NUCLEAR EXCITATION BY ELECTRON TRANSITION ON ^{197}Au AROUND THE K-ABSORPTION EDGE

Nuclear excitation by electron transition (NEET) on ^{197}Au occurs in the K-shell ionization between the $K \rightarrow M_1$-hole atomic transition ($1S_{1/2}$: 80.725keV → $3S_{1/2}$: 3.425 keV) and the $3/2^+ \rightarrow 1/2^+$ nuclear transition (0 → 77.351 keV), with a very small probability of less than 10^{-7} to the ionization. We succeeded in observing the first NEET signal on ^{197}Au at beamline **BL09XU** in 1999 [1]. Figure 1 shows a schematic view of NEET of ^{197}Au. The incident X-rays of 80.989 keV were then used to ionize the gold atoms above the K-absorption edge. In 2001, we observed the NEET events around the K-edge by sweeping the energy of the incident photons. In contrast to the existing model [2-4], assuming that NEET on 197Au could have occurred even below the K-edge due to a finite K-shell width, the actual NEET events appeared to start increasing above the K-edge with a fine structure existing at higher energies. However, we had a statistic problem because of the low efficiency of the single Si avalanche diode (Si-AD) detector.

We tried again the same measurements in 2004 after improving the detector efficiency by replacing the single Si-AD by a couple of Si-AD arrays. Radiation just emitted from excited nuclei, especially the L-internal conversion electron (maximum energy: 63 keV), was mainly detected by the detector. The efficiency of the Si-AD arrays was about 4.3-times higher than that of the single Si-AD. In the addition to the measurements at nuclear resonance, we observed the NEET events as a function of the incident-photon energy (E) around the K-edge. The results were recently reported in Ref. [5]. Figure 2 shows the numbers of the NEET events, N_{ne}. The solid curve was given by connecting the averages of five neighboring points. Here, ΔE_K in the horizontal axis was defined by $E - E_K$; E_K was the K-edge energy. The K-edge was set by fitting the derivative of the measured K-absorption, $d\mu/dE$ with the Lorentz form, shown as the closed circles and the dashed curve in Fig. 3. The FWHM of the K-edge, W_K, was 58 ± 3 eV. The open circles in Fig. 3 indicate the derivative of the NEET events around the leading part in Fig. 2, dN_{ne}/dE; the solid curve is its fitted Lorentz form. The NEET edge at E_{NEET} was determined by the peak and was located at $\Delta E_K = +(40 \pm 2)$ eV. The FWHM of the peak W_{NEET} was 14 ± 9 eV which was less than one third of W_K.

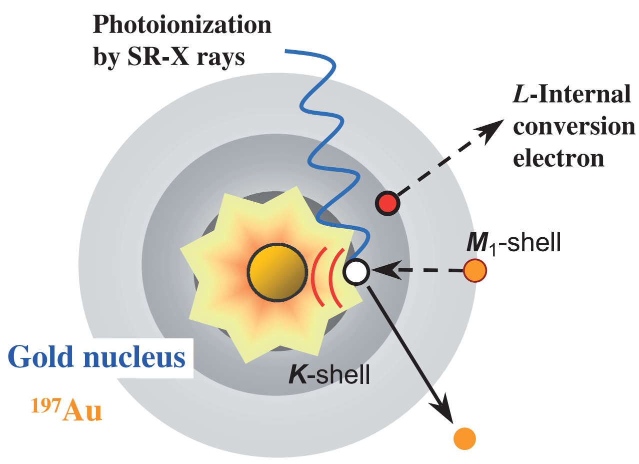

Fig. 1. Schematic view of NEET on ^{197}Au.

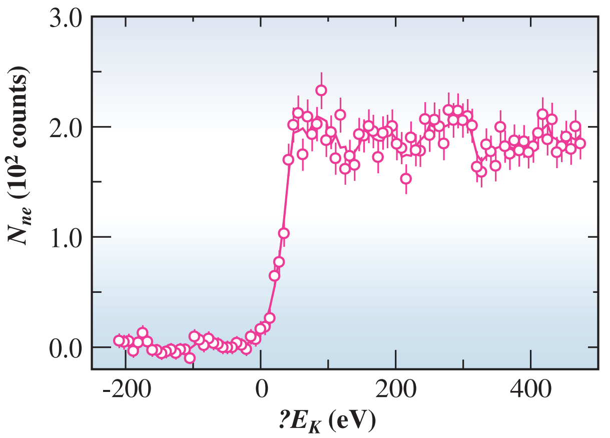

Fig. 2. Number of NEET events as a function of ΔE_K (where $\Delta E_K = 0$ eV means the K-absorption edge).

