Mass-positioning of nanodiamonds using squeegee technique

PURDUE UNIVERSITY

R. Cui, M. Y. Shalaginov, S. Bogdanov, D. Wang, K. Chaudhuri, X. Meng, and V. M. Shalaev
School of Electrical and Computer Engineering and Birck Nanotechnology Center, Purdue University, West Lafayette, IN 47907, USA

Abstract

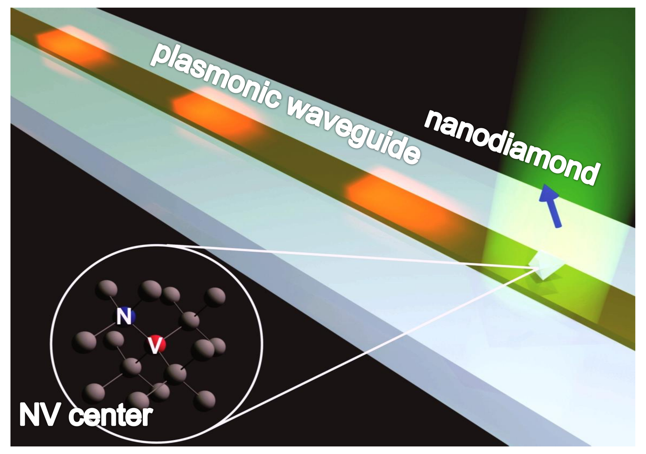
Problem:
To position nanodiamonds on-chip precisely and efficiently in order to increase interaction with nanoscale photonic structures.

Scope of work:
We fabricated nanostructures using both EBL and FIB and used the squeegee technique to position large scale arrays of NDs. We performed quantitative analysis to optimize the filling ratio i.e. the probability that every hole has a ND.

Results:
Using the squeegee technique, we achieved a 100% filling ratio in holes with diameters of 125nm. This technique has the advantage of being fast, simple, and inexpensive.

Introduction

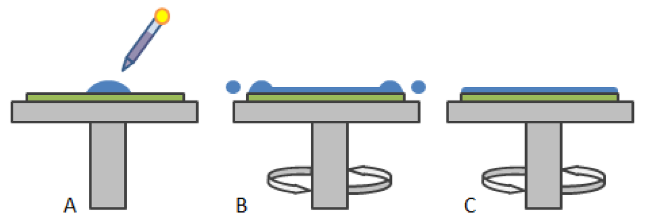
Relevance:
Positioning nanodiamonds near nanophotonic structures is of vital importance for building integrated quantum systems [1].



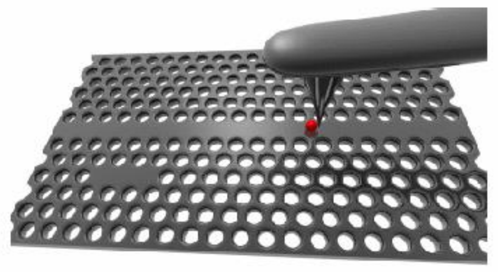
single-photon source
- photostable
- operates at room temperature
- broadband emission spectrum (600-800 nm)

spin-based qubit
- long spin coherence time
- can be read out optically

Conventional Solutions:

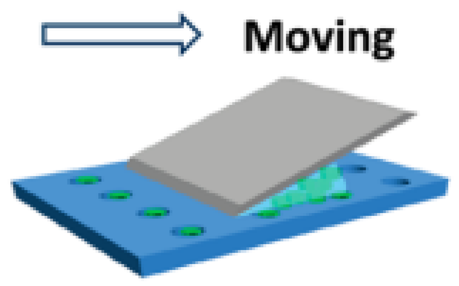


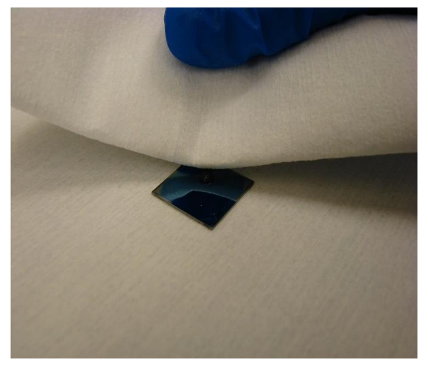
Spincoating
- fast
- non-deterministic



Scanning probe technique [2]
- precise positioning
- time-consuming
- costly

New Solution:



