

PRODUCTION OF ATOMIC NEGATIVE ION BEAMS OF THE GROUP IA  
ELEMENTS\*

CONF-8810242 2

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DE89 004183

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A method has been developed which enables the direct sputter generation of atomic negative ion beams of all members of the Group IA elements (Li, Na, K, Rb, and Cs). The method consists of the use of sputter samples formed by pressing mixtures of the carbonates of the Group IA elements and 10% (atomic) Cu, Ag, or other metal powder. The following intensities are typical of those observed from carbonate samples subjected to ~ 3 KeV cesium ion bombardment:  $\text{Li}^-: \geq 0.5 \mu\text{A}$ ;  $\text{Na}^-: \geq 0.5 \mu\text{A}$ ;  $\text{K}^-: \geq 0.5 \mu\text{A}$ ;  $\text{Rb}^-: \geq 0.5 \mu\text{A}$ ;  $\text{Cs}^-: \geq 0.2 \mu\text{A}$ .

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\* Research sponsored by the U.S. Department of Energy under contract DE-AC05-84OR21400 with Martin Marietta Energy Systems, Inc.

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## I.0 Introduction

Sputter-type negative ion sources are used extensively in tandem electrostatic accelerator-based applied and basic research programs.<sup>1-3</sup> Such sources can be used to produce either atomic or molecular negative ion beams from many of the chemically active elements. For tandem electrostatic accelerator applications, atomic negative ion beams are much preferred over molecular beams because of energy partition in the low energy stage of the accelerator and Coulomb explosion problems in the terminal stripping process. Heretofore, however, a universal method for formation of useful intensities of atomic negative ion beams from the Group IA elements has not been available.

The Group IA elements constitute ~ 8% of the elements which are considered viable candidates for negative ion production, and their formation by the sputter technique would allow a common source to be used for the production of useful beam intensities of almost every chemically active element in the periodic chart. While sequential charge exchange between an initially positive ion beam and an alkaline or alkaline-earth metal vapor offers a universal method for efficiently producing Group IA atomic negative ion beams at the few- $\mu\text{A}$ -intensity level, sources of this type are more complex in design, more tedious to operate, and have much shorter lifetimes than state-of-the-art cesium sputter negative ion sources. The development of a method based on the use of standard sputter-type negative ion sources is therefore highly desirable. Such sources are versatile, have long lifetimes, and are easy to operate.

In the past, efforts to produce useful negative ion beams by sputtering Group IA elements, for example, Li metal, have been unsuccessful. In the course of such experiments, it was discovered that  $\text{Li}^-$  ion beams can be produced by bleeding  $\text{O}_2$  over Li metal samples during the sputtering process. Even though some successes have been achieved by use of this method, this technique has generally proved to be erratic and undependable. As well, the physio-chemical properties of Li metal make sample preparation and handling difficult. The properties of the other members of the group, with the possible exception of Na, preclude their use as sputter probes in elemental form. The method described in this paper for the formation of Group IA elemental atomic negative ion beams is based on the use of the carbonates of these elements to form sputter samples for use in conventional sputter-type negative ion sources.

## 2.0 Sputter Probe Material Selection and Sputter Probe Fabrication

The present developments were prompted by sputter source experiments with Li/Cu alloys in 50%/50% atomic proportions. The results of these experiments proved to be very disappointing, yielding  $\text{Li}^-$  beam intensities of only a few nA. However, after exposing the Li/Cu samples to dry air for extended periods of time (several months) and thus conversion from Li/Cu to  $\text{Li}_2\text{O}/\text{Cu}$ ,  $\text{Li}^-$  negative ion beams from the same sputter probes grew to more than 2  $\mu\text{A}$  at a sputter probe voltage  $\leq 3$  kV.

