Proceedings of the

Advanced Architectures in Photonics

September 21–24, 2014
Prague, Czech Republic

Volume 1

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Proceeding of the Advanced Architectures in Photonics
http://aap-conference.com/aap-proceedings

ISSN: 2336-6036
September 2014

Published by **Involved Ltd.**
Address: Siroka 1, 53701, Chrudim, Czech Republic
Email: info@involved.cz, Tel. +420 732 974 096

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POSTERS presented at AAP 2014

Proceedings of the Advanced Architectures in Photonics 1, 37 (2014).

PREPARATION OF SPARSE PERIODIC PLASMONIC ARRAYS BY MULTIPLE-BEAM INTERFERENCE LITHOGRAPHY

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① INTRODUCTION

A novel method for fabrication of sparse periodic arrays of plasmonic nanostructures for applications in surface enhanced Raman scattering (SERS) or affinity biosensing is presented. The technique is based on interference of eight or more coherent optical beams originating from diffraction of a collimated laser beam on a special transmission phase mask. This arrangement ensures the fulfilment of strict phase relations among all interfering beams and yields a high-contrast interference pattern with periodicaly ordered narrow maxima.

② MULTIPLE-BEAM INTERFERENCE LITHOGRAPHY: PRINCIPLE

Interference lithography (IL) is a common technique for preparation of various types of periodic nanostructures. The contrast of the standard two-beam interference pattern and thus attainable dimensions of the prepared nanostructures could be improved by utilizing a larger number of coherent beams to form the recording interference pattern.

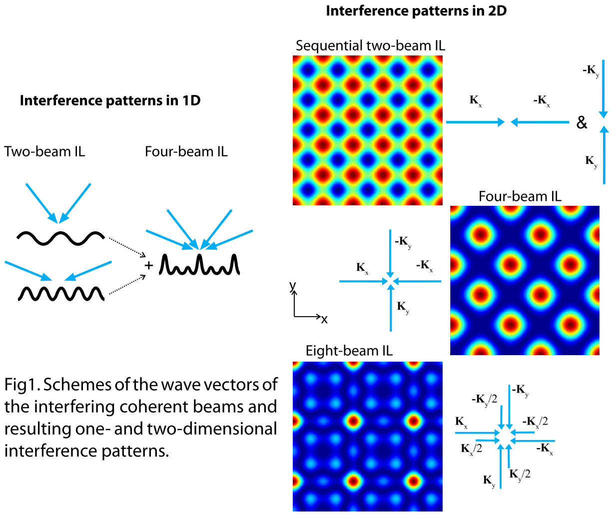

Fig1. Schemes of the wave vectors of the interfering coherent beams and resulting one- and two-dimensional interference patterns.

③ INTERFEROMETER SETUP

A beam from a 325 nm line of a He-Cd laser was collimated by a dublet lens and transmitted through a special phase mask (Fig. 2). All transmitted diffraction orders impinged on a photosensitive layer on a glass substrate placed closely (0.15 mm - 4 mm) behind the phase mask.

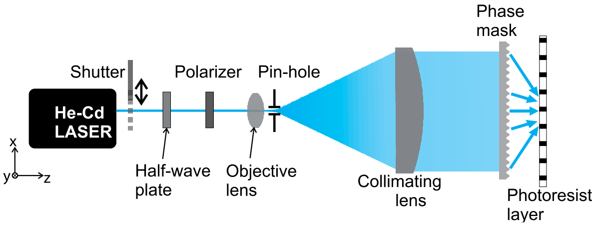

Fig. 2. Scheme of the multiple-beam interferometric setup.

This research was supported by the National Science Foundation of the Czech Republic.

④ DESIGN OF THE PHASE MASK

Based on a theoretical model of multiple-beam interference, a special phase mask with period 800 nm in both directions was prepared (Fig.3a). Modulation depth was designed to provide optimum diffraction efficiencies of all 21 transmitted orders to form a sparse interference pattern with high contrast (Fig.3b). Diffraction efficiencies were calculated using the 2D rigorous coupled wave analysis (RCWA). Designed phase mask was fabricated using sequential two-beam IL on a photoresist (AZ MiR 701)-coated SF2 glass substrate.

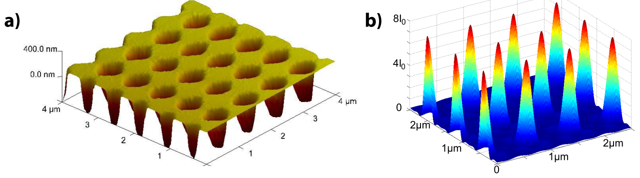

Fig. 3. a) AFM scan of the surface of the prepared phase mask with 800 nm period and 595 nm modulation depth and b) calculated interference pattern formed by all 21diffraction orders transmitted by such mask.

⑤ FABRICATION PROCEDURE

The photoresist layer exposed in multiple-beam interferometer was wet developed in AZ 726 developer so that a periodic array of nanoholes was obtained (Fig. 4, left). A thin gold layer was then evaporated in vacuum on top of the structure. In order to obtain an array of separated gold nanodisks (Fig. 4, right), the photoresist layer was lifted-off in acetone.

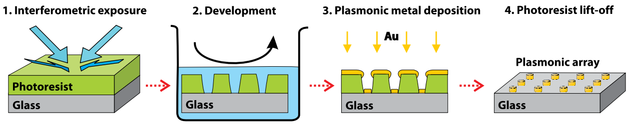

Fig. 4. Scheme of the fabrication procedure.

⑥ CHARACTERIZATION

Prepared plasmonic arrays were characterized morphologically using scanning electron microscope (SEM). Measured nanodisk diameters were from about 150 nm to 270 nm depending on the applied exposure dose.

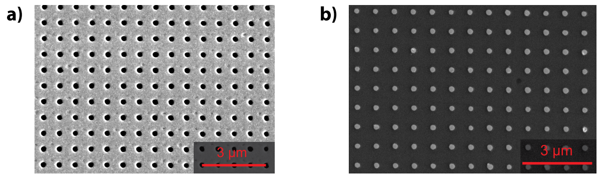

Fig. 5. SEM photographs of the fabricated sparse plasmonic arrays: a) gold-coated nanostructured photoresist; b) array of nanodisks (diameter ~215nm, height 30 nm, period 800nm) after lift-off of the sacrificial photoresist layer.

⑦ CONCLUSIONS

A novel method for fabrication of sparse plasmonic arrays is presented. It provides following **features and benefits**:

- **Fabrication of large areas (several mm^2) of perfectly periodic 2D sparse plasmonic arrays**
- **Rapid patterning: photoresist exposure ~15 minutes**
- **Nanoparticle size < 20% of the array period**
- **Complex periodic patterns attainable by consecutive interferometric exposures**