SOLUTION BASED SYNTHESIS OF NANOCRYSTALLINE DIAMOND THIN FILMS

REU: Anne Rebecca

Mentor: Dr. Adarsh D. Radadia

Rowan University

Institute for Micromanufacturing, Biomedical Engineering Center, Louisiana Tech University

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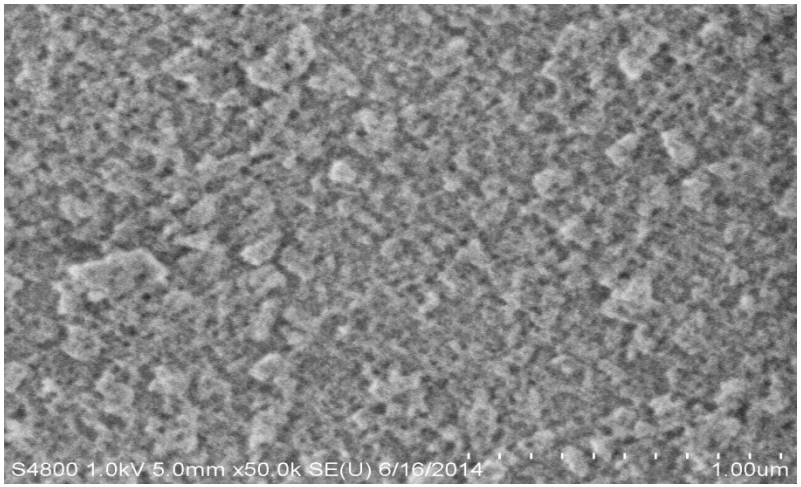
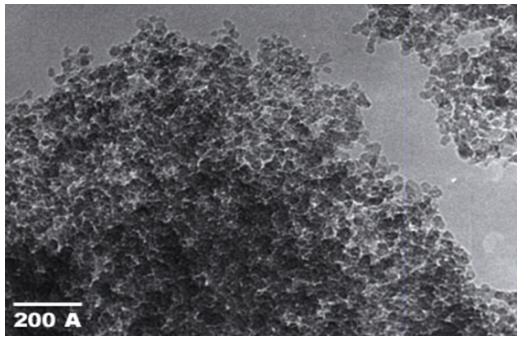
RESEARCH EXPERIENCES FOR UNDERGRADUATES

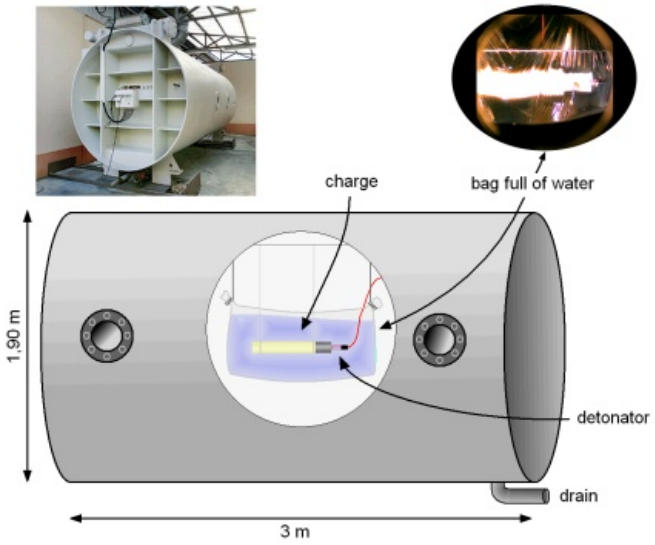
Agenda

- Introduction
  - Materials
    - Methods
      - Results
        - Analysis
          - Conclusion
            - Acknowledgements

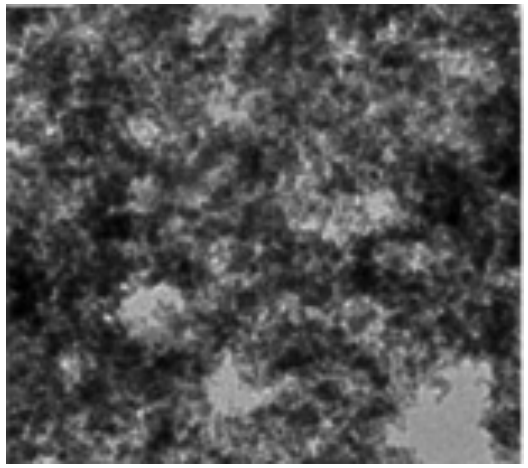




Introduction: Detonation Nanodiamonds (DNDs)



