Redolfi et al. *EPJ Quantum Technology* (2025) 12:25
https://doi.org/10.1140/epjqt/s40507-025-00329-2

EPJ.org

EPJ Quantum Technology
a SpringerOpen Journal

RESEARCH Open Access

Integration of germanium-vacancy single photon emitters arrays in diamond nanopillars

Elisa Redolfi[1,2*], Vanna Pugliese[1], Elia Scattolo[3], Alessandro Cian[3], Elena Missale[3], Felipe Favaro de Oliveira[4], Gediminas Seniutinas[4], Sviatoslav Ditalia Tchernij[1,2], Rossana Dell'Anna[3], Paolo Traina[2], Paolo Olivero[1,2], Damiano Giubertoni[3] and Jacopo Forneris[1,2]

*Correspondence: elisa.redolfi@unito.it
[1]University of Torino and Istituto Nazionale di Fisica Nucleare, sezione di Torino, 10125 Torino, Italy
[2]Istituto Nazionale di Ricerca Metrologica (INRiM), 10135 Torino, Italy
Full list of author information is available at the end of the article

Abstract

The nanoscale fabrication of μm-spaced single-photon emitter arrays is crucial for the development of integrated photonic chips. We report on the fabrication and systematic characterization of germanium-vacancy (GeV) color centers arrays in diamond obtained upon ion implantation at the nanoscale. Ge^{2+} ion implantations at 35 keV and 70 keV energies were carried out using a focused ion beam (FIB) equipped with a liquid metal alloy ion source. The arrays of emitters are subsequently aligned to ⌀300 nm nanopillar waveguiding structures, fabricated using a combination of electron-beam lithography and plasma etching. The photon collection efficiency and photoluminescence (PL) signal-to-background ratio increased by a factor 8 with respect to the unstructured sample. The photophysical properties of the GeV emitters fabricated by this approach were unaltered with respect to those found in unprocessed diamond. The efficiency of the overall manufacturing process to fabricate individual GeV centers was assessed. Up to 33% of the fabricated nanopillars, depending on ion implantation parameters, were found to contain single emitters.

Keywords: Single-photon sources; Diamond; Ion irradiation; Ion implantation; Formation yield; Nanowire; Collection efficiency; Photoluminescence; Nanopatterning

1 Introduction

The use of color centers in diamond emerged as a promising avenue for a variety of advanced applications in quantum technologies, ranging from high-precision sensing and quantum computing to secure communications [1, 2]. Among these, nitrogen-vacancy (NV) centers have attracted significant attention due to their specific opto-physical and spin properties, which allow for reliable operation under both ambient and cryogenic conditions [3]. However, in applications where spectral stability plays a key role such as quantum network nodes [2], NV centers have encountered challenges stemming from spectral instabilities determined by their strong sensitivity to local crystal environment [4]. In this context, alternative emitters based on group-IV color centers in diamond, such as silicon-vacancy (SiV) and germanium-vacancy (GeV) centers, demonstrated superior