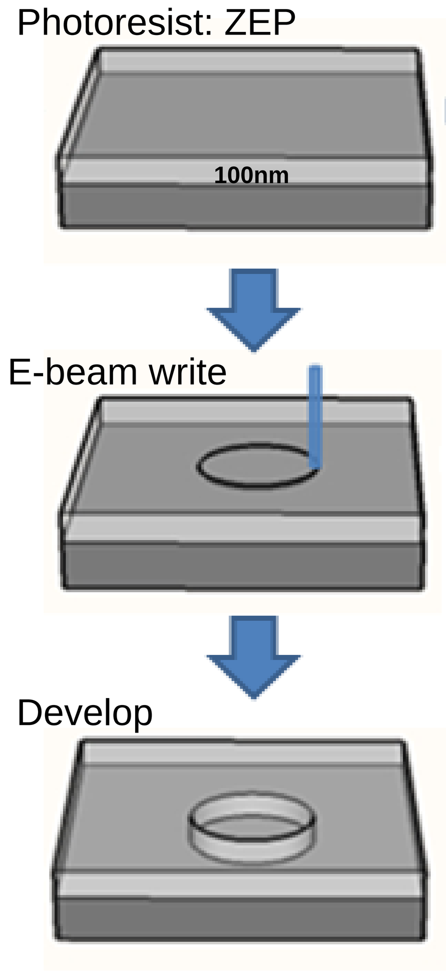


Squeegee technique [3]
- precisely located
- mass-positioned

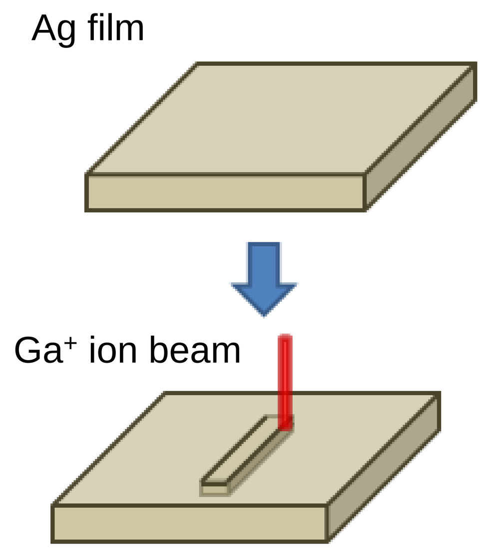
Process of nanodiamonds positioning

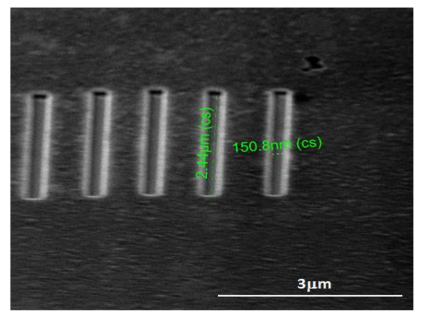
Nanostructure array fabrication:

