STM-induced light emission from organic multilayer structures

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[Introduction]

Scanning tunneling microscopy induced light emission (STM-LE) enables us to obtain information about local optical properties in a sample surface. Although several mechanisms, such as surface-plasmon-mediated processes for organic-monolayer systems formed on Au and Ag surfaces, have been proposed to explain STM-LE spectra, details are still uncovered. Furthermore, experiments have been performed, in general, for the basic simple structures instead of practically applicable structures.

In this paper, we present some of our recent results of STM-LE study performed on electro-luminescent multilayer structures, aiming at further advance of this interesting method.

[Experiment]

An Alq_3/rubrene/Au multilayer structure, for example, was prepared as a sample for experiment. The organic films were grown by vacuum deposition, and the film thickness of each layer was monitored using a QCO. As shown by the schematic illustration in Fig. 1(a), the rubrene molecular layer has a quantum well sandwiched by the metal substrate and the Alq_3 layer, which confines injected electrons and holes in the layer of rubrene molecules and increases the efficiency of light emission through their combination at the local quantum well. Measurements were performed at room temperature in air and at about 20 K in vacuum. A mechanically cut PtIr was used as a STM tip. The light emitted from the tunnel junction was focused onto an entrance edge of an optical fiber and introduced into a monochromater. A CCD was used for detection. Optical measurements were performed after STM observation to image the topography of the area. At about 20 K in vacuum, we could stabilize the molecular structures and succeeded in obtaining reproducible STM-LE spectra.

[Results and discussion]

Figure 1(a) shows a photoluminescence (PL) spectrum of rubrene powder. For an electroluminescence (EL) of the present multilayer structure, photon emission of this wavelength is expected to occur through the combination of electrons and holes at the middle (rubrene) layer as shown in an inset of the figure.

Figure 1(b) shows STM-LE spectra obtained by repeated measurements for the same place of an Alq_3/rubrene/TPD/Au sample in air at room temperature. A prominent signal was observed at about 600 nm for the first measurement (thick line). This component is close to the PL spectrum of rubrene shown in Fig. 1(a), as expected. The 600 nm-signal was weakened in the second measurement, and the signal from Au surface plasmon became dominant (thin line). This results suggests desorption of molecules under this experimental condition, which supports that the signal is originated from the rubrene molecules in the layered structure.

This is the first demonstration of the STM-LE measurement of an organic-multilayer structures practically designed for an optical device.

In addition, we developed a wavelength-resolved 2D photon mapping system and investigated the spectral intensity distributions in detail. The results, together with those from other systems, will be introduced and discussed at the colloquium.

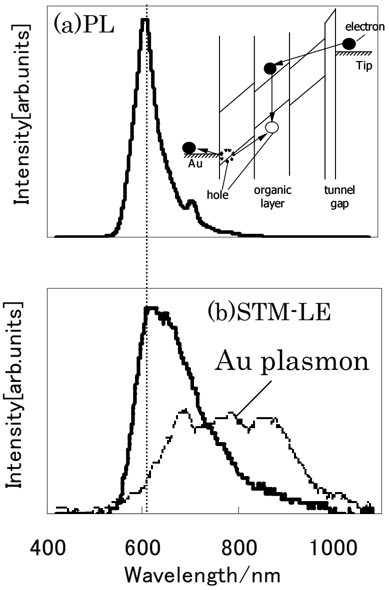

Fig.1 (a) A PL spectrum from rubrene powder (**Inset:** Energy diagram of the layer structure); (b) A sequential STM-LE spectra from Alq_3/rubrene/TPD/Au obtained in air at room temperature (Bias voltage: 5.0 V, tunneling current: 3 nA, exposure time of CCD: 128 sec/spectrum). Thick and thin lines stand for first and second measurements.