FIELD EVAPORATION CHARGE STATE OF BORON IONS : A TEMPERATURE EFFECT STUDY

A. Menand, C. Martin, J. Sarrau

► To cite this version:

A. Menand, C. Martin, J. Sarrau. FIELD EVAPORATION CHARGE STATE OF BORON IONS : A TEMPERATURE EFFECT STUDY. Journal de Physique Colloques, 1984, 45 (C9), pp.C9-95-C9-98. 10.1051/jphyscol:1984917 . jpa-00224395

HAL Id: jpa-00224395

<https://hal.science/jpa-00224395>

Submitted on 1 Jan 1984

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

FIELD EVAPORATION CHARGE STATE OF BORON IONS :
A TEMPERATURE EFFECT STUDY

A. Menand, C. Martin and J.M. Sarrau

*Laboratoire de Microscopie Ionique⁺, Faculté des Sciences de Rouen,
BP 67, 76130 Mont-Saint-Aignan, France*

Résumé - Une étude de la charge des ions Bore évaporés par effet de champ, met en évidence une différence pour les états de charge des ions B_{10} et B_{11} . Cette différence dépend de la température de l'échantillon. Une explication de cet effet dû au départ des ions à basse température par effet tunnel ionique est donnée.

Abstract - We have observed the mass to charge ratio of field evaporated Boron ions. A difference between the charge state of B_{10} and B_{11} ions is observed. This difference is temperature dependent. An explanation is given in terms of ionic tunneling desorption of Boron ions at low temperature.

INTRODUCTION

As it has been previously reported [1], an isotopic variation in field evaporation charge state of boron ions has been observed. The proportion of B_{10} ions field evaporating as doubly charged ions is found to be less than the corresponding figure for B_{11} ions. This effect is predicted by the post-ionisation model of Haydock and Kingham [2]. B_{10}^+ ions being less massive than B_{11}^+ ions travel faster and so spend less time in the "post-ionisation zone" in which the transition from B^+ to B^{2+} is expected to occur. The maximum of difference between the probabilities of post-ionisation calculated for Boron ions is $\Delta P = 1.6\%$ [1]. In practice the observed difference ΔP_{exp} is much more pronounced than expected with $\Delta P_{\text{exp}} = 4.6\%$ for experiment at 78 K.

It has been assumed by Menand and Kingham [1] that this discrepancy could be explained in terms of evaporation of boron ions by ionic tunneling at low temperature. The purpose of this paper is to test this assumption by varying the sample temperature.

EXPERIMENTAL

The experiments were made with samples of Fe Ni Mo B metallic glass, the specimens were prepared from tapes of 50 μm thickness and about 0.2 mm width, by anodic electropolishing in a solution of 10 % perchloric acid in 2-Butoxyethanol. We used a ToF atom probe [3] with a 30 cm flight length which allows a large analysis area. Timing was by means of a three channel 400 MHz digital counter with a dead time of 5 ns, low temperatures was obtained by means of a cryogenerator.

RESULTS AND DISCUSSION1 - Temperature dependence of isotopic effect

Table 1 gives the results obtained at temperature values ranging from 170 K to 300 K : 20304 boron ions were detected of which 19.88 % were B_{10} in good agree-

⁺UA CNRS 808

ment with the isotopic relative abundance. The average proportion of B_{10} in the doubly charged peak is 19.46 % whereas the proportion of B_{10} in the singly charged peak is 20.41 %. The average difference ΔP_{exp} between the probabilities of post-ionisation of B_{10} and B_{11} is 1.5 %.

Experiment	B_{10}^{2+}	B_{11}^{2+}	B_{10}^{+}	B_{11}^{+}	$B_{10}^{2+}/\Sigma B_{10} \%$	$B_{11}^{2+}/\Sigma B_{11} \%$	$\Delta P_{\text{exp}} \%$
1	235	996	360	1342	39.5	41.8	+ 2.3
2	382	1472	320	1126	54.4	56.6	+ 2.2
3	224	933	181	692	55.3	57.4	+ 2.1
4	152	663	124	475	55.1	58.2	+ 3.1
5	425	1658	301	1177	58.5	58.5	0
6	393	1789	270	1209	59.3	59.7	+ 0.4
7	413	1723	256	1043	61.7	62.3	+ 0.6
Total	2224	9204	1812	7064	55.1	56.58	1,48

Table 1 - Number of B_{10}^{2+} , B_{10}^{+} , B_{11}^{2+} and B_{11}^{+} ions observed in seven experiments of Fe Ni Mo B, at temperature ranging from 170 K to 300 K. Each experiment gives an estimate of the relative abundance of B_{10}^{2+} and B_{11}^{2+} (i.e. $(B_{10}^{2+}/\Sigma B_{10})$ and $(B_{11}^{2+}/\Sigma B_{11})$) and of the difference in these quantities, ΔP_{exp}

The results on the abundance of singly and doubly charged ions of the two isotopes of boron at temperature between 20 K and 300 K are summarised in table 2, they show a significant temperature effect.