Electron beam lithography



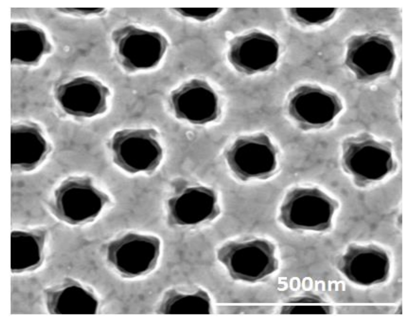
Focused ion beam lithography



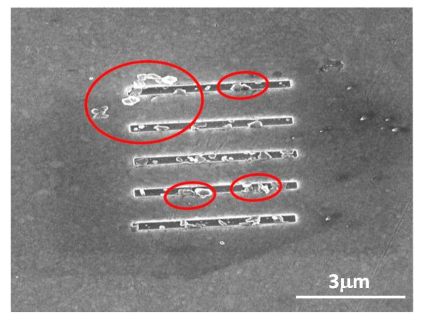


Slot waveguides

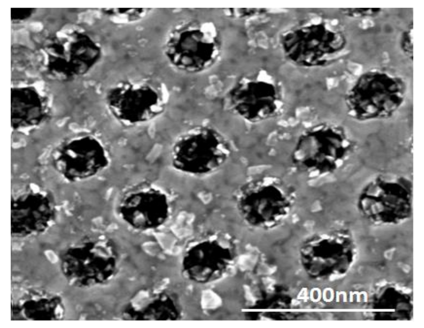
Nanodiamonds deposition:



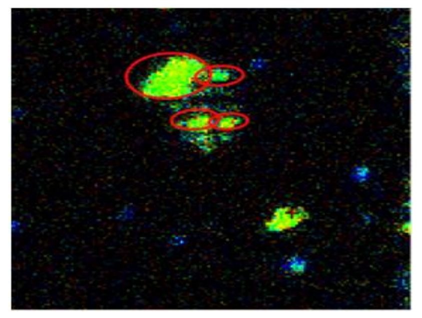
Nanohole array after fabrication



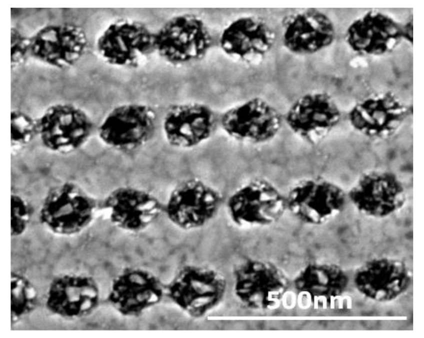
SEM scan



Nanoholes after squeegee procedure
- 40 μl droplet of nanodiamond suspension
- sweep with a cleanroom wipe