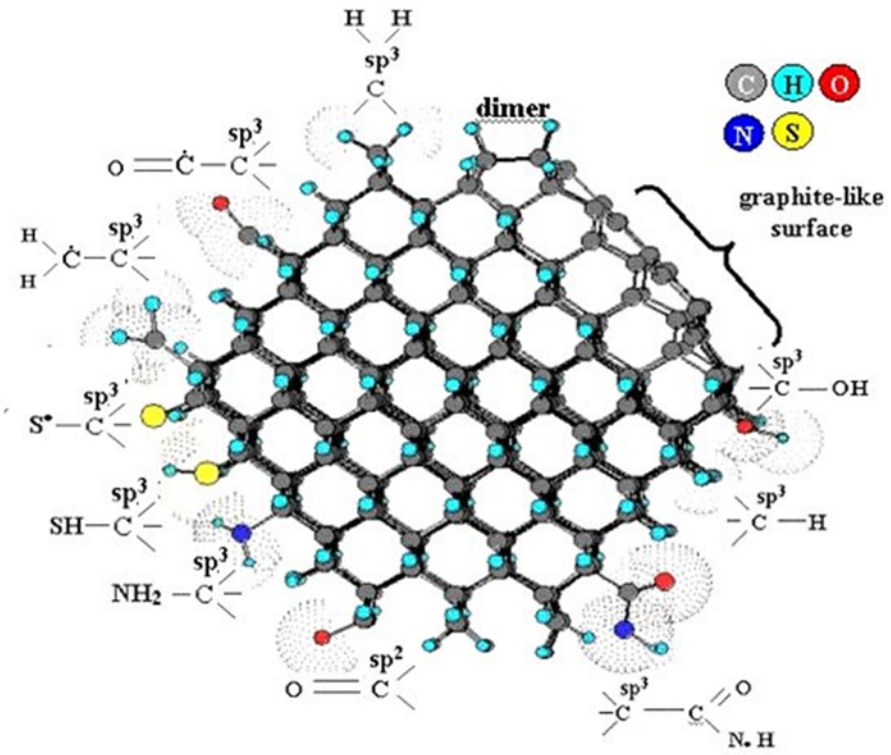
Synthesis process.



TEM image

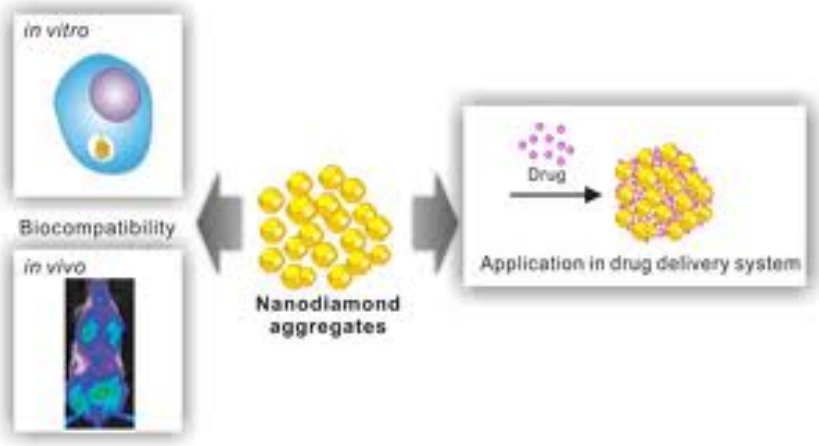
- First discovered by Russian scientists trying to discard ammunitions.
- Unit sizes are 4-10 nm.
- Usually exist as aggregates of 30-500 nm
- Produced by detonation process.
- TNT and RDX

Detonation Nanodiamonds (DNDs)



- Highly tailorable surface chemistry
- Functional groups on the surface (hydroxyl, carboxyl, amine, amide, …)
- Important for purification and application purposes.

