Bidirectional graphene plasmon launched by nanoridge structures

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Surface plasmon polariton of graphene offers many interesting aspects over traditional gold/silver plasmon, for example, long propagation range, high plasmon confinement, and plasma frequency in infrared region. To excite propagating graphene plasmon, metallic-coated tips and gold antenna have been used as near-field plasmon launcher. Periodic graphene grating has also been also discussed. In this study, we present numerical simulation of graphene plasmon launching by using graphene nanoridge structure. Using graphene nanoridge, this method does not require periodic structure or an introduction of foreign entity (tip or antenna) into the system. Since nanoridge structures are naturally occurred in graphene prepared by SiC sublimation or chemical vapor deposition (CVD), this method has potential to be realized. The simulation was done by finite element method (FEM) using Comsol Multiphysics. The simulated graphene model is large single-layer flat graphene sheet, which contains nanoridge with 100-250 nm width in the middle (similar scale to nanoridges in real epitaxial and CVD graphene).[1] The structure is illuminated by gaussian beam of 2.5-8.0 μm wavelength infrared light. Only TM surface plasmon is considered in this simulation.

The results show that single nanoridge structure can couple light into graphene plasmon. Unlike gold/silver plasmon, graphene plasmon wavelength can be extremely shorter than excitation wavelength, and thus be several times smaller than coupling structure. The plasmon waves launched from every point on the nanoridge therefore interfere which each other. When curve length of nanoridge is multiples of plasmon wavelength, the interference is totally destructive and thus plasmon cannot propagate from the ridge (“confined mode”). In other cases, plasmon propagates onto flat graphene (“launching mode”). The phase of propagating plasmon wave is flipped by π between each launching mode. The effect of nanoridge height is simple, as higher ridge providing stronger plasmon wave. However, unlike periodic graphene ripple grating, the height of nanoridge also affects the ridge curve length. This subsequently affects excitation wavelength which gives maximum/minimum plasmon amplitude. For double nanoridge structures, plasmon wave launched from each ridge must propagate over another ridge. Using asymmetric ridge pair (e.g. 100 and 150 nm width), plasmon from each ridge experiences different phase delay. Therefore, tuning of excitation wavelength and ridge separation can control constructive/destructive interference on both side, thus plasmon launching can be bi-directional, unidirectional, or confined, depending on the parameters. In conclusion, non-periodic nanoridge(s) can launch graphene plasmon which is highly-adjustable (amplitude, phase, direction) by controlling excitation wavelength, ridge size, and ridge separation.

[1]S. Vantasin, Y. Tanaka et al., *Phys Chem Chem Phys*, 2015, **17**, 28993–28999.