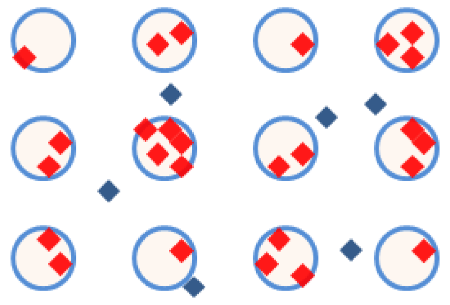


Confocal microscopy



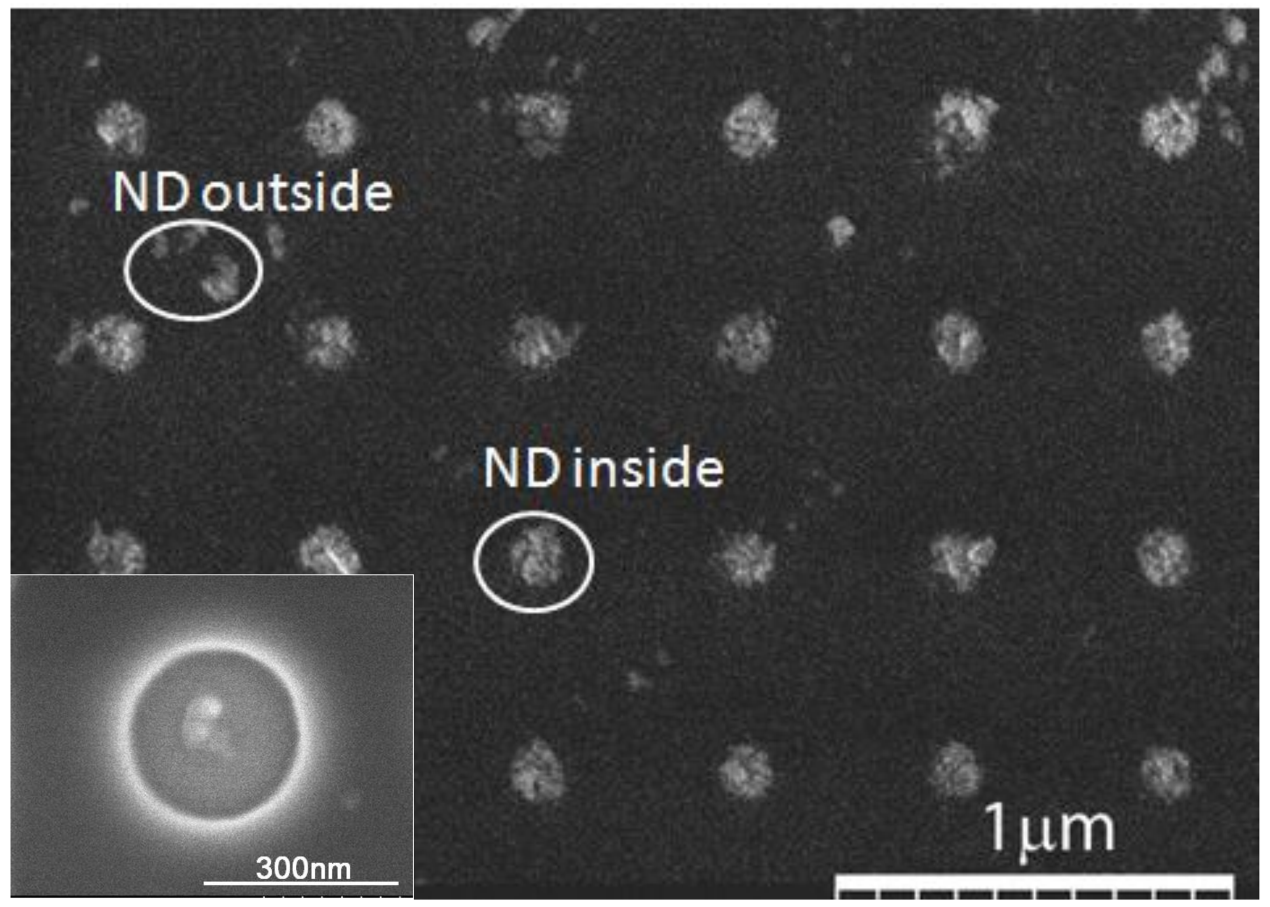
Nanohole after cleaning
- 40μl droplet of water

Analysis:



- Figure of merit = $\frac{\text{\# of ND inside}}{\text{\# of ND outside}}$
- Filling ratio = $\frac{\text{\# of nanoholes filled}}{\text{\# of nanoholes}}$

Results



nanodiamond inside nanohole

Best result: 125 nm nanoholes with nanodiamonds

Conclusions

- Using Matlab and Ledit, we automated the EBL and FIB fabrication procedures which allowed us to create nanohole patterns and slot waveguides quickly and accurately
- best result: 100% filling ratio (optimal nanohole diameter:**125** nm)
- technique provides fast and cheap (filling thousands of holes in few hours)

Future plan
- use the developed positioning technique to fabricate nanophotonic structures with nanodiamonds

References

[1] I. Aharonovich et al., “Diamond Photonics”, Nat. Photon. **5**(7), 397-405 (2011)
[2] J. Wolters et al., “Enhancement of the zero phonon line emission from a single nitrogen vacancy center in a nanodiamond via coupling to a photonic crystal cavity”, Appl. Phys. Lett. **97** (14), 141108 (2010)
[3] M. Saboktakin et al., “Plasmonic Enhancement of Nanophosphor Upconversion Luminescence in Au Nanohole Arrays”, ACS Nano **7**(8), 7186-7192 (2013).

Acknowledgements

This work was supported by AFOSR-MURI grant (FA9550-10-1-0264), NSF-MRSEC grant (DMR-1120923)