Detonation Nanodiamonds (DNDs)

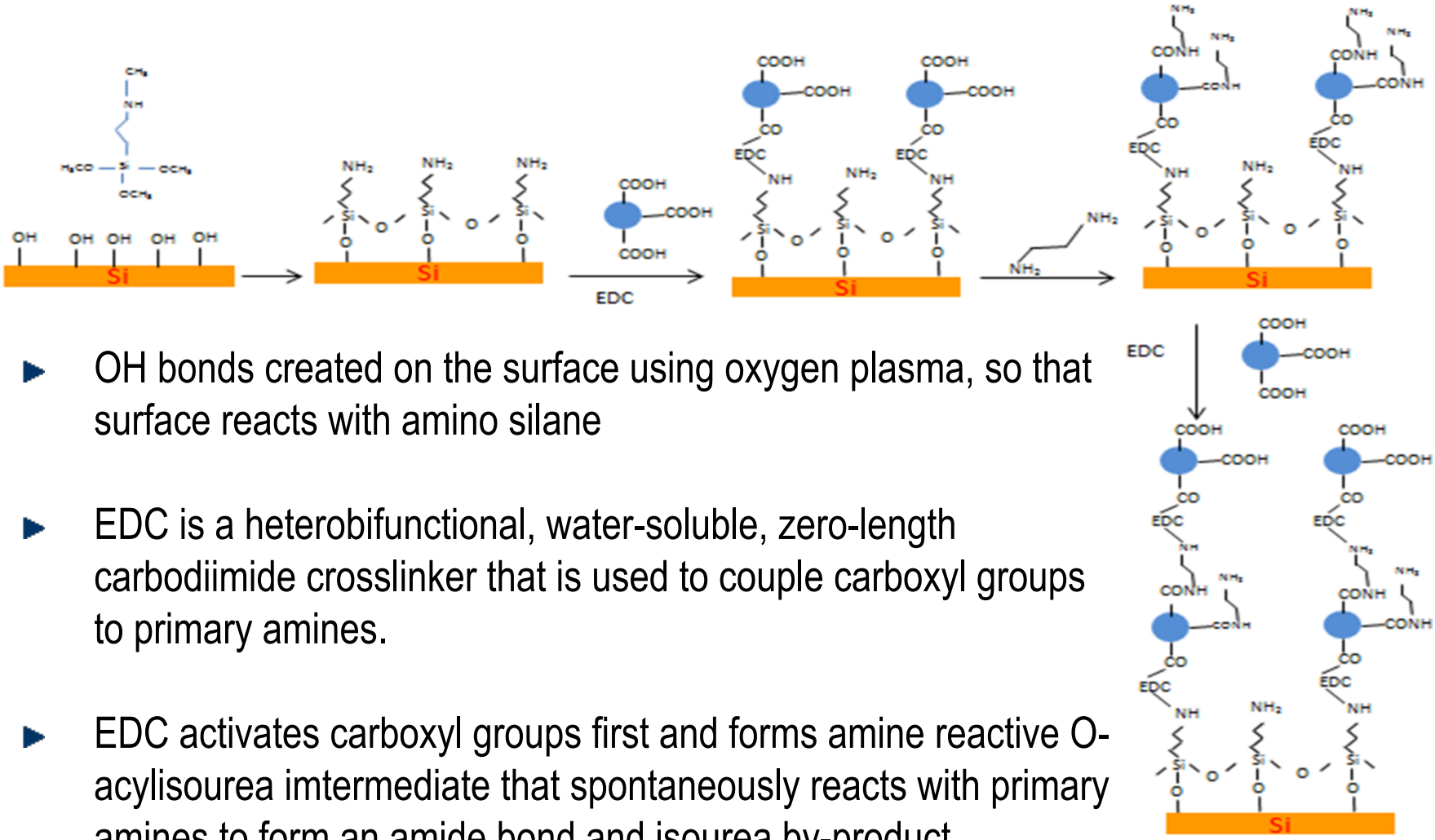


- Low cytotoxicity
- Applications in biomedicine (Surgical implants, drug delivery), Microelectromechanical systems (MEMS), optical, tribology (low roughness), thermal management (highly conductive.

