ANNALES
UNIVERSITATIS MARIAE CURIE-SKŁODOWSKA
LUBLIN—POLONIA
VOL. XL/XLI, 1 SECTIO AAA 1985/1986

Instytut Fizyki UMCS

B. ADAMCZYK, L. MICHALAK

Characteristics of Effusive Molecular Beams Crossed by Electron Beam

Charakterystyka efuzyjnych wiązek molekularnych przecinanych wiązką elektronową

Характеристика эффузионных молекулярных пучков в поперечном пучке электронов

Dedicated to Professor
Stanisław Szpikowski on occasion
of his 60th birthday

INTRODUCTION

The application of molecular beams for present scientific investigation and technology is on increase. The molecular beam is often, in particular, used in ion sources where it is ionized by an electron beam. Here, it is usually collimated by a set of slots located at a certain distance from an effusing hole (Fig. 1 version I) [1]. Such a system of forming the molecular beam ensures its defined cross-section and homogeneity but, on the other hand, weakens significantly its intensity. It is possible to obtain an intensity increase of the beam collimated in such a manner

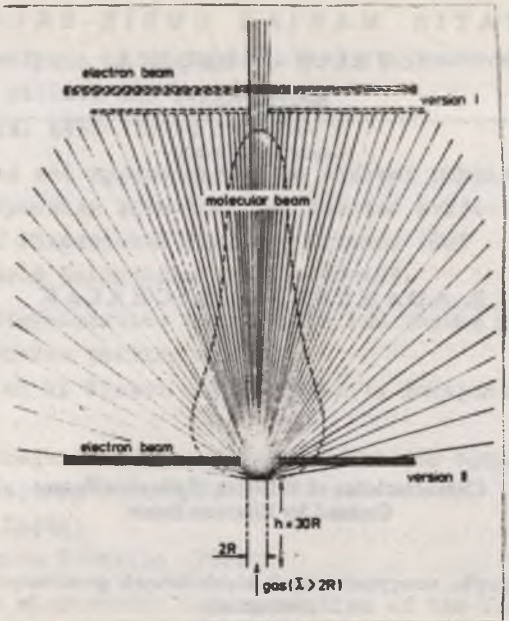

Fig.1. The effusive molecular beam formed by the capillary of the length h = 30R. Version I: the molecular beam slot collimated being crossed by the electron beam just above the effusive hole. Broken line shows points of the same values of the beam intensity.

by increasing a pressure of a gas being metered, however, it deteriorates a vacuum inside a collision chamber and also, what is often very significant causes an excessive consumption of the gas sample. The other solution is ionizing the molecular beam just above the effusive hole (Fig. 1, version II). It is necessary to remember, however, that such a beam has its cross-section outline difficult to determine as well as a large gradient of density both in longitudinal and lateral directions [2, 3, 4]. Moreover, in case of the electron beam cross-section comparable with the base cross-section of the molecular beam formed in such a manner, it is necessary to expect a heterogeneity in the area of the electron beam. Therefore it is necessary to know these parameters of the molecular beam formed in such a way (version II) for using it in ion sources. In this paper some characteristics of the system are going to be presented which comprises the molecular beam formed by a capillary only and this beam is crossed by the electron beam.

APPARATUS

The characteristics of the molecular beam crossed by the electron beam were investigated by means of the cycloidal mass spectrometer [5, 6]. Nitrogen was fed to the capillary from

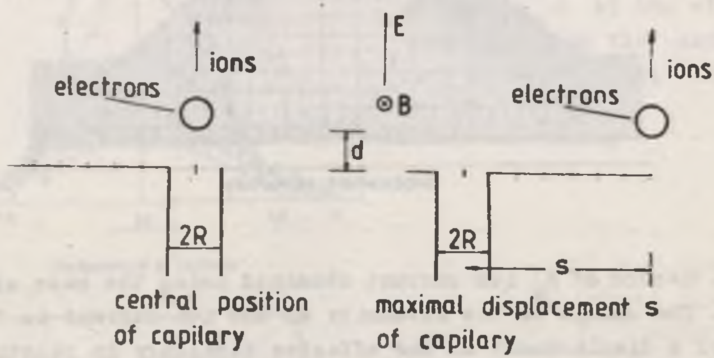

Fig.2. The set for investigation the effect of crossing the effusive molecular beam by the electron beam. The forming molecular beam is being shifted in s and d directions in relation to the electron beam. E and B - analysing electric and magnetic fields of the cycloidal mass spectrometer. The ions produced are registered by means of a collector not shown in the drawing. Capillary diameter: 2R = 0.4 mm; electron beam diameter: 0.2 mm.

a tank where a suitable low pressure prevailed. N_2^+ ions generated as a result of collisions of electrons with nitrogen molecules, following their passage via an analysing system (crossed fields E and B), were reaching a collector where they were registered as the ion current. Thus the intensity of the ion current provided information on the effect of crossing the molecular beam with the electron beam.