The results obtained from the  $\text{Li}_2\text{O}/\text{Cu}$  samples suggested the formation of sputter probes from mixtures of  $\text{Li}_2\text{O}$  and Cu or Ag powder. (In fact, Brand, in independent developments, has used this technique to form  $\text{Li}_2\text{O} + \text{Ag}$  powder sputter probes for use in a standard sputter negative ion source which are

reported to yield a few  $\mu\text{A}$  of  $\text{Li}^-$ .)<sup>6</sup> However, the oxides of the more chemically active members of the group (Kb, Rb, and Cs) are highly deliquescent, properties which present problems during probe formation and storage. In the belief that the Group IA carbonates would be somewhat less hygroscopic ( $\text{Li}_2\text{CO}_3$  and  $\text{Na}_2\text{CO}_3$ ) and deliquescent ( $\text{K}_2\text{CO}_3$ ,  $\text{Rb}_2\text{CO}_3$  and  $\text{Cs}_2\text{CO}_3$ ) and thus easier to form into sputter samples and store, mixtures of the Group IA element carbonates and  $\sim 10\%$  (atomic) Cu powder were pressed at  $3.4 \times 10^3$  bars into pellets of diameter  $\phi = 6$  mm and thickness  $t \simeq 4$  mm for use in the cylindrical ionizer geometry source.<sup>2,3</sup>

### 3.0 Experimental Results

The sputter probes were evaluated using a test facility equipped with provisions for mass analysis.<sup>7</sup> A schematic of the source used in these experiments is shown in Fig. 1. Figure 2 provides examples of the dependence of mass analyzed negative ion yield on sputter probe voltage for each member of the group. A list of mass analyzed beam intensities realized from each of the Group IA elements is displayed in Table 1. These results were subsequently confirmed by accelerating each of the beams to the terminal of the 25URC tandem accelerator and performing charge-state analysis. The lifetimes of the carbonate probes were limited by sputter erosion. Experience to date indicates that the lifetimes of the probes decrease as the mass of the Group IA element increases and range from  $> 40$  hours for  $\text{Li}_2\text{CO}_3$  probes to  $\sim 4$ -6 hours for  $\text{Cs}_2\text{CO}_3$  probes.

Sputter probes formed from the oxides and other compounds of these elements offer alternative and perhaps improved methods for achieving even

higher negative ion beam intensities. Work is in progress to investigate the negative ion beam capabilities of the oxides as well as other compounds.

#### 4.0 Discussion and Conclusions

The application of the technique described above enables the formation of atomic negative ion beams from all of the Group IA elements at intensity levels useful in tandem electrostatic accelerator research programs. This development thus adds ~ 8% to the inventory of species that can be produced in conventional sputter-type negative ion sources. The requirement that these materials be in compound form for production as atomic negative ion species suggests the possibility of a molecular dissociation formation mechanism rather than the surface ionization mechanism which occurs during sputtering of metal surfaces covered with minute amounts of a Group IA element. However, it should be pointed out that the surface work functions of the carbonates before and after ion bombardment are unknown and, in fact, may be low enough for reconsideration of the surface ionization mechanism.

#### Acknowledgements

The authors would like to express their thanks to the operations staff of the 25URC accelerator for assistance in charge-state analysis of each of the Group IA element atomic negative ion beams.

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## Figure Captions

1. Schematic drawing of the cylindrical geometry ionizer negative ion source used for generation of Group IA element atomic negative ion beams.
2. Examples of Group IA element negative ion beam intensity versus sputter probe voltage. Source: Cylindrical geometry ionizer.

Table 1. Typical Group IA element atomic negative ion beam intensities produced by sputtering Group IA element carbonates.

