Deterministic fabrication of dielectric loaded waveguides coupled to single nitrogen vacancy centers in nanodiamonds

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Deterministic Coupling of a Single Nitrogen Vacancy Center to a Dielectric Loaded Plasmonic Waveguide

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Abstract: We report on the fabrication of dielectric-loaded-waveguides which are excited by single-nitrogen-vacancy (NV) centers in nanodiamonds. The waveguides are deterministically written onto the pre-characterized nanodiamonds by using electron beam lithography of hydrogen silsesquioxane (HSQ) resist on silver-coated silicon substrate. Change in lifetime for NV-centers is observed after fabrication of waveguides and an antibunching in correlation measurement confirms that nanodiamonds contain single NV-centers.

Confined plasmon polariton modes can be utilized to enhance and channel the emission from individual quantum emitters [1, 2]. Various waveguide configurations, including plasmonic gap waveguides, metal nanowire, and V-grooves have been considered for coupling to quantum emitters, but the propagation length is limited due to the ohmic losses [3]. Dielectric loaded waveguides have been proposed as a waveguide which support confined modes at relatively lower loss. Here, we employed the method of top-down fabrication [4], and coupled a preselected single nitrogen-vacancy (NV) in a nanodiamond to a dielectric loaded waveguide (Fig. 1).

First, a silicon sample is coated with a silver film, on which gold markers are made, and subsequently, nanodiamonds are spin coated. The sample is then characterized by scanning in a fluorescence confocal microscope. In Fig. 1a, markers (+) and a nanodiamond can be observed from the fluorescence image obtained from confocal microscopy. Lifetime, spectrum and autocorrelation measurements were taken for the nanodiamonds. Waveguides were fabricated using electron beam lithography onto the nanodiamonds which were found to be single photon emitters. Postfabrication galvanometer scanned images show the coupling of the emitter to the dielectric loaded waveguide, and subsequent emission from the grating at the two ends (inset in Fig. 1a). A reduction in lifetime (from ~14.3 ns to ~7.5 ns) is observed for the coupled NV center (Fig. 1b). The antibunching dip for the NV-center in the second-order correlation function measurements can be observed both before and after fabrication of the waveguide.

In conclusion, we have presented a dielectric loaded plasmonic waveguide coupled to a single NV center. Dielectric loaded waveguides can be used for making different components such as beam splitters, cavities, and thus can provide a platform for on chip processing of quantum information.

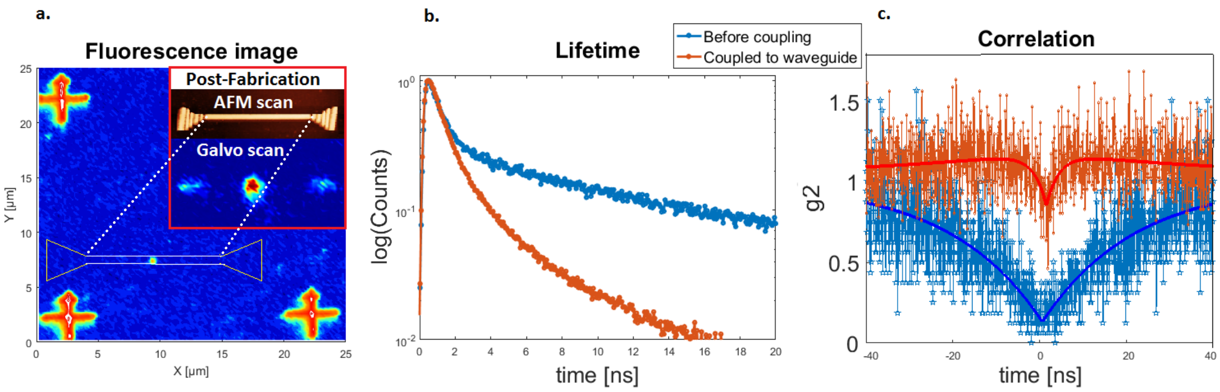

Fig. 1 (a) Fluorescence scan map of nanodiamonds spin coated on a sample with markers of gold fabricated on silver surface. Struture indicates the nanodiamond and the position on the sample where waveguide is fabricated. In the inset an atomic force microscope (AFM) image of the fabricated waveguide and a galvanometric mirror scan image, where the nanodiamond is excited and a fluorescence image of the focal plane is taken, is presented. Emission from the gratings at the ends of the waveguide, when nanodiamond is excited, confirms the coupling of NV-center to the waveguide mode. (b) lifetime and (c) autocorrelation of the NV-center before and after waveguide fabrication.

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