Excitation Functions of the Slow and Fast Groups of the Excited Hydrogen Atom Produced in e–H_2 Collisions

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Synopsis. Excitation functions of the fast group of $H^*(n=3,4)$ show two thresholds at 22—23 and about 27 eV. Their comparison indicates that the dissociation process through the $^1\Sigma_u^+(2p\sigma_u)(nl\sigma_g)$ states are relatively more important for $H^*(n=4)$.

Electron-impact excitation of hydrogen is a basic process in plasma, and its dynamical analysis is a key for a reliable simulation of a plasma.

The Doppler profile analysis has shown that the excited hydrogen atom produced in electron–H_2 collisions consists of slow and fast groups.[1—4] The emission cross sections of the two groups have been obtained separately and their Fano plots have disclosed the symmetry character of the two groups.[5,6] The fast group consists of three components:[7,8] dissociation through the $^1\Sigma_g^+(2p\sigma_u)^2$ state, through the $^1\Sigma_u^+(2p\sigma_u)(nl\sigma_g)$ states and through the $^1\Pi_u$ states. However, their relative contribution has not been determined quantitatively.

We have measured excitation functions of the slow and fast groups separately and compared the relative contribution of dissociation of the fast group through the $^1\Sigma_g^+(2p\sigma_u)^2$ state and that through the $^1\Sigma_u^+(2p\sigma_u)(nl\sigma_g)$ states for $H^*(n=3)$ and $H^*(n=4)$.

Experimental

The apparatus is described in detail in Refs. 9 and 10. In brief, the collision chamber has a rotatable electron gun and a gas cell, and was evacuated by a turbo-molecular pump (500 l/s). The Doppler profiles were obtained with a Fabry–Pérot interferometer (Mizojiri Opt.) with a typical optical resolution of 0.010 nm at 90° with respect to the electron beam. A wide electron beam was used so as to minimize the effect of escape of the excited atom from the observation region.

The electron energy was calibrated with the threshold of N_2^+ (B–X: 391.4 nm) at 18.75 eV and He (^{1}s–^{1}p: 501.5 nm) at 23.09 eV. The gas pressure was 0.02 Pa at the wall of the collision chamber. The observed signal was corrected for any variation in the electron beam current.

Results and Discussion

A typical Doppler profile of the Balmer-α line is shown in Fig. 1. The central peak was assigned to the slow group of H^* and the broad wing to the fast group of H^*.[1—4]

The excitation functions of the Balmer lines were measured previously under a low optical resolution.[1,11—13] Among them, Karolis and Harting[12] found four thresholds at about 16, 26, 35, and 43 eV, and this finding indicates that there are a few dissociation processes for the formation of H^*. By using a higher optical resolution, it is possible to separate H^* into the two groups, and the excitation function of each group would be more useful in the analysis of the dissociation dynamics of hydrogen.[3)]

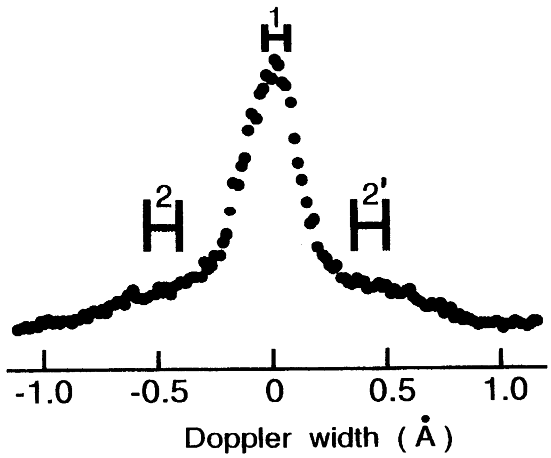

Fig. 1. The Doppler profile of the Balmer-α line measured at 100 eV at an optical resolution of 0.010 nm. 1: Observed region for the slow group, 2,2′: observed regions for the fast group.

The observed wavelength of the interferometer was fixed at region 1 (see Fig. 1) when the excitation of the slow group was measured, and the result is shown in Fig. 2. This excitation function is entirely due to the slow group below the threshold of the fast group. The excitation functions of both the Balmer-α and β lines have a threshold at about 17 eV, and this finding agrees with the previous result for $H^*(n=4)$.[3)]

The observed wavelength of the interferometer was fixed at region either 2 or 2′ (see Fig. 1) when the excitation function of the fast group was measured; there is no overlap of the slow group. The measurements at region 2 and 2′ were carried out alternately and averaged. The results are shown in Fig. 3. Because the cross section of the Balmer-α line is much larger than that of the Balmer-β line, the two functions were normalized at 21—27 eV in order to make comparison easier. The excitation function of the Balmer-β line agrees well with the previous result,[3)] though the present data have higher signal-to-noise ratio due to improvements of the apparatus.