RESULTS OF MEASUREMENTS

A graph of N_2^+ mass spectrum is shown in Fig. 3. A change in the height of peaks is caused by shifting the effusive capillary

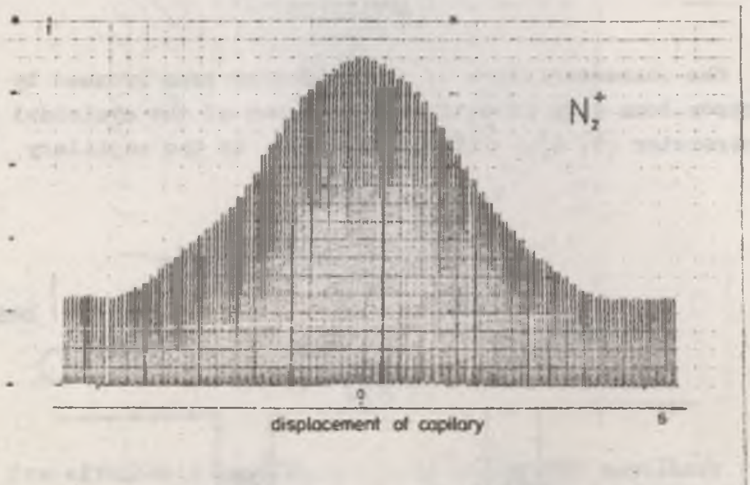

Fig.3. Record of N_2^+ ion current obtained using the mass spectrometer. The change in the intensity of the ion current is the result of s displacement of the effusive capillary in relation to the electron beam (see Fig. 2).

in s direction in relation to the electron beam. A double measurement of the ion current intensity was performed at each s position. Similar measurements as those shown in Fig. 3, were performed for the capillary of a length h = 30R (6 mm) and diameter 2R = 0.4 mm at various distances d of the electron beam from the capillary outlet (Fig. 4). A change in the ion current intensity as a function of d distance of the electron beam from the capillary axis is shown in Fig. 5. When the electron beam was displaced by s = 3R from the capillary axis the changes in the ion current in function of d distance are such shown in Fig. 6.

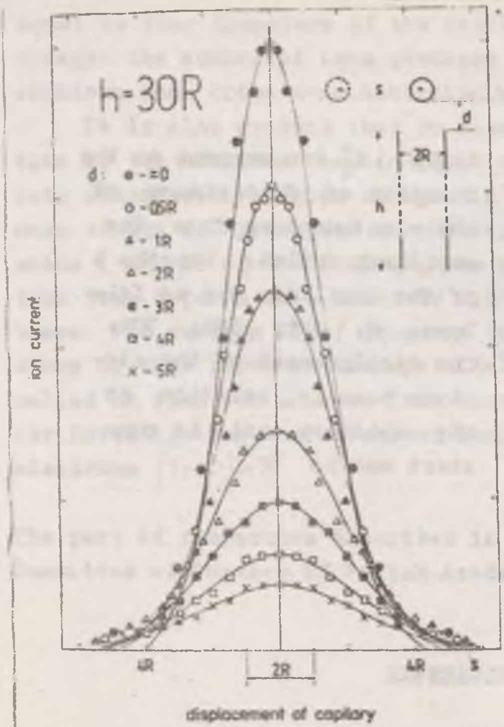

Fig.4. N_2^+ ion current as the function of s displacement of the electron beam in relation to the molecular beam generated by the effusive capillary of the length h = 30R. The distances d of the electron beam from the capillary hole: 0; 0,5R; 1R; 2R; 3R; 4R; 5R.

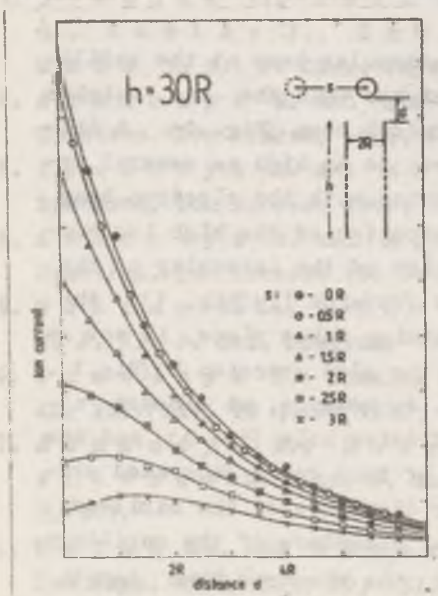

Fig. 5. N_2^+ ion current as the function of the distance of the electron beam from the capillary outlet. s-displacements of the electron beam: 0; 0,5R; 1R; 1.5R; 2R; 2.5R; 3R.

