Nuclear Instruments and Methods in Physics Research A274 (1989) 415-418
North-Holland, Amsterdam

NEW METHODS OF ENHANCING ION BEAM INTENSITIES FROM TWO TYPES OF SPUTTER NEGATIVE ION SOURCES

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Received 22 January 1988 and in revised form 15 August 1988

In the Munich HICONEX 834 source [2] Cs_2CrO_4, CsI and CsF as target additives have been investigated. It is shown that adding Cs_2CrO_4 in suitable ratios improves Cs coverage and achieves the effect of the simultaneous spraying of O_2. The intensities of Fe^-, Ag^- and Cu^- ion beams increase by 10, 6 and 3.5 times the values obtained with pure Fe, Ag and Cu targets, respectively. Negative beams of the halogens can be obtained conveniently by mixing corresponding Cs halides with metal to form sputter targets. In the Munich high current source [6], a Fe target with an admixture of 5% Fe_2O_3 produces about twice the Fe^- beam current as compared to that from a pure Fe target without damaging the ionizer.

1. Introduction

Since 1974 sputter-type negative ion sources have been used in almost all tandem accelerator laboratories. Any improvement in ion current from such sources is desirable.

In the universal negative ion source (UNIS), Middleton [1] and Braun-Elwert et al. [2] proved that spraying O_2 onto the target surface is a very efficient method to enhance beam intensities for some elements, particularly for metals. Middleton also tried to spray Cs vapour onto the Cu target surface directly with the aim of getting optimum Cs coverage and some encouraging results were obtained [3]. Unfortunately, he failed to get a stable beam because of difficulties in controlling the Cs vapour pressure. In our experiments, we discovered that similar improvements can be achieved by mixing Cs_2CrO_4 with metal powder to form sputter targets in suitable weight ratios while reducing the vacuum load and simplifying source operation. We also mixed CsI, CsF with metal powder to form sputter targets, respectively, and found that this procedure is a very good method for producing halogen ion beams.

In the high intensity negative ion source, as is well known, the Cs coverage can be optimized and there is not much trouble in spraying NH_3 and H_2 into the source. However, if O_2 is sprayed onto the target surface, the ionizer will be easily damaged. During the investigations for producing Fe^- beams we admixed a little Fe_2O_3 with Fe powder to form the sputter target. During the sputtering, the amount of oxygen on the target is sufficient to achieve the effect of spraying O_2 without having high O_2 pressures in the source chamber. As a result, the Fe^- beam was enhanced and the ionizer was not damaged.

All experiments were performed using the ion source test stand of the Munich Tandem Accelerator Laboratory. A schematic drawing of the test stand is shown in fig. 1. The analysis slits were set to a width of 3 mm to achieve the desired mass resolution.

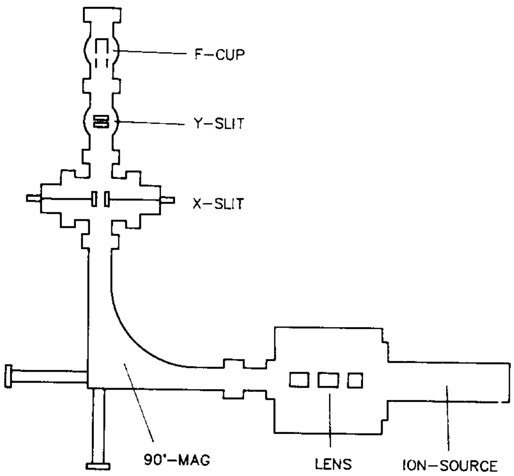

Fig. 1. Schematic drawing of the ion source test stand.

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(North-Holland Physics Publishing Division)

2. Universal negative ion source

The source used in our experiments is a Model 834 negative sputter ion source manufactured by General Ionex Corp. [4] operated in the reflection mode developed by Brand [5]. Fig. 2 shows the target geometry used in these experiments. Brand discovered that a Cs collection cup in front of the sputtered target material is an efficient way to enhance beam intensities. We did not attempt to optimize the depth of the cup; a 2 mm cup depth was chosen. All sputter target discs were pressed to a diameter of 5 mm.

The principles used for selecting additives for this source are:

(1) They should consist of Cs and other desirable components.
(2) They should have sufficiently high melting points.
(3) The composition should provide an optimum Cs coverage and at the same time an optimum amount of oxygen for a particular element.
(4) They should not contain undesirable elements. The unwanted elements should not easily generate negative ions and the mass of the undesirable ion species should be considerably different from the desired species.

