



## S<sup>-</sup> velocity images of dissociative electron attachment to OCS



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### ABSTRACT

Dissociative electron attachments to OCS with the attachment energies of 4.3, 4.7, 5.0, 6.2, 6.5, 6.8, and 7.0 eV are investigated by measuring the S<sup>-</sup> momentum distributions with time-sliced anion velocity image mapping technique. In this energy range, the ground-state fragmentation, e<sup>-</sup> + OCS → CO( $\tilde{X}^1\Sigma^+$ ) + S<sup>-</sup>(<sup>2</sup>P<sub>u</sub>), is only one dissociation pathway allowed in energy. All velocity images show the predominant feature of the low-speed S<sup>-</sup> ions, but the middle- and high-speed S<sup>-</sup> ions appear at the higher attachment energies (6.2–7.0 eV). The trimodal speed distribution of S<sup>-</sup> ion should be attributed to the different populations of the rovibrational states of CO fragment, however, the dynamic details of above dissociations are still unclear and demand theoretical calculations.

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### 1. Introduction

Dissociative electron attachment (DEA) is a fundamental process and frequently observed in plasma, interstellar space and ionization radiative damages to biological system [1]. For a triatomic molecule target ABC, its DEA process e<sup>-</sup> + ABC → A<sup>-</sup> + BC or A<sup>-</sup> + B + C usually shows rich information about the distributions of excess energy within various freedom degrees of the fragments, such as translational energy and internal energy (electronic, vibrational and rotational) [2–4]. In the DEA to molecular carbonyl sulfide (OCS), a sulphur anion (S<sup>-</sup>) is the predominant negatively-charged fragment [5–9]. When the electron attachment energy (E<sub>e</sub>) is lower than the threshold of the ion-pair formation e<sup>-</sup> + OCS → S<sup>-</sup> + CO<sup>+</sup> (15.0 ± 0.25 eV), three peaks at E<sub>e</sub> = 1.4, 4.7, 7.0 eV have been observed in the S<sup>-</sup> production efficiency curve and attributed to the DEA processes to the ground-state CO( $\tilde{X}^1\Sigma^+$ ) plus S<sup>-</sup>(<sup>2</sup>P<sub>u</sub>); while the electronic excited-state CO(a<sup>3</sup>Π, a<sup>3</sup>Σ, d<sup>3</sup>Δ, D<sup>1</sup>Δ) plus S<sup>-</sup>(<sup>2</sup>P<sub>u</sub>) could be produced around the peak at 10.2 eV [8,9]. The peak at 1.4 eV showed an hump profile and was assigned as with the CO( $\tilde{X}^1\Sigma^+$ ) at a series of vibrational state (ν = 0, 1, 2, 3, 4) [5–7].

The recent studies indicated that the peak at 1.4 eV was related to <sup>2</sup>Π resonant state of OCS<sup>-</sup> formed in the electron attachment and there were the Π/Δ overlapped resonances around 3.8 eV