Materials

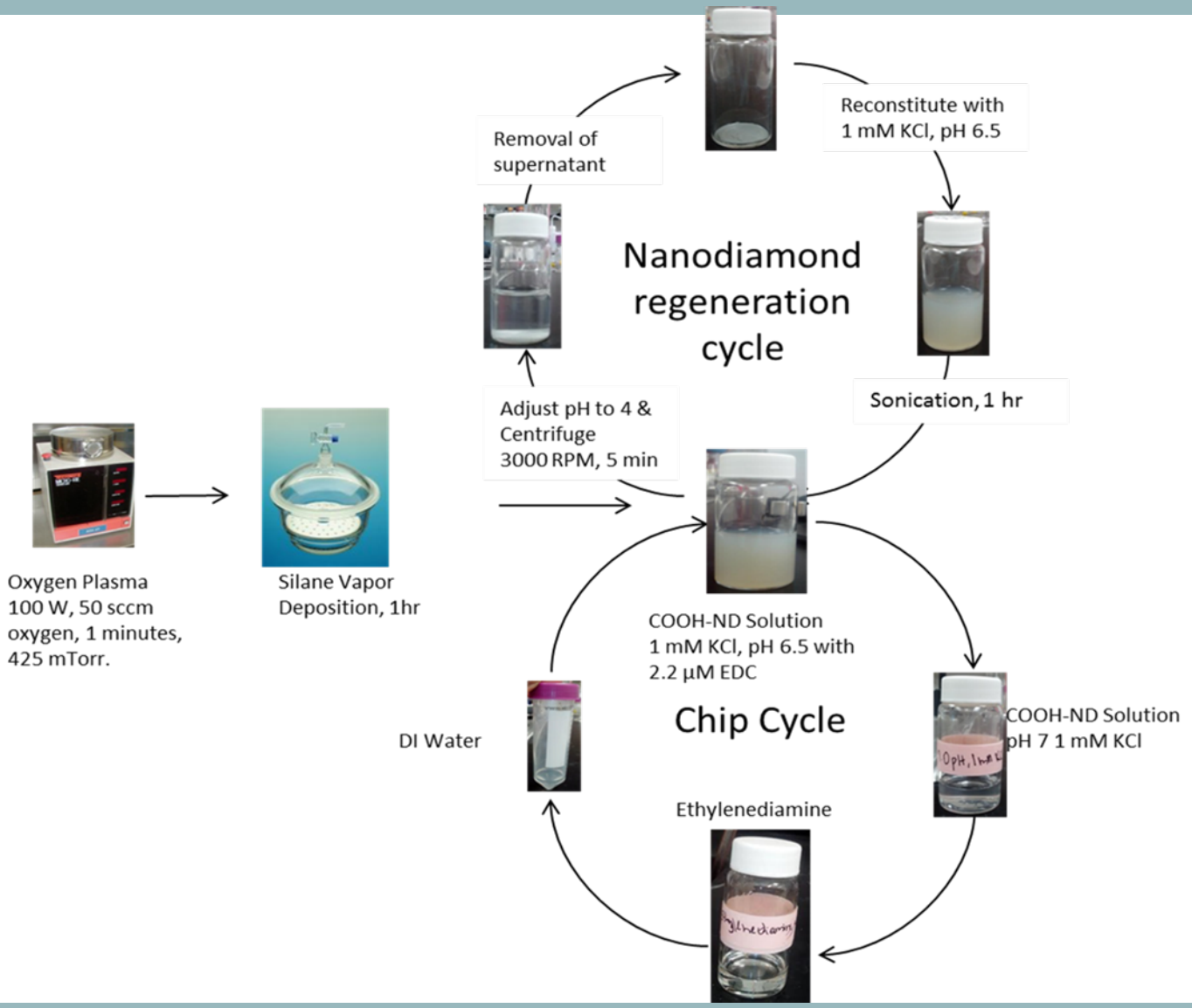
- 50 nm average diameter carboxylated DND aggregates
- 3 aminopropyltriethoxy-silane (Amino Silane)
- Deionized (DI) water
- 1 mM pH 6.5 KCl
- 1 mM pH 7 KCl
- 1 mM pH 4 HCl
- 1 cm × 1 cm silicon chips
- 1 cm × 1 cm glass chips
- 1-Ethyl-3-(3-dimethylaminopropyl)carbodiimide (EDC)

