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# Guiding of long-range surface plasmon polaritons along channels in periodic arrays of scatterers

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**Abstract:** We investigate waveguiding of long-range surface plasmon polaritons in periodic arrays of scatterers at telecommunication wavelengths. A propagation loss of approximately 6 dB/mm and a coupling loss of 0.5 dB is reported for 8- $\mu\text{m}$ -wide channels.

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Materials with periodic modulation of the refractive index also called photonic bandgap (PBG) structures, pave the way to the design of ultra-compact integrated optical circuits [1]. A new and interesting approach suggested recently is to employ the PBG technique for guiding of surface plasmon polaritons (SPPs) [2]. To overcome limitations connected to the inherently high propagation loss for SPPs propagating along a metal-dielectric interface one can use a symmetric structure where a metal film is embedded in a dielectric. Such a structure supports propagation of long-range SPPs (LR-SPPs) whose loss decreases drastically with the reduction of the film thickness [3]. Guiding of light along thin metal stripes embedded in dielectric via excitation of LR-SPPs has generated a lot of interest due to relatively easy fabrication, low propagation loss and efficient coupling with single mode fiber [4]. We investigate waveguiding of long-range surface plasmon polaritons in periodic arrays of scatterers with linear defects.

LR-SPP stripe waveguides are fabricated by coating a silicon substrate with a 15- $\mu\text{m}$ -thick Benzocyclobutene (BCB) polymer layer, photolithographic patterning of stripes, gold deposition and lift-off followed by coating with the top cladding comprising another 15- $\mu\text{m}$ -thick BCB layer. A photonic bandgap structure is obtained by applying a symmetric periodic array of gold bumps below and above the stripe waveguide. Gold bumps are patterned using electron-beam lithography and formed by metal deposition and lift-off. A microscope image of a waveguide introduced by missing rows of bumps in LR-SPPBG structure together with the detail of the corresponding mask design and a top image of light scattered from the channel is shown in Fig. 1.

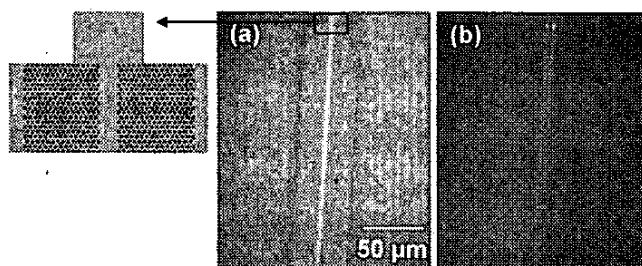


Fig. 1. 240- $\mu\text{m}$ -long and 4.5- $\mu\text{m}$ -wide LR-SPPBG channel ( $\Gamma\text{K}$  orientation) together with the detail of the mask design (a) and light scattered from the waveguide (b).

LR-SPPBG structures based on triangular lattice with different periods (550, 570, 590 nm) are optically characterized in the wavelength range from 1400 nm to 1600 nm. Transmission and reflection measurements are performed on the fabricated samples containing LR-SPPBG waveguides of different lengths (from 30 to 600  $\mu\text{m}$ ) and widths (from 3 to 27 rows of bumps missing). The dependence of the back-reflection peak on the LR-SPPBG waveguide length is presented in Fig. 2. Typical transmission spectra for channels in structures with different lattice periods are shown in Fig. 3. We observe a sign of the LR-SPP bandgap in the  $\Gamma\text{K}$  direction from transmission spectra with characteristic cut-offs and strong reflections from LR-SPPBG structures. These distinctive features in the measured wavelength dependencies of transmission and reflection are found to scale in accordance with the lattice period.

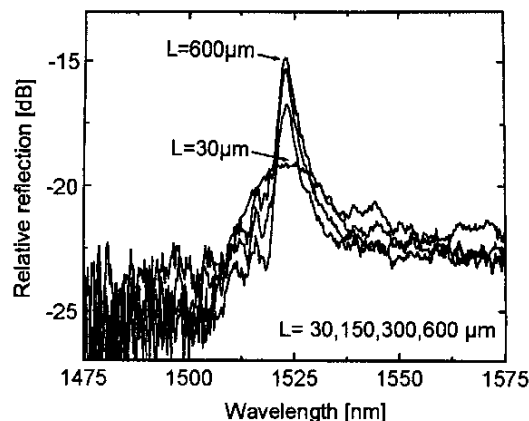


Fig. 2. Reflection from LR-SPPBG waveguides of different lengths (lattice period 570 nm, ΓK orientation, channel width 3.2 μm).

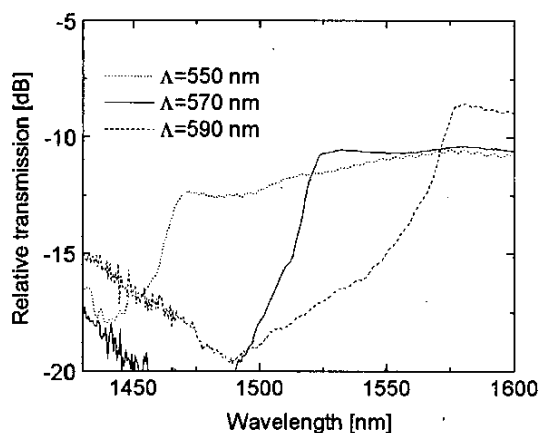


Fig. 3. Transmission through LR-SPPBG waveguides for different lattice periods (ΓK orientation, channel length 300 μm, width 4.5 μm).

From the transmission spectra for different lengths of LR-SPPBG waveguides a propagation and a coupling loss is estimated for different channel widths at the wavelength 1550 nm. The propagation loss decreases gradually with the increasing width of the channel from ~ 50 dB/mm for a 1-μm-wide channel to approximately 6 dB/mm for a 8-μm-wide channel. The coupling loss between a LR-SPPBG channel and a stripe waveguide is found to be 6 dB for a 1-μm-wide channel and ~ 0.5 dB for a 8-μm-wide one.

We believe that combining LR-SPP waveguides with PBG channels makes these structures promising candidates for novel integrated optical components.

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