sputtered samples without mass separation. In some applications (for example in case of removal of superficial layers in studying impurity range distribution of implanted samples) the high precision of sectionic is required [13,14]. Sufficient accuracy of sputtering process can be reached when ion beam has a stable energy spread, current density and mass composition during the sputtering time.

It is well known [15] that the plasmatic ion sources emit various impurities together with the base, usually noble gas ion beam. These impurities originated from gas absorption in source construction parts as well as from residual gases filling the apparatus. This can be easily seen from the Fig. 2 where ion current of $Ar^+$ and $N_2^+$ as a function of operation time of the source are shown. To decrease the impurities coming with the base ion beam, the source ought to be heated for at least 3–4 hours. Similar results have been obtained in [16] where ion etching rate vs. operation time of the Kaufman type ion source was investigated.

To eliminate such inconvenience, in the arrangement presented in this paper the ions pass through the radiofrequency mass filter. The mass analyser has 12 equally spaced wolfram grids. The distance between each other is 9 mm. Radio-frequency voltage of 1÷4 MHz and ±50 V of amplitude

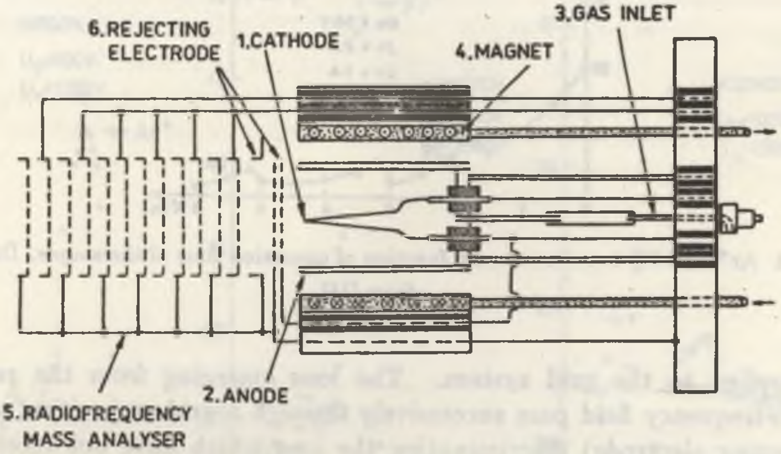

Fig. 1 a. Schematic diagram of ion source, 1 cathode, 2 anode, 3 gas inlet, 4 magner, 5 radiofrequency mass analyser, 6 rejecting electrode

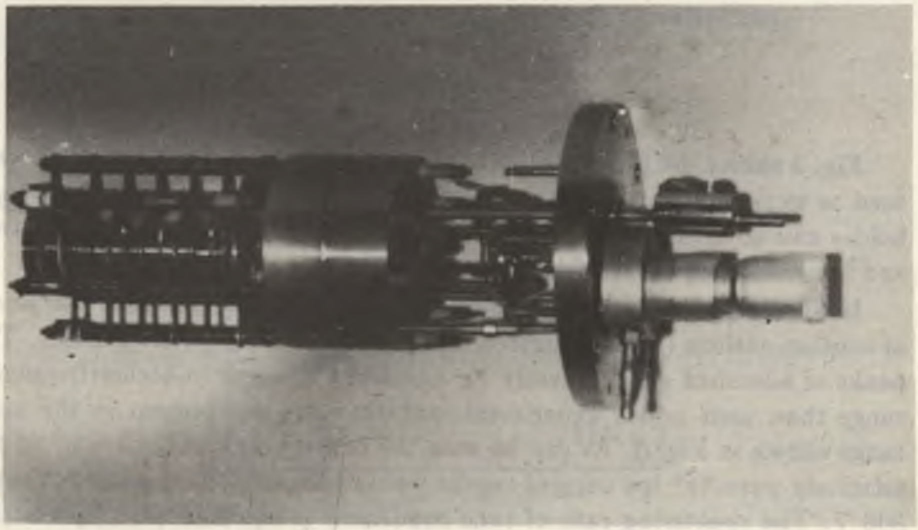

Fig. 1 b.

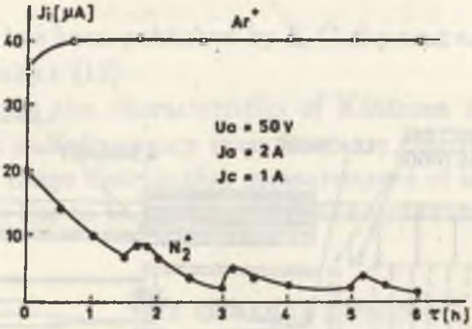

Fig. 2. $Ar^+$ and $N_2^+$ ion current as a function of operation time of the source. Data taken from [15]

is applied to the grid system. The ions emerging from the region of radio-frequency field pass successively through a grid at positive potential (rejecting electrode) discriminating the ions which have not received the maximum possible energy. The resolution attained was only between 2 to 5 (depending on positive potential on rejecting grid), but it is enough to eliminate various kind of impurities from base ion beam.

