Long-Range Surface Plasmon Polariton Devices Fabricated By Nanoimprint Lithography

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In recent years, surface plasmon photonics have received increasing interest [1].The unique properties of surface plasmon polaritons (SPPs) can be harnessed to improve light extraction from light-emitting diodes, to realize highly surface-sensitive detectors, to surpass the conventional diffraction limit in integrated optics, etc. However, the applicability of surface plasmon waveguides to integrated optics is often limited by high propagation loss caused by absorption in the metal and by difficulties in coupling light in and out of the waveguides. One way to overcome these problems is to use so-called long-range SPP (LR-SPP) waveguides which consist of an ultra-thin layer of metal embedded in a dielectric material. Such structures have been fabricated previously, using glass-polymer [2] or polymer-polymer sandwiches [3], leading to new device designs compatible with standard optical fibre technology, including devices containing sub-wavelength features patterned with electron-beam lithography [4].

The aim of the present work is to develop a fabrication process for LR- SPP waveguides compatible with NIL and wafer bonding. This technique is well suited for mass production of components with nano-scale features and allows the LR-SPP waveguide technology to be integrated into more complex device geometries, e.g. including microfluidic channels. As a cladding material, we used mr-I T85-20.0 nanoimprint resist from micro resist technology GmbH. This material has an excellent chemical resistance, low water absorption, and high optical transparency which is compatible with UV lithography and metal deposition [5].

In order to demonstrate the use of nanoimprint technology waveguides with reflection gratings based on small periodic perturbations in the metal film were fabricated as follows, figure 1: A silicon stamp was patterned using electron beam lithography and etching, to define 20 nm deep gratings with a period of 500 nm and lengths of up to 4 mm. This stamp was imprinted into a silicon wafer spin-coated with a 20 µm thick layer of mr-I T85. Photoresist patterning, deposition of a 12 nm gold layer and lift-off were used to define straight, 8 µm wide waveguides. The top polymer cladding was formed by spin-coating a Pyrex wafer with a similar mr-I T85 layer and the two wafers were then bonded together at 100°C and 10 kN in a parallel plate embossing machine. The bonded wafers were diced for optical transmission measurements. The finished device is shown in figure 2.

Transmission measurements were carried out by launching light from a broadband ASE source around 1550 nm wavelength, through a polarization controller into a polarization-maintaining fibre. The light was coupled directly from the fibre to the waveguides using end-fire coupling of TM polarized light (the metallic stripe waveguide only supports TM polarization). The output was coupled into a spectrum analyzer using a standard single-mode fibre.

Investigated devices (figure 3) showed pronounced Bragg-grating behaviour where the dip in the transmission is increasing with increasing grating length.

References:

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Figures:

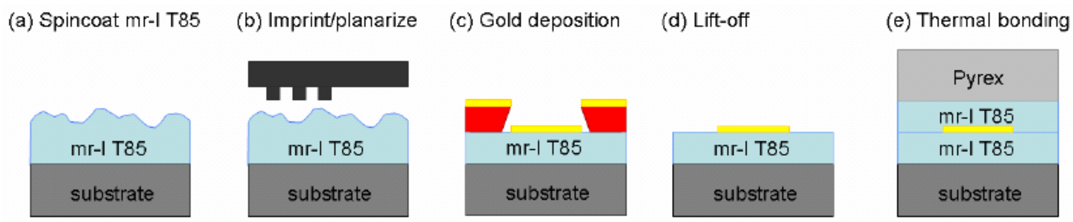

Figure 1: Outline of the fabrication process. (a) mr-I T85 is spin-coated on a Si wafer. (b) imprint of mr-I T85 film. (c) UV-lithography defines the waveguide and gold is deposited. (d) Lift-off of the gold film. (e) A mr-I T85 covered Pyrex wafer is bonded on top to embed the waveguide.

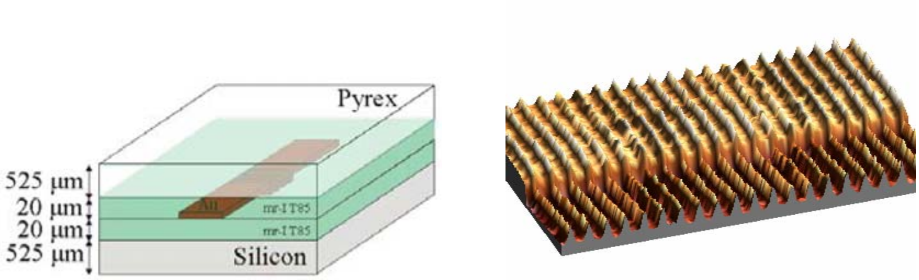

Figure 2: Left: Schematic of the device structure containing an LR-SPP waveguide with a reflection grating, fabricated by nanoimprint technology. Right: AFM image of the edge of the Au stripe, with the 500 nm period reflection grating.imprinted in the underlying polymer.

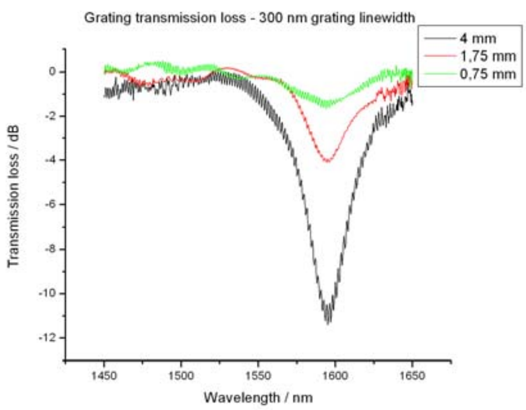

Figure 3: Transmission spectra through gratings of varying length.