

Integration of nanodiamonds with NV-centers on optical silicon nitride structures

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Abstract. In this work we had developed optical structures from silicon nitride for further integration of the nanodiamonds containing NV-centers with them. We have introduced method of the nanodiamonds solution application on the substrates. The work has practical meaning in nanophotonics sphere and in development of optical devices with single-photon sources.

One of the main targets of nanophotonics is development and application of integral optical circuits for creation of the on-chip devices that can be used in transmission and processing both classical and quantum signals. For the quantum optical micro-circuits there is an unsolved problem of integration of all the components, including the source, logical elements and detectors. Application of nanodiamonds with NV-centres as single-photon sources is very perspective due to the advantages, such as a possibility to work with a room-temperature and a big time of conservation of the quantum state [1].

For integration of the nanodiamonds (solution with affiliated COOH group and NV centers contained) were used substrates of Si (525 μm) with thermally grown oxide (2 μm) and Si₃N₄ (200 nm) on top. Thicknesses of dielectric layers provide the most efficient outcome of the light through the diffraction couplers of NV-centers radiation.

On a Fig. 1 (a) there is a diagram of the waveguide structure developed. Apodised diffraction grating couplers with period 542 nm and fill-factor 0.4 were picked up for the effective input and output of the radiation on the wavelength 680 nm. The structure was divided on layers, corresponding to different doses for electron-beam lithography for the proximity effects correction using NanoMaker. The first stage of production was photolithography, evaporation of Ti/Au and lift-off in acetone, were formed golden signs which were used for the superimposition on the further stages with e-beam lithography.

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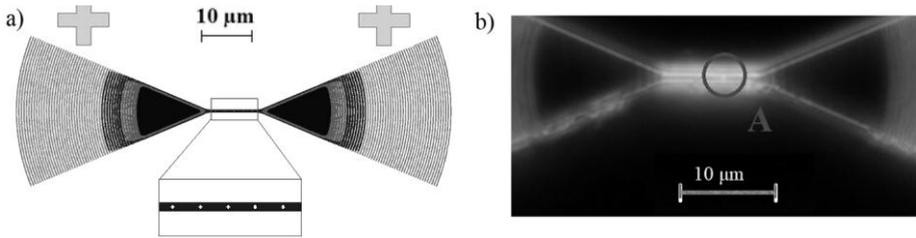


Fig. 1. Structures of Si_3N_4 for the integration of nanodiamonds. (a) Schematics of the nanophotonic device with two diffraction grating couplers, waveguide, golden markers and holes for nanodiamonds. (b) Microphotograph of nanophotonic structure in a dark field. Structure after application of nanodiamonds and erasing of the resist. Letter “A” is put near some nanodiamond-like spot.

The next stage produced the nanophotonic device with electron-beam lithography and plasma etching in CHF_3 atmosphere. Then the waveguides were provided with 5 holes each in a positive electronic resist PMMA 3%, 200 nm diameter with e-beam lithography.

Due to the studied articles [2-4] was developed a method of nanodiamonds integration with nanophotonic structure. For separation of the nanodiamonds the solution was put into UV bath for 3 hours. 25 μl of the solution were poured on the sample put on the hot-plate at temperature of 30-35 $^\circ\text{C}$. For better adhesion there IPA was used with the solution. After heating the hot-plate to 65-70 $^\circ\text{C}$ the solution evaporated. Lift-off in acetone erased electronic resist, leaving nanodiamonds in the holes. In optical microscope were observed some pieces that looked like nanodiamonds. Measurements in AFM (NT-MDT) showed some bunches of matter, left after lift-off on the holes' places. It's not clear if the bunches are single nanodiamonds or small groups of them and are there any NV-centers. Further should be measured the correlation function of 2nd order $g^2(\tau)$ on confocal laser scanning microscope, that will give us the clear information about the bunches.

Our research introduces a simple way of realization of the nanodiamonds integration with optical structures on Si_3N_4 .

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