Visualization of surface plasmon propagation in a crystal waveguide by momentum-resolved cathodoluminescence spectroscopy

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Next generation on-chip optical devices require light manipulation in time and space, that is, control of group velocity of light in subwavelength dimensions. A waveguide in plasmonic crystal (PlC) fullls such requirements oering nanoscale light connement in the dispersion-tunable plasmonic crystal matrix. Especially, PlCs with a triangular lattice (Tri-PlCs) are attractive due to full bandgap (FBG) formation, where no SPP propagation is allowed [1]. In this study, we have performed local dispersion measurements of PlC waveguides by using cathodoluminescence (CL) combined with a scanning transmission electron microscopy (STEM) (Fig. 1a).

The investigated Tri-PlC waveguide was composed of a silver dot array on a silver surface. The distance between the lattice points (P) was 300 nm, and the diameter and the height of the dot were about 150 and 100 nm, respectively. For the momentum-resolved CL measurements, the light emitted parallel to the *xz* plane was detected by successively changing the angle selection pinhole position in the *z* direction [2]. Fig. 1b shows the dispersion pattern taken from the PlC waveguide with a line defect width of 520 nm. A dispersion curve of the guided SPP mode appears in the FBG of the Tri-PlC, and the group velocity in the *x* direction is 7.5 times slower than the light speed in vacuum by assuming a linear dispersion in the range of 1.95 to 2.10 eV.

We also obtained photon maps of the guided SPP mode to visualize propagation behavior (Fig. 1c). To detect non-radiative SPPs, we connected the Tri-PlC waveguide to a one-dimensional grating (left end) which can convert SPPs to light in the corresponding energy region. The decay of the SPP propagating along the waveguide is observed. It should be noticed that a periodic oscillation feature appears in the waveguide, and the oscillation period is equal to the lattice spacing. This oscillation pattern suggests that the dot array facing the waveguide causes Bragg reection of the guided SPPs in the direction of the waveguide (*x* axis). We also found that this Bragg reflection forms another small bandgap in the dispersion curve of the guided SPP mode. At this waveguide bandgap, the group velocity seems reaching infinitesimal, suggesting PlC waveguides can be a platform to enhance light-material interaction. In addition, from the experimental data and modeling, a simple relation between the waveguide bandgap energy and the line defect width W was revealed, that is, the waveguide bandgap energy is proportional to W^{-2} [3].

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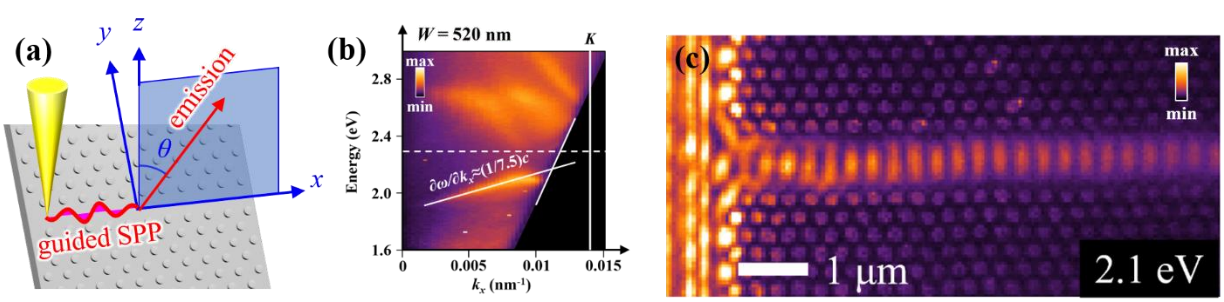

Fig. 1 (a) Schematic of the local dispersion measurement in the Tri-PlC waveguide. (b) Dispersion pattern taken from the Tri-PlC waveguide with a line defect width of 520 nm. (c) Monochromatic photon map of a PlC waveguide with a line defect width of 1040 nm connected to the 1D grating taken at 2.1 eV.