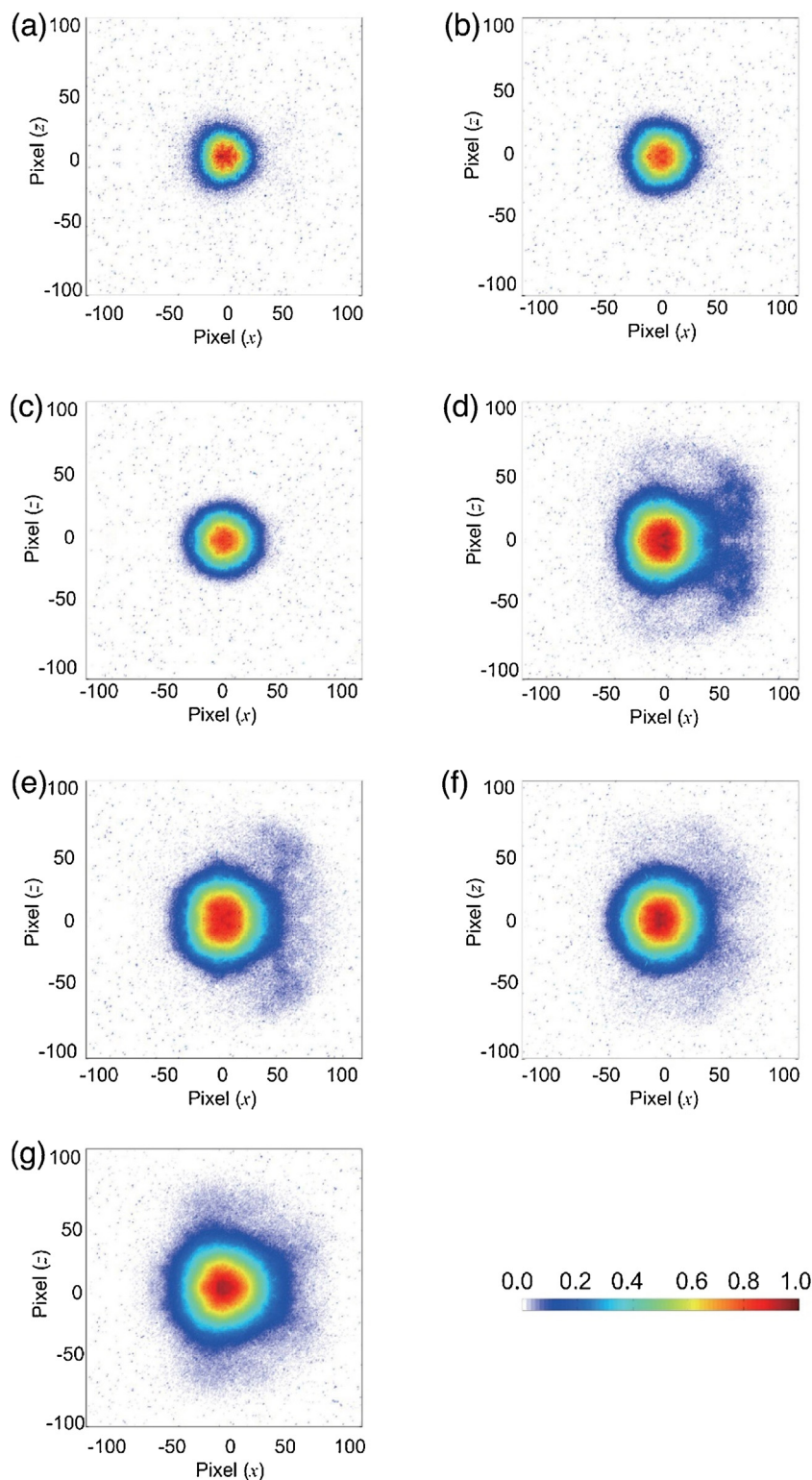
[10,11]. Iga et al. assigned the peak at 4.7 eV as the dissociation via <sup>2</sup>Δ resonant state [8,9]. Using the time-of-flight (TOF) technique, the translational (kinetic) energies of S<sup>-</sup> [E<sub>k</sub>(S<sup>-</sup>)] were also measured at the attachment energies of the peak positions [8,9], indicating that the S<sup>-</sup> ions produced at 7.0 eV were faster. However, the absolute values of E<sub>k</sub>(S<sup>-</sup>) for above dissociations are unknown, furthermore, the possible resonant states of OCS<sup>-</sup> formed at the higher E<sub>e</sub> values are either unavailable. In this work, we focus on the DEA processes of OCS at the E<sub>e</sub> values around 4.7 and 7.0 eV, by measuring the S<sup>-</sup> momentum distribution with time-sliced anion velocity image mapping technique. In this electron attachment energy range, the E<sub>k</sub> value and angular distributions of the S<sup>-</sup> ions produced in e<sup>-</sup> + OCS → CO( $\tilde{X}^1\Sigma^+$ ) + S<sup>-</sup>(<sup>2</sup>P<sub>u</sub>) will be obtained with the state-of-the-art ion mapping technique.

### 2. Experimental method

Our home-made anion velocity imaging apparatus has been described in detail elsewhere [12] and updated recently [4]. In this work, an effusive molecular beam of OCS (along the y axis) was perpendicular to the pulsed (250 ns width) electron beam (along the x axis, with a thermal energy spread of ~0.5 eV), which was emitted from a home-made electron gun and collimated with a homogeneous magnetic field (strength, 20 gauss) produced by a pair of Helmholtz coils. Fragments of S<sup>-</sup> produced in the DEA process were periodically pushed out of the reaction area and then passed through the TOF tube. The S<sup>-</sup> ions produced in one electron pulse expanded and formed a Newton sphere by space and

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**Fig. 1.** Time-sliced velocity images of  $S^-$  ions measured at the electron attachment energy 4.3 (a), 4.7 (b), 5.0 (c), 6.2 (d), 6.5 (e), 6.8 (f), and 7.0 (g) eV. The relative intensity is normalized respectively, but the images are plotted in the same scale. The electron incident direction is from left to right and across the image center.

velocity focusing. The three-dimensional momentum distribution of the  $S^-$  ions was detected with microchannel plates and a phosphor screen by applying a high-voltage pulse (width of 45 ns) to the rear microchannel plate. The time-sliced image (in the  $x$ - $z$  plane) at the center of the Newton sphere of  $S^-$  ions was recorded directly with a charge-coupled-device camera. The ion kinetic energies

were determined accurately from the image (with an uncertainty of  $<0.1$  eV in determination of the dissociation threshold [13]). The OCS sample (purity  $>99\%$ ) was commercial and used directly in the experiments. No contaminants were found by testing the electron-impact ionization mass spectra.

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