Normally, it is rather difficult to meet all requests and two or more additives may be better in some cases.

In the following, we show the results for each element that has been tested.

2.1. Iron

Middleton [1] found that the Fe^- beams could be increased by factors of 3 by spraying O_2 onto the Fe target surface at an optimum O_2 partial pressure.

We mixed Cs_2CrO_4 and Fe powder in different weight ratios and pressed them into discs. For comparison the pure Fe target was also pressed from Fe powder. Results of tests in the same system and under the same conditions are listed in table 1. We found a mixture of a 5% Cs_2CrO_4 + 95% Fe target to be best. The corresponding Fe^- beam intensity was found to be more than 10 times that from a pure Fe target. Interestingly, the Fe^- beam from a 10% Cs_2CrO_4 + 90% Fe target was less than that from a 5% Cs_2CrO_4 + 95% Fe target. The reverse results were found for FeO^- beams. This shows that the generating conditions for Fe^- and FeO^- are different.

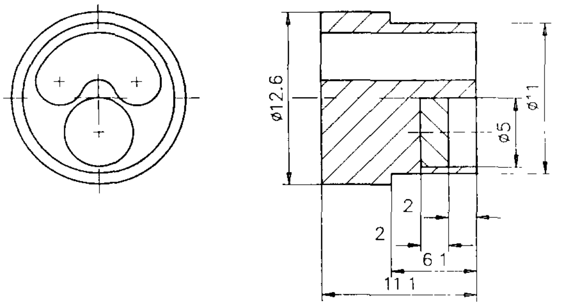

Fig. 2. Schematic drawing of the sputter target. (Units are in mm.)

Table 1
Intensities of Fe^-, FeO^- and O (in nA) for different ratios of Cs_2CrO_4/Fe

Target	Pure Fe	5% Cs_2CrO_4 +95% Fe	10% Cs_2CrO_4 90% Fe
$^{56}Fe^-$	8	87	67
$^{56}FeO^-$	53	185	195
$^{16}O^-$	940	3800	4400

2.2. Silver

Middleton [1] reported that Ag^- beams increase about 4.5 times by spraying Ag samples with O_2. When we investigated the effect of mixing Ag into Fe + Cs_2SrO_4 in order to improve the Fe^- yield, we found the exciting result that the $^{107}Ag^-$ beam increased by as much as 6 times the value obtained with a pure Ag target while the Fe^- yield did not show any improvements. Table 2 displays the results found for different targets. Comparing the results of a 10% Cs_2CrO_4 + 25% Ag + 65% Fe target with those from a 10% Cs_2CrO_4 + 45% Ag + 45% Fe target it is speculated that a higher Ag^- beam intensity could be obtained from a 10% Cs_2CrO_4 + 90% Ag mixture. The Ag^- beam data from the pure Ag target were taken from table 2 of ref. [1]. In that work, the analysis slits were set to a width of 6.8 mm which was much wider than our settings (3 mm).

The Ag^- beam intensity from a 10% CsF + 25% Ag + 65% Fe target was less than that from a 10% Cs_2CrO_4 + 25% Ag + 65% Fe target but much better than that from a pure Ag target. It is speculated that CsF improves the Cs coverage but does not offer the benefit of spraying O_2.

Although only 10% CsF was contained in the 10% CsF + 25% Ag + 65% Fe target, an 8.3 μA F^- beam

Table 2
The Ag^-, F^- and O^- yields (in nA) of different targets

Target	Pure Ag	(10% Cs_2CrO_4 +25% Ag +65% Fe)	(10% Cs_2CrO_4 +45% Ag +45% Fe)	(10% CsF +25% Ag) +65% Fe)
$^{107}Ag^-$	80 [a]	380	485	238
$^{109}Ag^-$		355	430	228
$^{16}O^-$		4000	4300	–
$^{19}F^-$				8300

[a] From ref. [1].

Table 3
Cu^-, O^- and Cr^- beam intensities (in nA) for different ratios of Cs_2CrO_4/Cu

Target	Pure Cu	5% Cs_2CrO_4 + 95% Cu	10% Cs_2CrO_4 + 90% Cu	15% Cs_2CrO_4 + 85% Cu
$^{63}Cu^-$	480	1000	1750	1790
$^{16}O^-$	930	1400	4500	8200
$^{52}Cr^-$		8.7	27.5	65

was obtained. It is speculated that a higher F^- beam current could be achieved if the target contained more CsF. This method is convenient and will be adaptable for other halogen elements as well.

