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An apparatus for the low-energy inverse photoemission spectroscopy is described. In this technique, low energy electron having kinetic energy below 4 eV is incident to the sample and detect the emitted photons in the near ultraviolet range (below 5 eV, longer than 250 nm) to investigate the unoccupied states of the solid materials. Compared with the prototype apparatus reported previously [H. Yoshida, Chem. Phys. Lett. 539–540, 180–185 (2012)], the collection efficiency of photons is improved by a factor of four and practically any conductive substrates can be used. The overall resolution is 0.27 eV.

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FIG. 1. Schematic diagram of the LEIPS apparatus.

The intensity of the spectra can be compared with those of CuPc in the previous report \(^{17}\) because the IPES spectra around the energy gap are mainly contributed from the organic ligand rather than the central metal.\(^{23}\) The intensities of Fig. 3 are one order of magnitude higher than the previous ones (Fig. 4 of Ref. 17) if the throughput of the filters is taken into account. This increase of the signal intensity can be understood from the two reasons. First, the collection efficiency of the photon is improved by a factor of four. Second, the photon detector is installed in the same side of the electron gun so that the photons are not absorbed by the sample and substrate; the transmittance of 20-nm-thick ITO used in Ref. 17 as a substrate is only 40% in 250–300 nm.

In summary, an experimental apparatus for the LEIPS is described. Compared with the prototypical apparatus for LEIPS,\(^ {17}\) the solid angle for the photon collection is increased fourfold by placing the focusing lens in the vacuum. In addition, the photon detector is installed facing the sample surface. This allows us to use opaque substrates in NUV range (any materials that have electrical conductivity). The photon signals are not lost by the absorption in the sample and substrate together with the improved collection efficiency, the signal intensity is increased by one order of magnitude. The overall resolution, estimated from the Fermi edge of Ag film, is 0.27 eV.

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The error function is integral of the Gaussian function. Hence, the fitting the error function to the original spectrum is mathematically equivalent to fitting the Gaussian function to the first derivative of the spectrum.