Why was the NEET edge ΔE_K higher than E_K and why was W_{NEET} narrower than W_K? Our understanding is as follows. From the energy conservation rule between the initial and the final states, NEET just occurs when the energy of the K-hole state (E_{Kh}) is the same as the sum of the nuclear transition energy (E_N) and the M_1-hole state energy (E_{M1h}). Using the reference values, E_{NEET} (=E_{Kh}) is given by $\Delta E_K = +51$ eV, which is near, but different from the observed value of +40 eV. This may suggest that the absolute values of E_N and E_K should be revised. By adopting an M_1-level width of 14.3 eV (FWHM), a beam width of 3.5 eV (FWHM), and neglecting the very narrow width of the nuclear level, the observed W_{NEET} should be less than the sum of these widths, 18 eV, since an energy width in the

NEET transition depends on the widths of the initial and final states. Our result of 14 ± 9 eV includes the expected value. Moreover, a fine structure of the NEET events is seen at $E > E_{NEET}$ in Fig. 2. If energy conservation is strictly maintained involving the energy of an ejected photoelectron from the K shell, this feature may be explained by a common mechanism with the modulation of extended X-ray absorption fine structure (EXAFS). The EXAFS modulation means a variation of the photoabsorption rate, or an interference effect produced by the outgoing photoelectron scattered from near neighboring atoms. The scattering process of the photoelectron in NEET should also affect the atomic transition rate. At $E > E_{NEET}$, the excess energy of $\varepsilon_{NEET} = E - E_{NEET}$ $(= E - (E_N + E_{M1}))$ is transferred to an outgoing photoelectron emitted in NEET. Since the kinetic energy, ε_{ph}, of the normal photoelectron emitted from the K-shell without NEET, satisfies $E - E_K$, ε_{NEET} should be ΔE_{NA} $(= E_N - (E_K - E_{M1}))$ lower than ε_{ph} at the same E. We will precisely confirm these prospects by experiments in the near future.

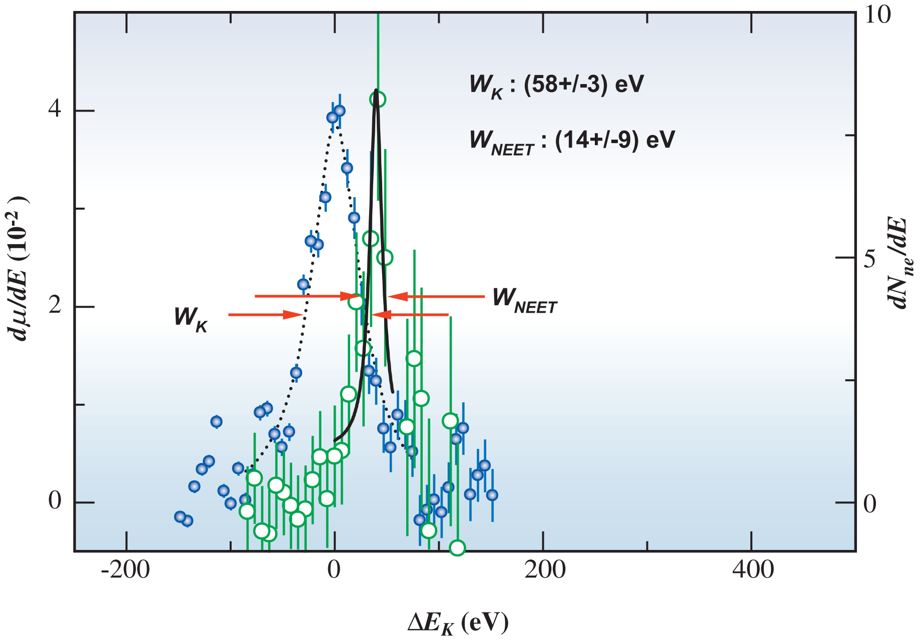

Fig. 3. Derivative of the K-absorption curve (closed circles) and its Lorentz fitting (dotted curve); the peak was set to $\Delta E_K = 0$ eV. The derivative of the NEET events, dN_{ne}/dE, is also plotted by the open circles; the solid curve is its Lorentz fitting. The arrows indicate the FWHM of the NEET edge, W_{NEET}, and that of the K-edge, W_K.

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