Anisotropic plasmons in quasi-metallic 2-D materials

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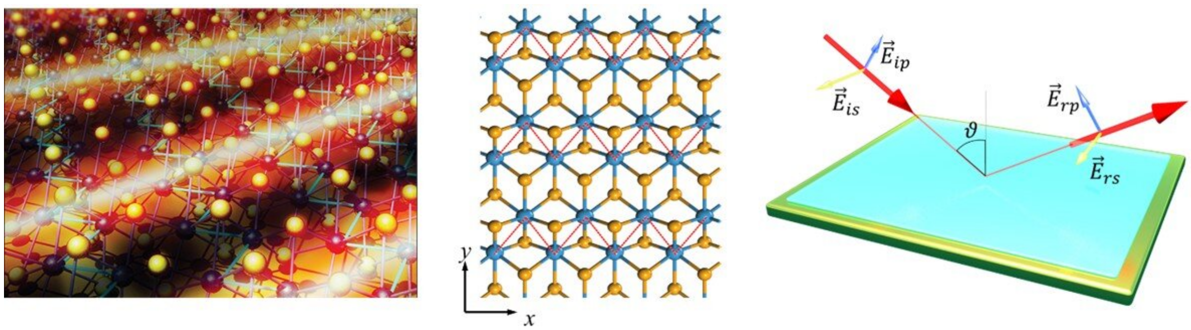

Figure shows (left) a visual representation of the mid-infrared anisotropic plasmon in quasi-metallic phase 2D-TMDs. (Middle) Quasi-metallic phase monolayer- tungsten diselenide (WSe2) with its directional zig-zag tungsten (W, blue dots) structure traced by red dashed-lines. (Right) Schematic of high-resolution spectroscopic ellipsometry used to probe the plasmon of thin-film systems. This is a non-invasive optical technique based on the change in the polarisation state of light as it is reflected obliquely from a thin film sample. Credit: Advanced Science

National University of Singapore physicists have discovered new mid-infrared anisotropic collective charge excitations in quasi-metallic phase two-dimensional (2-D) transition-metal dichalcogenides (TMDs).

Low-dimensional periodical patterned structures, such as 2-D layered systems or one-dimensional (1D) chained structures in material systems, exhibit intriguing wave phenomena due to the interactions between the many particles in the system (many-body interactions). These low-dimensional periodical structures result in unique material properties that have generated considerable research interest for use in various device applications. Quasi-metallic phase 2-D-TMDs have a distorted sandwich configuration where the transition-metal atoms form a 1D zig-zag chain structure (see Figure). This 1D periodic structure gives rise to unique anisotropic material properties which significantly influence the electronic features of 2-D-TMDs.

A research team led by Prof Andrew Wee from the Department of Physics, NUS has directly observed new mid-infrared regime plasmons in quasi-metallic phase monolayer tungsten diselenide (WSe_2) and molybdenum disulphide (MoS_2).

WSe_2 and MoS_2 have two phases, a quasi-metallic phase and a semiconducting phase. This phenomenon is only present in the quasi-metallic phase, but absent from the semiconducting phase. Theoretical calculations using first principles reveal that these plasmons are anisotropic in nature. This means that, while they are present in the direction perpendicular to the zig-zag transition-metal chain, they do not propagate along the zig-zag chain.

By combining high-resolution spectroscopic techniques and detailed first-principles analysis, the long-range Coulomb interactions between the zig-zag chains have been identified as the key mechanism driving this 1-D collective excitation. The research team also postulated a possible relationship between the observed plasmon excitations and the unconventional superconducting mechanism in quasi-metallic phase 2-D-TMDs.

Dr. Yin Xinmao, a research fellow on the team, said, "The quasi-metallic phase 2-D-TMDs consist of 1D zig-zag metal chains stacked periodically along a single axis which gives rise to unique electronic and optoelectronic properties. This finding by the team on the mid-infrared plasmons potentially open up new ways of exploiting plasmons in scientific and engineering applications as plasmons in typical metals are usually found only in the ultraviolet range."

Prof Wee added, "It is important to study these charge collective modes in 2-D-chained systems for the development of next-generation applications. These range from field-effect transistors to photodetectors and other optoelectronic devices."

The team plans to further investigate such novel collective excitations in other low-dimensional periodic structures, in the hope of unraveling more understanding of the unconventional superconductivity.

More information: Chi Sin Tang et al. Anisotropic Collective Charge Excitations in Quasimetallic 2D Transition-Metal Dichalcogenides, *Advanced Science* (2020). DOI: 10.1002/advs.201902726

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