Optical Materials 156 (2024) 115967

Contents lists available at ScienceDirect

Optical Materials

journal homepage: www.elsevier.com/locate/optmat

Research article

Tracking the creation of single photon emitters in AlN by implantation and annealing

H.B. Yağcı [a,b], E. Nieto Hernández [c,d], J.K. Cannon [a,b], S.G. Bishop [a,b], E. Corte [c,d], J.P. Hadden [a,b], P. Olivero [c,d], J. Forneris [c,d], A.J. Bennett [a,b,*]

[a] School of Engineering, Cardiff University, Queen's Buildings, 14-17 The Parade, Cardiff, CF24 3AA, United Kingdom
[b] Translational Research Hub, Cardiff University, Maindy Rd, Cardiff, CF24 4HQ, United Kingdom
[c] Dipartimento di Fisica e Centro Inter-Dipartimentale "NIS", Universita di Torino, via Pietro Giuria 1, Torino, 10125, Italy
[d] Istituto Nazionale di Fisica Nucleare (INFN), Sezione di Torino, via Pietro Giuria 1, Torino, 10125, Italy

ARTICLE INFO

Dataset link: http://doi.org/10.17035/d.2024.0324890985

Keywords:
Single-photon emitter
Aluminium nitride
Ion implantation
Colour centre

ABSTRACT

In this study, we inspect and analyse the effect of Al implantation into AlN by conducting confocal microscopy on the ion implanted regions, before and after implantation, followed by an annealing step. The independent effect of annealing is studied in an unimplanted control region, which showed that annealing alone does not produce new emitters. Through tracking individual locations in a lithographically patterned sample, we observe that point-like emitters are created in the implanted regions after annealing. The newly created quantum emitters show anti-bunching under ambient conditions and are spectrally similar to the previously discovered emitters in as-grown AlN.

1. Introduction

Quantum technologies including quantum sensing, communications and computing have emerged as a potentially paradigm-changing sector, attracting strong scientific interest and substantial investments [1]. The major reason for this interest is the quantum advantage over classical information processing paradigms for specific and demanding computational problems. The advantage relies heavily on finding platforms hosting qubits that can be reliably prepared, manipulated and measured [2]. One such platform is colour centres in wide-bandgap semiconductors. An extensively investigated system is the negatively charged nitrogen-vacancy centre in diamond (NV^-) [3], which hosts an electron spin which can be manipulated using microwave fields and read out optically [4], even at room temperature.

Other colour centres in semiconductors are being investigated for narrow transitions, high brightness, longer coherence lifetimes or ease of photonics integration; notable examples are SiV [5] and SnV [6] in diamond, divacancy centre [7] and V_{Si} [8] in silicon carbide (SiC), T- [9] and G- [10] centre in silicon and carbon-related defects [11] in hexagonal boron nitride (hBN). Recently, quantum emitters have also been detected in III-nitrides, such as AlN [12] and GaN [13]. Owing to the unique qualities of III-nitrides such as tunable bandgap and piezoelectricity, these emitters are promising candidates for electronically- or mechanically-modulated single photon sources in ambient conditions.

AlN is hypothesised to host defect complexes that can be useful as potential qubits due to its large bandgap (6.02 eV). Varley et al. previously conducted an ab initio study on the vacancy complexes with group IVA and IVB elements, and reported that Ti-, Zr-vacancy centres can be hosted within the bandgap, with the ground state sufficiently apart from the valence band of AlN [14]. Previously conducted experiments in Ti-implanted AlN found an electron spin resonance signal in implanted samples but could not confirm optical activity [15]. Aghdaei et al. reported formation of broad peaks in Zr-implanted AlN [16], but in a comprehensive study Senichev et al. found that emission in Zr-implanted AlN is statistically not different than Kr-implanted AlN with similar ion damage [17]. In line with our previous observations in Al-implanted AlN [18], these results point to a native origin for the created single-photon emitters (SPE). While these studies demonstrated SPE creation by statistically comparing different samples, the creation event of a single distinct emitter was not microscopically assessed.

In this study, we rigorously inspect and analyse the effect of Al implantation into AlN by conducting confocal microscopy on the ion implanted regions, before and after implantation, followed by an annealing step. The independent effect of annealing is studied in an unimplanted control region, which showed that annealing alone does not produce new emitters. Through tracking individual locations in a lithographically patterned sample, we observe that point-like emitters

* Corresponding author.
E-mail addresses: yagcihb@cardiff.ac.uk (H.B. Yağcı), benneta19@cardiff.ac.uk (A.J. Bennett).

https://doi.org/10.1016/j.optmat.2024.115967
Received 23 June 2024; Received in revised form 28 July 2024; Accepted 11 August 2024
Available online 13 August 2024