Dissociative Electron Attachment to 1,2-Dichlorobenzene using Mass Spectrometry with Phosphor Screen

Chuan-jin Xuan, Xu-dong Wang, Lei Xia, Bin Wu, Hao Li, Shan-xi Tian*

National Laboratory for Physical Sciences at the Microscale and Department of Chemical Physics, University of Science and Technology of China, Hefei 230026, China

(Dated: Received on August 5, 2014; Accepted on September 23, 2014)

Anion mass spectrometry is developed on the basis of our home-made anion velocity map imaging apparatus. The Cl\textsuperscript{−} product efficiency curve for dissociative electron attachment to 1,2-dichlorobenzene is obtained from 0.2 eV to 8 eV, meanwhile the sliced images of this anion are recorded at 1.2 and 6.0 eV corresponding to two peak positions of the product efficiency curve.

Key words: Dissociative electron attachment, 1,2-Dichlorobenzene, Anion mass spectrometry

I. INTRODUCTION

Dissociative electron attachment (DEA) is a secondary process of ionization radiation damages to biomolecules, but plays an important role in the chemical bond cleavages [1]. In this process, temporary negative ion, (AB)\textsuperscript{−}, is the essential intermediate and can spontaneounsly decay through the dissociation to A and B\textsuperscript{−} fragments. Information about the production efficiency and dynamics can be achieved by measurements of the mass spectrum and momentum distribution of the anionic fragment B\textsuperscript{−} [2−7]. Recently, the state-of-the-art technique about ion velocity map imaging (VMI) [8] was introduced and successfully applied to record the kinetic energy and angular distributions of B\textsuperscript{−} [5−7]. In our apparatus [5] and the conventional VMI machines [8], the detector consisting of microchannel plates (MCPs) plus phosphor screen and a CCD camera exhibits the higher ion detection efficiency than the wedge-and-strip [6] or delay-line [7] anode position-sensitive detector. In the measurements of ion mass spectrum, a photomultiplier tube is usually required and set behind the phosphor screen [8]; however, the anion mass spectrum can be synchronously recorded during the ion imaging if the wedge-and-strip [6] or delay-line [7] anode position-sensitive detector is adopted. Moreover, the mass spectral resolution heavily relies on the persistence time of light emission of the phosphor used in the detector.

In this work, we report an ion mass spectrum system including the phosphor screen detector (imaging APD-P20, PHOTONIS, Inc.) in our apparatus [5], and the DEA of 1,2-dichlorobenzene (1,2-C\textsubscript{6}H\textsubscript{4}Cl\textsubscript{2}) is investigated with anion mass spectrum and VMI experiments.

II. EXPERIMENTAL DEVELOPMENT

As shown in Fig.1, the anion signals of DEA are transformed to the multiplication electrons via secondary emission of the MCPs, then the photons emit from the phosphor screen by the electron hitting. The high voltages (HV1-3) applied on the MCPs and phosphor screen increase progressively. To record the ion arrival time on the detector, without the photomultiplier tube, a pulse-coupling circuit is used to record the current pulse induced by the ion bunches. In the present case, the upper (left) coating layer of phosphor screen is an aluminized mylar, and it can be used as the conductive plate behind the MCPs to collect the multiplication electrons induced by the ionic products. A short current pulse on the DC voltage of the phosphor screen (HV3) will be induced when a bunch of the multiplication electrons arrives at the aluminized mylar. Therefore, see Fig.1, the short pulse decoupled from the inductance coils (8 coils) on a ferrite ring is preamplified with VT120 (ORTEC, Inc.), then feeds the 100-picosecond Time Digitizer/Multichannel Scaler 9353 (ORTEC, Inc.) as the “start” of time-of-flight. The “end” is the pulse of incident electron [5]. Obviously the shape of “end” pulse is independent of the light emission persistence of the phosphor used in the detector.

III. RESULTS AND DISCUSSION

The predominant anionic product of the DEA of 1,2-C\textsubscript{6}H\textsubscript{4}Cl\textsubscript{2} was Cl\textsuperscript{−} and its yield efficiency curve was...
of 1,2-C₆H₄Cl₂ observed with electron transmission spectroscopy (ETS). On the other hand, the vertical electron attachments explored with electron transmission spectroscopy (ETS) indicated π*, σ*, σ*, π* resonant states of 1,2-C₆H₄Cl₂⁻ [10]. The low-energy peak of Cl⁻ lies between the first two states in energy, thus these Cl⁻ ions could be produced via the π*/σ* state coupling [11, 12] in the C–Cl bond elongation.

Two Cl⁻ peaks locate the energies higher than the energetic thresholds of two-body and three-body dissociations, respectively. The VMI experiments can provide further information about the dissociation kinetics. As shown in Fig. 3, two sliced images exhibit the low kinetic energies and nearly isotropic angular distributions of Cl⁻ at 1.2 and 6.0 eV. The excessive energy after the dissociation could be transformed into the internal energy of chlorophenyl or benzyne radical.

IV. CONCLUSION

The combinational working modes of our VMI apparatus are presented, and the DEA of 1,2-dichlorobenzene is investigated as an example. In the future, we will improve the resolutions of both mass spectrum and velocity images. Benefiting from such ex-
FIG. 3 Sliced images of Cl\(^-\) formed via DEA to 1,2-dichlorobenzene at (a) 1.2 eV and (b) 6.0 eV. Intensity is normalized, the electron incident direction is from left to right and across the image center.

Experimental developments, more details about the DEA of large molecules will be revealed.

V. ACKNOWLEDGMENTS

This work was supported by the Ministry of Science and Technology of China (No.2011CB921401) and the National Natural Science Foundation of China (No.21273213).