The excitation functions of the fast group have two thresholds as indicated in Fig. 3; one is at 22—23 eV and the other at about 27 eV. The former was not

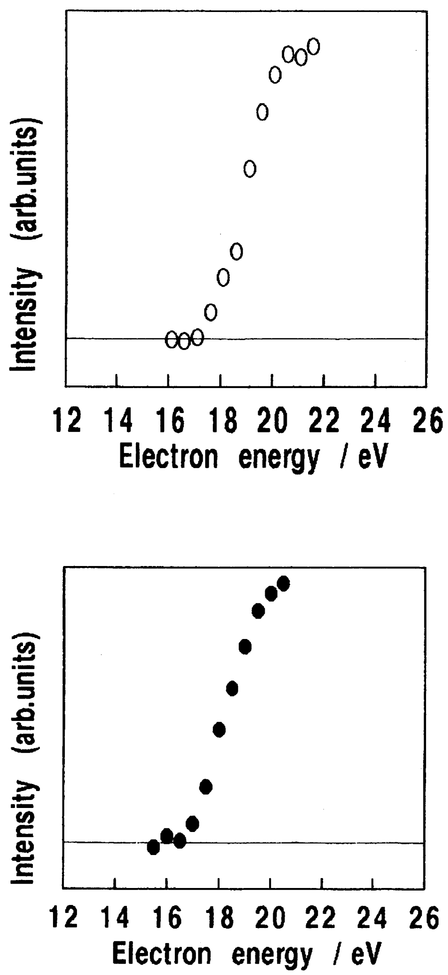

Fig. 2. Excitation functions of the Balmer-α and β lines at region 1. A threshold of the slow group is shown. ○: $H^*(n=3)$, ●: $H^*(n=4)$.

found at low resolution measurements; only the exitation function measured at higher resolution could show it, because it is weak. The region of 22—27 eV lies in the Q_1 region, and the two thresholds can be assigned to dissociation through the Franck–Condon region of the Rydberg states converging to the $^2\Sigma_u^+(2p\sigma_u)$ ionized state. The threshold at 22—23 eV was assigned to the dissociation through the lowest doubly-excited state, $^1\Sigma_g^+(2p\sigma_u)^2$.[3] $H^*(n=3,4)$ should be produced in predissociation through this state. The threshold at about 27 eV was assigned to the direct dissociation through a series of the doubly excited states, $^1\Sigma_u^+(2p\sigma_u)(nl\sigma_g)$.[3,14]

The excitation function of $H^*(n=4)$ has a larger slope and a relatively larger value at above 27 eV than that of $H^*(n=3)$. This finding indicates that the direct dissociation through the $^1\Sigma_u^+(2p\sigma_u)(nl\sigma_g)$ states is relatively more important for the formation of $H^*(n=4)$ than for that of $H^*(n=3)$.

The dissociation through a Σ_g state should be isotropic, and that through Σ_u should be anisotropic

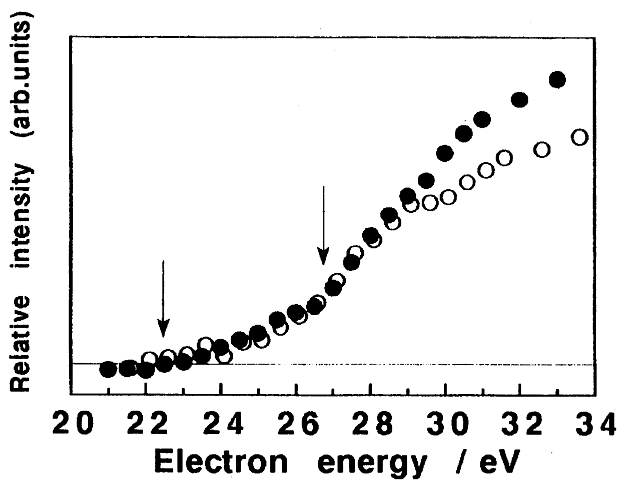

Fig. 3. Excitation functions of the Balmer-α and β lines at region 2 and 2′. Two thresholds of the fast group are shown. ○: $H^*(n=3)$, ●: $H^*(n=4)$.

and parallel with respect to the electron beam.[15] Because $H^*(n=4)$ has more contribution from the dissociation through the Σ_u symmetry, the Balmer-β line is expected to be more polarized than the Balmer-α line if the comparison is made only for the fast group.

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