Sputter Probe	Sputter Probe Voltage (KV)	Species	Intensity ( $\mu\text{A}$ )
$\text{Li}_2\text{CO}_3$	$\leq 3$	$\text{Li}^-$	$\geq 0.5$
$\text{Na}_2\text{CO}_3$	$\leq 3$	$\text{Na}^-$	$\geq 0.5$
$\text{K}_2\text{CO}_3$	$\leq 3$	$\text{K}^-$	$\geq 0.5$
$\text{Rb}_2\text{CO}_3$	$\leq 3$	$\text{Rb}^-$	$\geq 0.5$
$\text{Cs}_2\text{CO}_3$	$\leq 3$	$\text{Cs}^-$	$\geq 0.2$

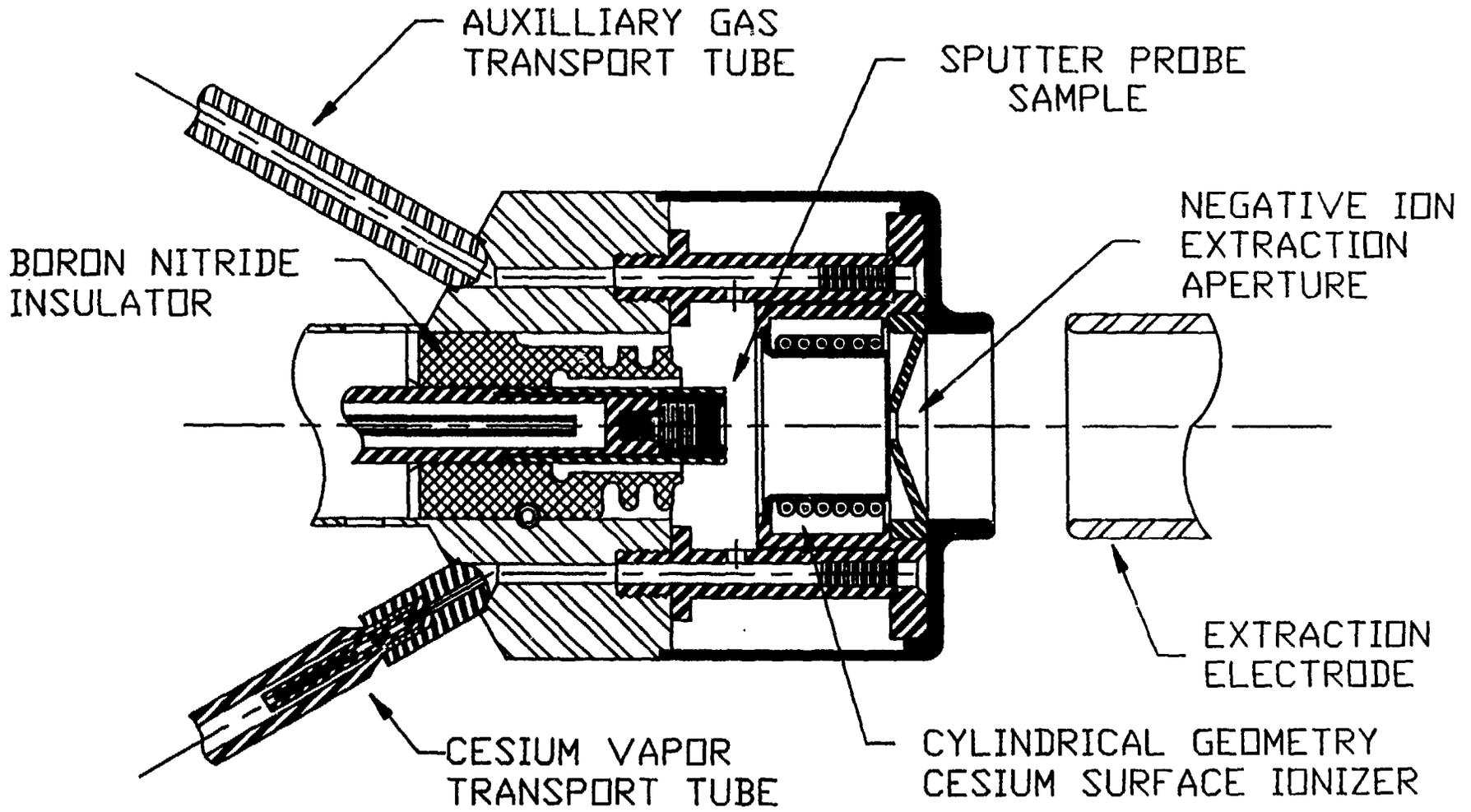


Fig. 1

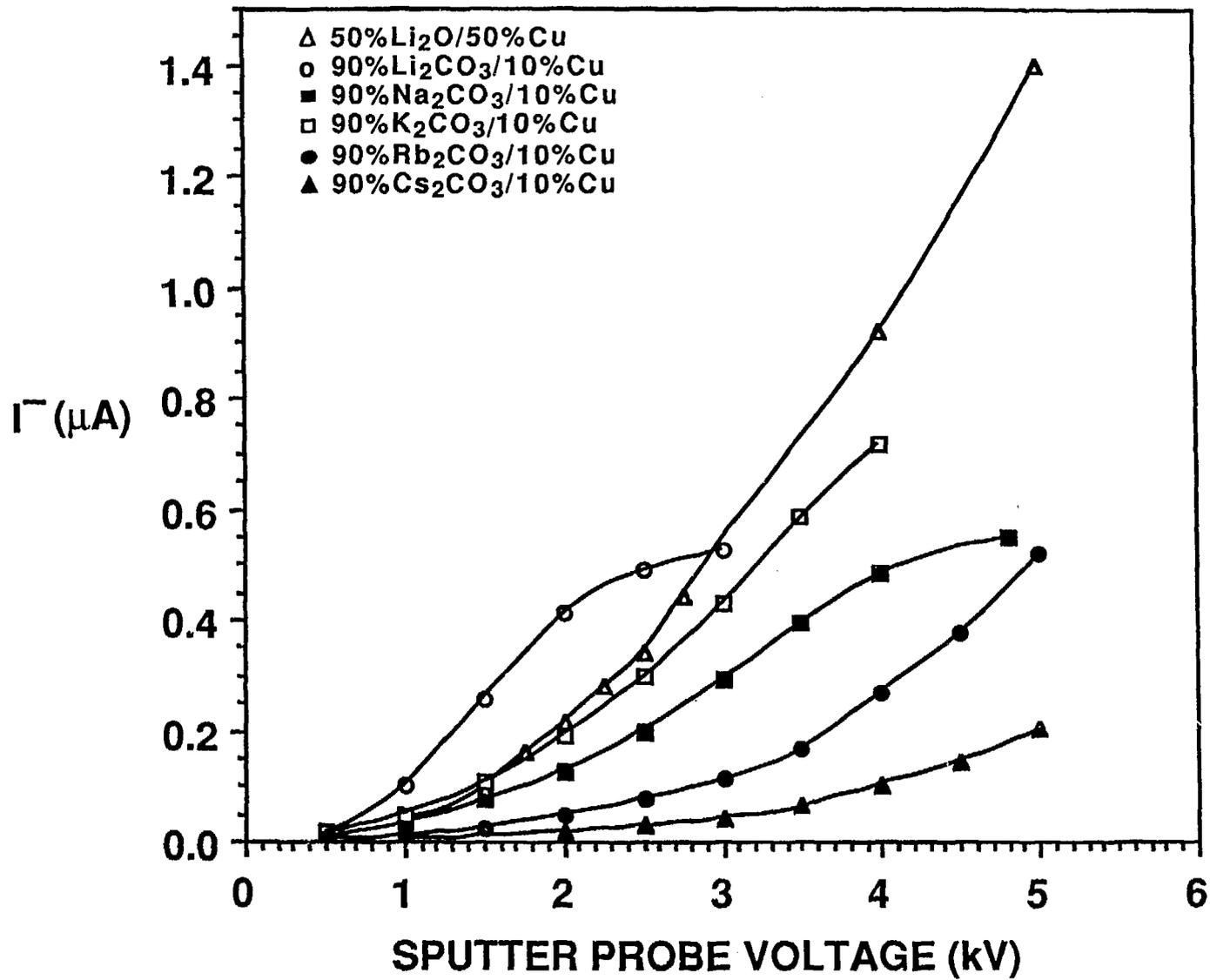


Fig. 2