2P010

Low-energy Electron Emissions after 2p Ionization of Argon Clusters by Synchrotron Radiation

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[Abstract]

Irradiation of matter with soft X-ray tends to electronically excite atoms and molecules, with subsequent relaxation processes leading to a production of low-energy electrons. Here, we investigated this process through the experiments carried out at SPring-8. Argon cluster was excited by using monochromatic light at BL17SU of SPring-8 synchrotron radiation source in Japan. In addition to photoelectrons, low-energy electrons were observed after 2p ionization of argon clusters. We find that low-energy electron production increases when the energy of photoelectron exceeds ionization potential of Ar. The experimental result indicates that low-energy electrons are not only produced by ICD but also by the inelastic ionizing collision of the photoelectrons with the surrounding Ar atoms.

[Introduction]

Irradiation of matter with X-rays tends to electronically excite atoms and molecules, followed by the emission of Auger electrons. Subsequent relaxation processes also lead to a production of low-energy electrons. In a biological system, a high potency for genotoxic effects has been assigned to these low-energy electrons [1]. Understanding the process of low-energy electron production by X-rays is therefore significant.

These low-energy electrons are traditionally believed to be secondary electrons produced via inelastic scattering of a photoelectron or Auger electrons by the surroundings. In 1997, a new relaxation mechanism was proposed that low-energy electrons are produced through interatomic Coulombic decay (ICD) of an electronically excited ion embedded in an environment [2]. The outline of ICD process is shown in Fig. 1. Suppose an inner valence electron is removed from subunit A. The vacancy is filled by an outer-valence electron and the released energy is transferred to a neighboring particle B, which then emits an ICD electron.

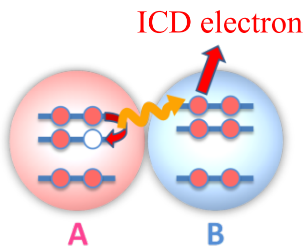

Fig. 1. Outline of ICD

ICD is a very general phenomenon in the loosely bound matter. Experimental efforts even yielded the demonstration of the existence of ICD in water, as a first step towards the realm of biology. The ICD process has been studied theoretically and experimentally in various systems [3]. In this study, we investigated the contributions of ICD electrons as well as low-energy electrons produced via inelastic scattering in argon clusters of dozens of atoms by synchrotron radiation.

[Methods]

Argon clusters (⟨n⟩~40 atoms/cluster) were produced in a supersonic jet expansion through a conical nozzle. The clusters were excited by using monochromatic light at BL17SU of SPring-8. The photon energies were set to be 258 eV and 268 eV, i.e. 10 eV and 20 eV above

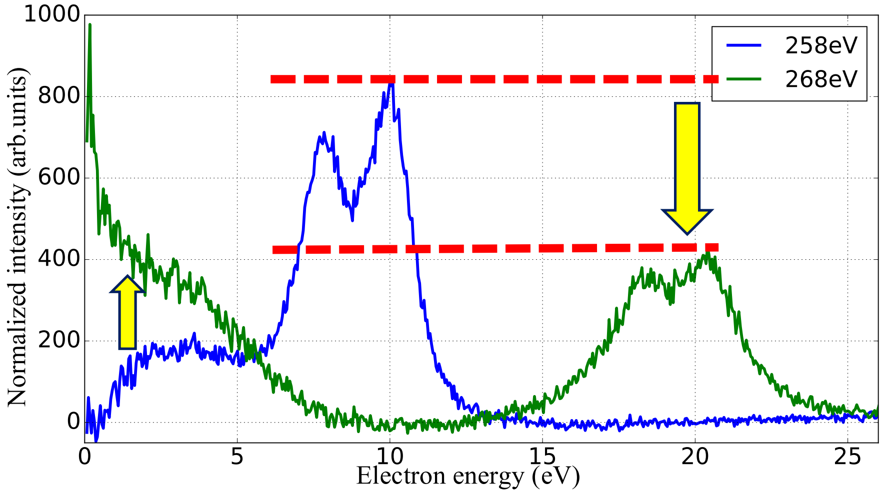

Fig. 2. Electron spectra of Ar cluster measured at photon energies of 258 eV and 268 eV

Ar 2p ionization threshold of 248 eV. Three-dimensional momenta of electrons and ions were measured in coincidence and calculated from time-of-flight and detected positions [4].

We expect the following reactions proceed after 2p photoionization of Ar cluster (Ar_n):

$$Ar_n + h\nu \rightarrow Ar_n^{+} + e^{-} \quad \text{(Ar 2p photoionization)}$$
$$\rightarrow Ar_n^{2+} + e^{-} \quad \text{(Auger decay)}$$
$$\rightarrow Ar_n^{3+} + e^{-} \quad \text{(ICD).}$$

Finally, the triply charged cluster releases three singly charged ions. We selected the decay channel where three monocations of Ar were detected.

[Results and Discussion]

In coincidence with the three ions, we identified the photoelectrons and low-energy electrons from electron spectra shown in Fig. 2. On electron spectra at both photon energies, the Ar 2p photoelectron signals were clearly observed at around 10 eV and 20 eV, respectively. The two asymmetric peaks visible were assigned to be $2p_{1/2}$ and $2p_{3/2}$ photoelectrons. After removing the contribution of Ar 2p photoelectrons at 258eV photon energy, the signal of ICD electrons was remained at around 3 eV. A significantly enhanced intensity showing an increasing tendency towards 0 eV was seen in low-energy region at 268eV photon energy, which indicates that aside from ICD electrons, other low-energy electrons were produced.

We found that low-energy electron yield at 268 eV photon energy was higher than that at 258 eV. In other words, low-energy electron production increases when the energy of photoelectron exceeds ionization potential of Ar. At the same time, the peaks assigned to be photoelectrons at around 20 eV showed weaker intensities than they were expected to have. The experimental results indicate that low-energy electrons are not only produced by ICD but also by the inelastic ionizing collision of the photoelectrons with the surrounding Ar atoms.

[References]

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