§9. Extremely Low-Energy Ar^+ - Ar Momentum Transfer Cross Section deduced from the Drift Velocity with Use of Monte Carlo Simulation

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Monte Carlo simulation is useful technique to study the fundamental and probability processes between charged particle and neutral gas. Mobilities and momentum transfer cross sections for various kinds of ion are proper targets of this simulation. Since measurements of low energy cross sections are difficult to determine with good absolute accuracy, it should be calculated by theory and simulation. The momentum transfer cross section in low energy collisions is the most dominant factor for mobility (drift velocity) over a wide range of the pressure normalized electric field, *E/p*, from 1 to 10^5 V/m-Torr. For argon (Ar) ions, many swarm experiments have been carried out [1-5] and have shown the dependence of drift velocity on *E/p*. Since those experimental results were in good agreement with each other, the data on drift velocity of Ar ions are credible over a wide range of *E/p*. We calculate the drift velocity of Ar ions in its parent gas with use of Monte Carlo method and deduce the momentum transfer cross section in extremely low energy collisions from the drift velocity in the present work.

We calculate the Ar ion (Ar^+) motion in the neutral Ar gas that is distributed in Maxwellian with the room temperature (300 K). In our simulation, an Ar^+ accelerated by an electric field collides with an Ar atom in a case that the condition $\xi \leq n\sigma v_r \Delta t$ is satisfied, where ξ is the random number, n, σ, v_r and Δt denote respectively the density of Ar gas, total cross section, the relative velocity between Ar and Ar^+, and the collision judge time which is adequately chosen. The collision processes between Ar^+ and Ar involve in the elastic scattering and the resonance charge exchange [6, 7]. The elastic scattering is assumed to be isotropic process. On the other hand, differential cross sections for the charge exchange have measured in a range from 1 to 10 eV [6]. The energy dependence of deflection angle due to charge exchange is given in the form:

$$\theta = \xi \left\{ \lambda(E) + \left(\frac{\pi}{2} - \lambda(E) \right) \frac{\exp(\xi / a(E)) - 1}{\exp(1/a(E)) - 1} \right\},$$

$$\lambda(E) = \frac{1}{2(1 + E^{1/3})}, \quad a(E) = \frac{1}{4(1 + E^{1/4})},$$

where ξ is the random number ranging from 0 to 1, and E is the impact energy normalized by 1 eV. We also consider the isotropic charge exchange process in this work. The differential cross section affects strongly the diffusion coefficient, which is discussed in a subsequent work.

Figure 1 shows the calculated drift velocity of Ar^+ in its parent gas. Several experimental data are also depicted here. The difference of drift velocity between the isotropic and anisotropic model in charge exchange process is about 5%. In the lower range of E/p, our results are in good agreement with experimental data. Figure 2 presents the momentum transfer cross section assumed in order that the simulated drift velocity may coincide with experimental data. Moreover, we present Cramer's experimental values [8] and the result from Chanin's paper [5] in Fig. 2. Our calculated value at 10^{-4} eV lies approximately 250% above Chanin's theory. The cross section we obtained connects better with experimental values around 4 eV than Chanin's calculation.

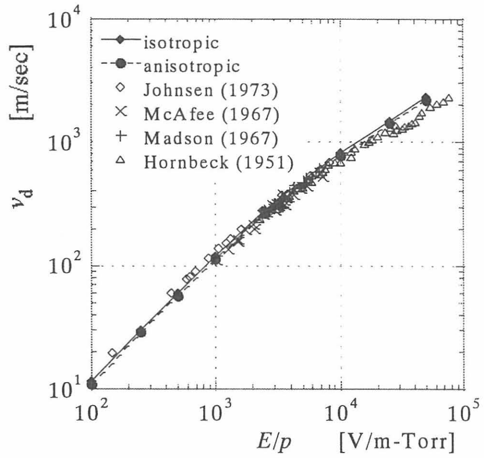

Fig.1 Comparison of calculated drift velocity with experimental data.

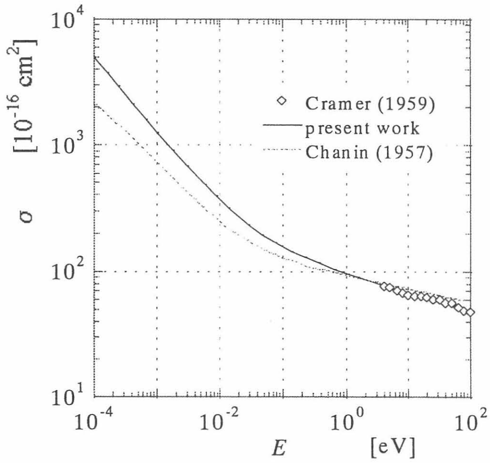

Fig.2 Momentum transfer cross section deduced from the drift velocity.

References

[1] J. A. Hornbeck, Phys. Rev. **84**, 615 (1951).
[2] J. M. Madson and H. J. Oskam, Phys. Lett. **25A**, 407 (1967).
[3] R. Johnsen, M. T. Leu and M. A. Biondi, Phys. Rev. A **8**, 2557 (1973).
[4] K. B. McAfee Jr., D. Sipler and D. Edelson, Phys. Rev. **160**, 130 (1967).
[5] L. M. Chanin and M. A. Biondi, Phys. Rev. **106**, 473 (1957).
[6] M. L. Vestal, C. R. Blakley and J. H. Futrell, Phys. Rev. A **17**, 1337 (1978).
[7] W. H. Cramer, J. Chem. Phys. **30**, 641 (1959).