Temperature	B_{10}^{2+}	B_{10}^{+}	B_{11}^{2+}	B_{11}^{+}	$B_{10}^{2+}/\Sigma B_{10} \%$	$B_{11}^{2+}/\Sigma B_{11} \%$	$\Delta P_{\text{exp}} \%$
20 K	414	627	1921	2028	39.8	48.6	+ 8.8
78 K	102	108	448	404	48.6	52.6	+ 4
170-240 K	993	985	4034	3635	50.2	52.6	+ 2.4
300 K	1231	827	5170	3429	59.8	60.1	+ 0.3

Table 2 - Number of B_{10}^{2+} , B_{10}^{+} , B_{11}^{2+} and B_{11}^{+} ions observed in the experiments on Fe Ni M B for different temperatures lying from 20 K to 300 K

In the temperature range 170-300 K the difference ΔP_{exp} is small 0.3-2.4 % which is consistent with the predicted value of 1.6 %, but at lower temperature ΔP_{exp} is larger, up to 8.8 % at 20 K. These results support our assumption of ionic tunneling at low temperature. The occurrence of ionic tunneling means that the lighter B_{10} ions will be more easily field evaporated than B_{11} , so they may be evaporated at field strength slightly lower than B_{11} . That is, if B_{11}^{+} ions are only evaporated at the maximum of the electric field pulse, B_{10} ions may be evaporated when the field is just less than its maximal value. As post-ionisation probabilities are strongly dependent on field strength $|1|$, only a 0.5 % difference in evaporation field strength is required to give a 3 % difference in post-ionisation probabilities.

2 - Constant field strength study

We have prepared a specimen with a very narrow taper angle which meant that the desorption field remained constant (with the tip voltage held constant) during the desorption of many atoms. The steadiness of the tip radius was verified by the measurement of BIV before and after each experiment. With this specimen we have performed experiments with increasing temperature (by switching off the cryogenic refrigerator). So during the course of the experiment, and as the evaporated ions were detected, the tip temperature was slowly increasing. Figure 1 gives the cumulative number of B^{2+} ions versus the total number of Boron detected ions, the corresponding temperatures are also indicated.

Fig. 1 - Cumulative number of B^{2+} ions observed against the total number of B ions observed

The sharp slope change within 140 K is the result of an interesting artefact. For temperatures under 140 K the evaporation rate was increasing very slowly and the average number of detected ions per pulse $\bar{n}$ lying from $5 \cdot 10^{-3}$ to $4 \cdot 10^{-2}$, but near 140 K the evaporation rate increased suddenly $\bar{n} > 3$, three Boron ions or more were produced for each pulse but obviously only 3 ions could be stored in the three channels digital counter. In this saturated regime doubly charged ions appear more abundant because they reach the detector first.

This sudden increase in the evaporation rate is interpreted as a change in the evaporation process from an essentially tunneling desorption of boron ions, to an essentially thermally activated evaporation. The transition temperature T_0 will be 140 ± 5 K.

It is particularly interesting to notice the steadiness of the charge ratio B^{2+}/LB at low and at high temperature (excepted in the saturated zone 140-165 K). This is an evidence for the post-ionisation model of Kingham, the charge state of boron ions is a function of field and not of temperature

Acknowledgements

The authors wish to thank Dr D. R. Kingham for fruitful discussions and valuable comments.

REFERENCES

- |1| A. MENAND and D. R. KINGHAM
J. Phys. D : Appl. Phys., 17 (1984) 203
- |2| R. HAYDOCK and D. R. KINGHAM
Phys. Rev. Lett., 44 (1980) 1520
- |3| C. MARTIN, D. BLAVETTE and J. M. SARRAU
Rev. Phys. Appl., 19 (1984) 27