Subnanometric optical control of electron emission sites

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In this presentation, we will provide an overview of our recent development of the optical control of electron emission sites.

By irradiating a sharp metallic needle with femtosecond light pulses, optical fields can be concentrated on the needle's apex, and these localized optical fields then generate electron emissions from the apex [1], as shown schematically in Figure 1(a). Such electron emissions can be used as optically-controlled ultrafast switches that are three to six orders of magnitude faster than current switching devices in modern computers. Concurrent plasmonic effects can spatially control the electron emission at its source on a scale of a few tens of nanometers [2]. For example, one can select emission sites A or B, as shown in Figure 1(b). The optical control of emission sites yields a device equivalent to multiple switches integrated into a nano-object, whose corresponding electronic circuit is shown in the right panel of Figure 1(b). Further acceleration of such a switch would be possible with advances in laser technology. However, further miniaturization of such a spatially controllable electron source is fundamentally difficult via plasmonics, and a paradigm shift is required.

Here, we realized that paradigm shift by employing a recently identified single-molecule electron source that generates electron emissions from individual fullerene molecules deposited on a metallic needle [3], as shown schematically in Figure 2. By illuminating the molecules with light, we discovered that largely modulated emission patterns appeared from a single molecule, approximately one nanometer in size [4]. These are quantum-mechanical phenomena that use variations of molecular orbitals. This scenario is well supported by simulations using density functional theory, which also explains the physics of electron emission patterns from single molecules via DC electric fields—an intractable question for

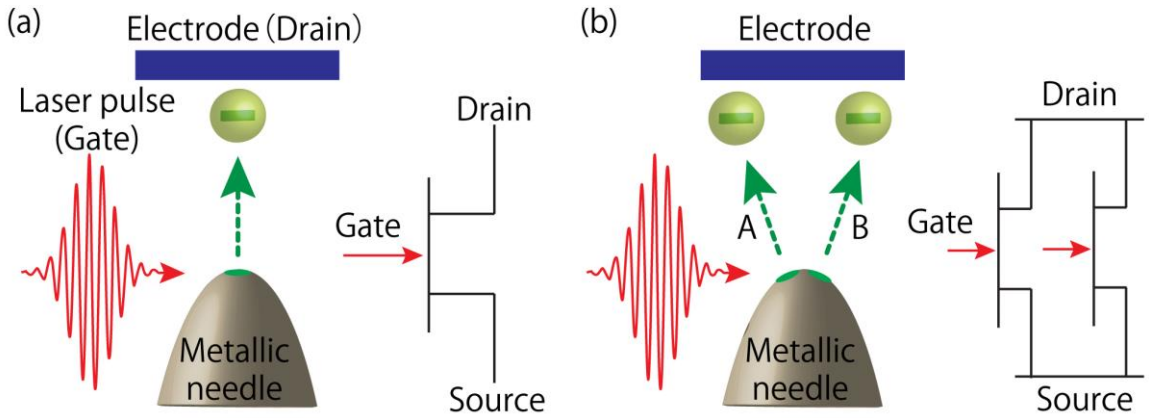

FIGURE 1. Conceptual diagram of how to induce ultrafast electron emission from a nano-object by irradiating a light pulse (a) and optical control of emission sites (b). Electronic circuits equivalent to these electron sources are drawn alongside the figures.

more than seven decades. In addition, we will further discuss optical controllability over emission sites at a single molecule. Our work will open the door to multiple ultrafast switches integrated into a single molecule.

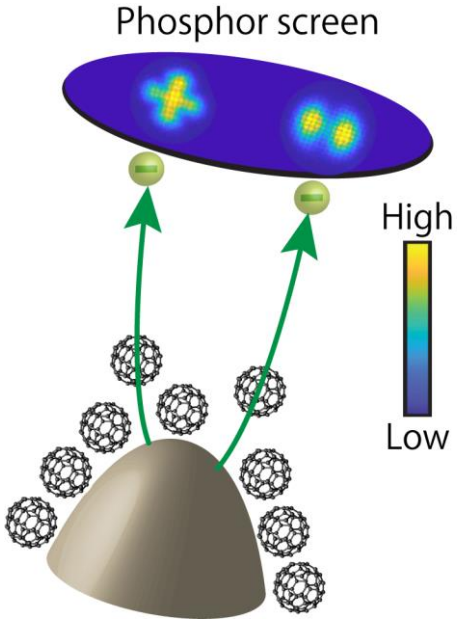

FIGURE 2. Schematic diagram of electron emissions from single fullerene molecules.

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