## 3. RESULTS

Fig. 3 shows the mass spectrum of ion beams when Ar, Kr and Xe were used as working gases. The ion current was detected directly on the sample holder and no arrangements like Faraday cup (to prevent secondary electron and ion emission) are used in the experiment.

In all cases, beside the expected ions, in the mass spectrum the peaks of contaminations (from sputtered elements of the source) are present. The peaks of adsorbed gases (mainly $N_2$ and $O_2$) can occur in higher frequency range than used in our experiment, and they are not present in the mass range shown in Fig. 3. As can be seen the density about 60 $\mu A/cm^2$ of the relatively pure $Ar^+$ ion current can be reached for extraction potential equal 900 V. The sputtering rate of such conditions is equal to $\sim$50 Å/min (for silicon sample).

We have measured also the sputtering rate as a function of operation time of the ion source. The results are shown in the Fig. 4, where also the data from [16] are plotted for comparison. The curve (a) (from [16]) was obtained without mass separation. As can be seen from the Fig. 4, when the

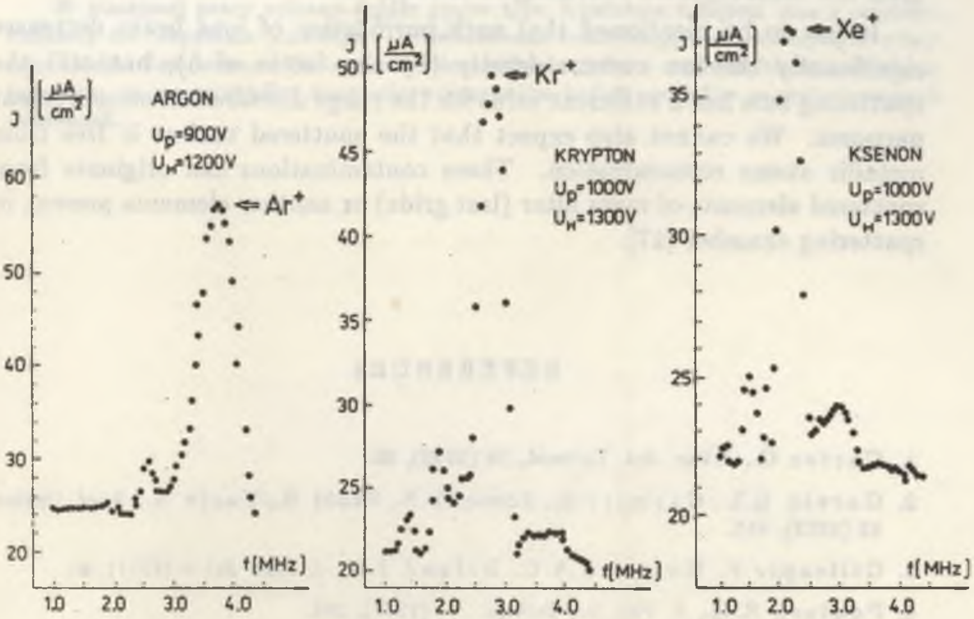

Fig. 3. Mass spectrum of ion beams for Ar, Kr and Xe as working gases

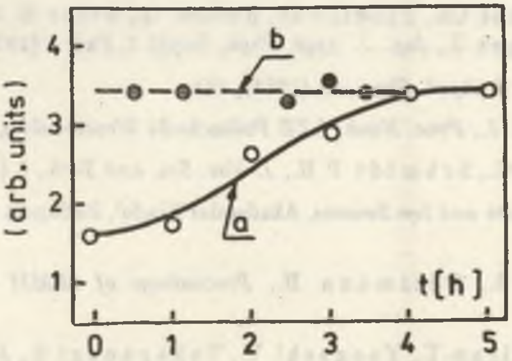

Fig. 4. Sputtering rate as a function of operation time of the ion source. Curve (a) — without mass separation — data taken from [16]. Curve (b) — with radiofrequency mass filter

radiofrequency mass filter is used, the stable etching rate can be obtained after few minutes from switching in the source.

It has to be mentioned that such purification of ions beam decreases significantly the ion current density (by the factor of 5), but still the sputtering rate has a sufficient value for the range distribution measurement purposes. We cannot also expect that the sputtered surface is free from metallic atoms contamination. These contaminations can originate from sputtered elements of mass filter (last grids) or another elements present in sputtering chamber [17].

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## STRESZCZENIE

W niniejszej pracy opisano źródło jonów typu Kaufmana z filtrem mas o częstości radiowej do rozpylania jonowego. Przedstawiono konstrukcję i charakterystyki pracy tego źródła. Zastosowanie filtru umożliwiło uzyskanie stałej w czasie szybkości rozpylania jonowego, co ma szczególne znaczenie w przypadku badań rozkładów zaimplantowanych domieszek.

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