Directional plasmon excitation at molecular scales

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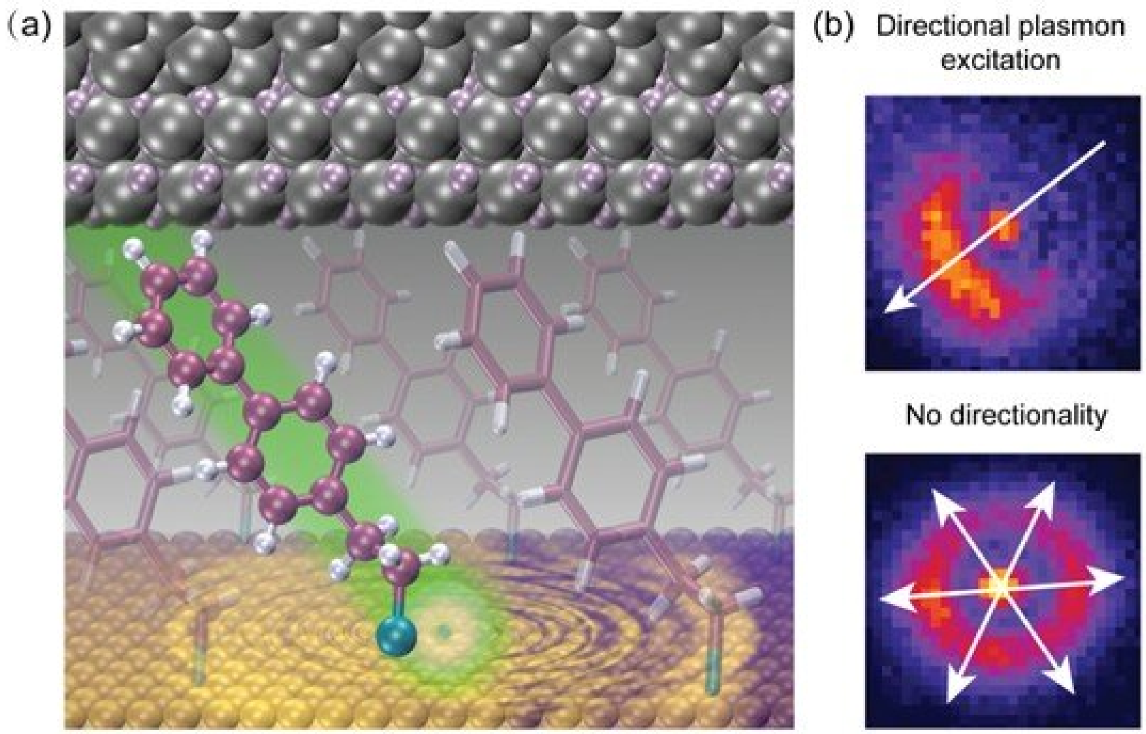

Figure (a) shows an artistic impression of the directional tunnelling in a molecular double-barrier junction followed by plasmon excitation [Credit: Harshini Venkata ANNADATA]. Figure (b) gives the experimental defocused light emission images showing the directional excitation of surface plasmon polaritons for samples containing molecules with and without a specific tilt angle. Credit: Nano Letters

NUS scientists have developed a method for directional excitation of plasmons at molecular length scale with electrically driven sources. Photonic devices which make use of light can transmit information much faster than nanoelectronic systems. However, they tend to be much larger in size and difficult to integrate with nanoelectronics systems.

Plasmonics, which involves the study of interactions between light and charged particles such as electrons in metal, has the potential to bridge the gap between nanoelectronics and photonics. One important aspect is to have excitation sources that can directly convert electrical signals into plasmons to overcome the mismatch in size between small nanoelectronic devices and large photonics elements which is limited by the large size of photons. Plasmons can be seen as confined light, up to 100 times smaller than photons, with dimensions compatible with nanoelectronics. It would also be highly desirable to be able to control the excitation direction of the plasmons, so as to steer them towards other components to reduce the need for optical elements.

A team lead by Prof Christian A. NIJHUIS from the Department of Chemistry, NUS, in collaboration with Dr. Nikodem TOMCZAK from the Institute of Materials Research and Engineering, Agency for Science, Technology and Research (IMRE, A*STAR) has discovered that the excitation direction of surface plasmon polaritons (SPPs) in a molecular (double-barrier) junction can be controlled by adjusting the tilt angle of the molecules to the electrode surface. These SPPs are light waves that function like photonic elements, carrying information at high speeds. The researchers were able to excite the plasmons along the tunneling direction without the use of large optical elements which can potentially cause complications in the design and fabrication of the devices.

The double-barrier molecular junction is made of monolayers of molecules that consist of two segments, a highly conductive unit and an insulating section. The molecules are sandwiched between two metallic electrodes. The tilt angle of the conductive segment along which electrons tunnel efficiently can be precisely controlled by changing the length of the insulating section. Unlike conventional metal oxide tunnel barriers, the tunnelling direction in these molecular double-barrier junctions can be precisely controlled.

Prof Nijhuis said, "These results are interesting because our plasmon sources are not diffraction limited and they demonstrate the manipulation of plasmons at molecular length scale without the use of large optical elements, such as antennae, or external light sources."

These results give new insights in light-matter interactions in tunnel junctions and are an important next step to integrate tunnel junctions with plasmonic waveguides.

More information: Wei Du et al. Directional Excitation of Surface Plasmon Polaritons via Molecular Through-Bond Tunneling across Double-Barrier Tunnel Junctions, *Nano Letters* (2019). DOI: 10.1021/acs.nanolett.9b01665

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