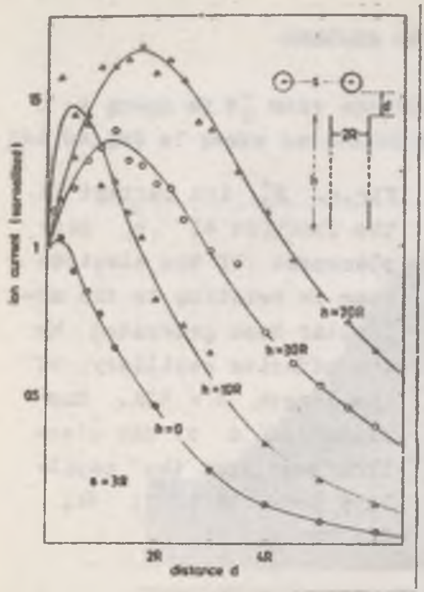

Fig.6. N_2^+ ion current as the function of d distance of the electron beam from the capillary outlet. Lengths h of the capillary are as follows: 0; 10R; 30R; 70R. The displacement of the electron beam in relation to the capillary axis is constant and is 3R.

CONCLUSION

The intensity of the effusive molecular beam at the capillary effusive outlet is considerably higher than the one outside the slot forming this beam into a parallel beam (Fig. 1). A difference in these intensities could even be as high as several orders of magnitude (Fig. 4). Thus ionizing with the electron beam near the effusive hole provides a generation of the high ion current. However, owing to the distribution of the intensity of the molecular beam near the effusive hole (version II)(Fig. 1), the length of a path, along which the ionizing takes place, is not so well defined as in the case of using the slot (version I)(Fig.1). Considering the results shown in Fig. 4, however, at closest approach of the electron beam to the effusive hole (d = 0) and its central position, then at least 95 % of ions being generated originate along the length equal to four diameters of the capillary. However, at d distance equal to four diameters of the capillary, only 80 % of ions are produced along the electron beam length equal to four diameters of the capillary. As d distance is increased the number of ions produced along the same length of the electron beam drops down accordingly.

It is also evident that in case of the version II, a deviation of the electron beam in relation to the effusive hole effects considerably higher changes in the ion current than in the case of the set presented as the version I. A choice between versions I and II of the ionizing the molecular beam with the electron beam depends on a concrete application of such crossing beams. The version II of crossing the beams is used by the authors of this paper in the cycloidal mass spectrometer with so called an open ion source. This spectrometer is mainly applied for investigating the effect of ionizing atoms and molecules by electrons [7-10].

The part of researches described in this paper was supported by Committee of Physics of Polish Academy of Sciences.

REFERENCES

1. Stephan K., Helm H., Kim Y. B., Seykora G., Ramler J., Grössl M., Märk E. and Märk T. D.: J. Chem. Phys. 1980, 73. 1.
2. Adamczyk B. and Michalak L.: Int. J. Mass Spectrom. Ion Proces. 1986, 69, 163.
3. Adamczyk B. and Michalak L.: Int. J. Mass Spectrom. Ion Proces. 1986, 71, 211.
4. Adamczyk B. and Michalak L.: Int. J. Mass Spectrom. Ion Proces. (to be published).
5. Schram B. L., Adamczyk B. and Boerboom A. J. H.: J. Sci. Instrum. 1966, 43, 638.
6. Adamczyk B.: Annales Univ. M. Curie-Skłodowska, Sectio AA, XXIV/XXV, 20 (1969/1970) 141.
7. Adamczyk B., Boerboom A. J. H. and Łukasiewicz M.: Int. J. Mass Spectrom. Ion Phys. 1972, 9, 407.
8. Hałas St. and Adamczyk B.: Int. J. Mass Spectrom. Ion Phys. 1972/1973, 10, 157.

9. B e d e r s k i K., W ó j c i k L. and A d a m c z y k B.: Int. J. Mass Spectrom. Ion Phys. 1980, 35, 171.
10. S t a ń s k i T. and A d a m c z y k B.: Int. J. Mass Spectrom Ion Phys. 1983, 46, 31.

STRESZCZENIE

Przy pomocy ruchomej, poprzecznej wiązki elektronowej o średnicy 0,2 mm i energii 150 eV badano rozkład natężenia efuzyjnych wiązek molekularnych azotu. Wiązki te były generowane przez kapilary o średnicy 2R = 0,4 mm i długości h = 0; 10R; 30R; 70R; (0, 2 mm, 6 mm, 14 mm). W skrzyżowanych polach elektrycznym i magnetycznym cykloidalnego spektrometru mas wydzielano jony N_2^+ wytwarzane w wyniku skrzyżowania wiązki molekularnej z elektronową. Miarą natężenia wiązki mokularnej było natężenie prądu jonowego N_2^+.

Р Е З Ю М Е

С помощью подвижного поперечного пучка электронов диаметром 0.2 мм с энергей I50 эВ исследовалось распределение интенсивностей эффузионных молекулярных пучков азота. Пучки эти генерировались капиллярами диаметром 2 R = 0.4 мм и длиной h = 0; I0 R; 30 R; 70 R (0, 2 мм, 6 мм и I4 мм). В скрещенных электрическом и магнитном полях циклоидального масс-спектрометра выделялись ионы N_2^+ образовавшиеся вследствие взаимодействия пересекающихся молекулярного и электронного пучков. Мерой интенсивности молекулярного пучка являлось напражение тока ионов N_2^+.