2.3. Copper

It has been known that copper can be easily sputtered and that the Cu^- beam current can be increased by a factor of 2 upon spraying with O_2. After testing the 15% Cs_2CrO_4 + 85% Cu mixture, the Cu^- beam current was increased 3.5 times that from a pure Cu target. Comparing the results listed in table 3, higher Cu^- currents can be obtained from targets containing more than 15% Cs_2CrO_4. Surprisingly, the amount of Cr in the 15% Cs_2CrO_4 + 85% Cu target is rather small but the Cr^- beam is up to 3.5 times more than from pure Cr targets (see ref. [1]).

2.4. Nickel

Middleton [1] discovered that spraying with O_2 is harmful for Ni^- beams. Therefore, we mixed CsI into a Ni target instead of Cs_2CrO_4 to improve the amount of Cs and to eliminate the presence of oxygen. Unfortunately, the elemental beam currents produced from such a target turned out to be still less than those from pure nickel targets.

Surprisingly, a 3 μA $^{127}I^-$ beam was obtained from a 20% CsI + 80% Ni target. This is comparable to the result obtained at Brookhaven National Laborytory (BNL) [1] of 4 μA $^{127}I^-$ from a potassium iodide cone.

Table 4
Fe^-, FeO^- and O^- beam intensities (in μA) for different ratios of Fe_2O_3/Fe

Target	Pure Fe	5% Fe_2O_3 + 95% Fe	10% Fe_2O_3 + 90% Fe
$^{56}Fe^-$	1.08	1.92	0.56
$^{56}FeO^-$	0.74	6.8	6.2
$^{16}O^-$	5.8	43	44
P [Torr] (near the extractor)	3×10^{-7}	5.8×10^{-7}	

3. The high intensity negative ion source (VHINIS)

The source used in the present experiments was developed by this laboratory [6] and is similar to the source model VI of Middleton [7]. We have only investigated the Fe^- beam for our heavy ion physics program. As described above, Fe_2O_3 was mixed into the Fe powder targets in different ratios of Fe_2O_3/Fe. The results listed in table 4 show that a 5% Fe_3O_3 + 95% Fe target is best. This mixture yielded about twice the Fe^- beam currents obtained from a pure Fe target while producing 6.8 μA of FeO^- and 43 μA of O^-.

Related to a pure Fe target, a 5% Fe_2O_3 + 95% Fe mixed target only causes a 3×10^{-7} Torr pressure increase in the extraction region of the source which does not damage the ionizer.

4. Discussion and conclusions

Although the VHINIS source produced much higher beam intensities than the UNIS source for most elements, the UNIS source has many advantages and is still an essential source for tandem accelerator operations. Therefore, efforts to improve this source are still worthwhile.

In the UNIS source, the main difficulty for enhancing beam intensities is to obtain optimum Cs coverage [8] (about half a monoatomic layer) because the Cs^+ beam acts both as the sputter medium and as a cover for the target surface with neutral Cs. Unfortunately, spraying Cs vapour directly onto the target surface is almost impossible. However, in the present work we examined the use of Cs compounds as target additives to improve the amount of Cs on the target surface; although Cs_2CrO_4 improves Cs coverage and replaces the need for spraying with O_2 onto the metal surface, targets containing two additives may be more efficient for enhancing beam currents; it is also concluded that Cs halide + metal targets are very suitable for producing strong halogen ion beams.

Although most elemental beam intensities are rather high in the VHINIS source, even higher intensities are expected for some special elements. Since the ionizer and target are in a common chamber, a certain amount of oxide as target additive is a good choice for providing oxygen without damaging the ionizer.

Although the investigations are very far from complete, the present ideas show promise as a means of increasing the beam intensities from a variety of elements.

Acknowledgements

I sincerely thank Prof. S. Skorka for his hospitality during my visit. I would also like to thank Mr. W. Carli, Dr. H. Münzer, Dr. G. Korschinek, Dr. H.J. Maier, Mr. W. Hagn and colleagues at the Munich Tandem Accelerator Laboratory for their friendly support and help.

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