Methods



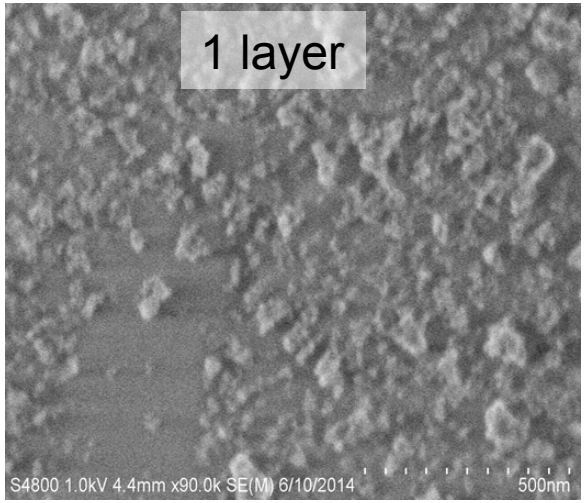
- OH bonds created on the surface using oxygen plasma, so that surface reacts with amino silane
- EDC is a heterobifunctional, water-soluble, zero-length carbodiimide crosslinker that is used to couple carboxyl groups to primary amines.
- EDC activates carboxyl groups first and forms amine reactive O-acylisourea imtermediate that spontaneously reacts with primary amines to form an amide bond and isourea by-product.

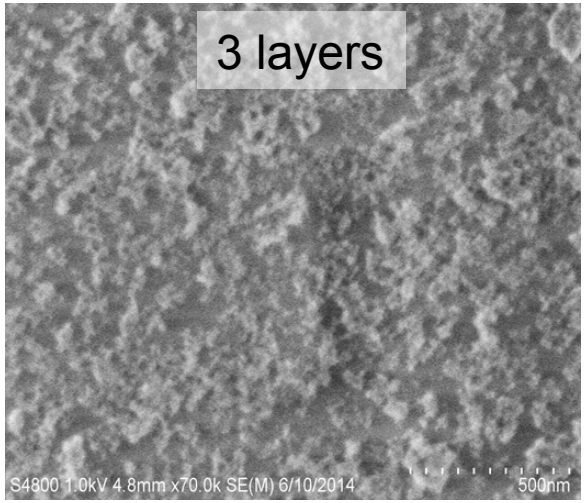
Methods

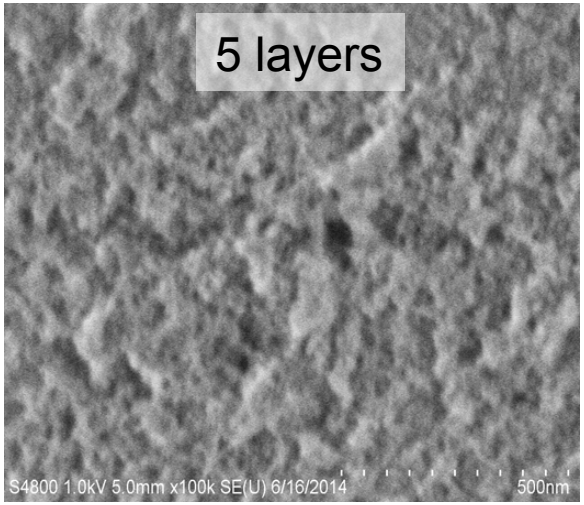

Reconstitute with
1 mM KCl, pH 6.5
Removal of
supernatant
Nanodiamond
regeneration
cycle
Sonication, 1 hr
Adjust pH to 4 &
Centrifuge
3000 RPM, 5 min
Oxygen Plasma
100 W, 50 sccm
oxygen, 1 minutes,
425 mTorr.
Silane Vapor
Deposition, 1hr
COOH-ND Solution
1 mM KCl, pH 6.5 with
2.2 µM EDC
Chip Cycle
DI Water
COOH-ND Solution
pH 7 1 mM KCl
Ethylenediamine

Results

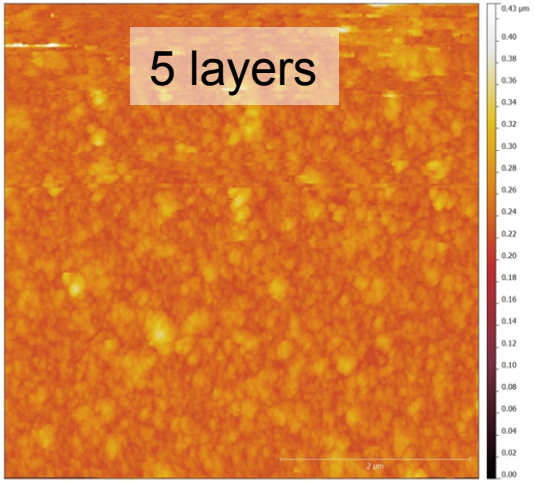
Scanning Electron Microscopy

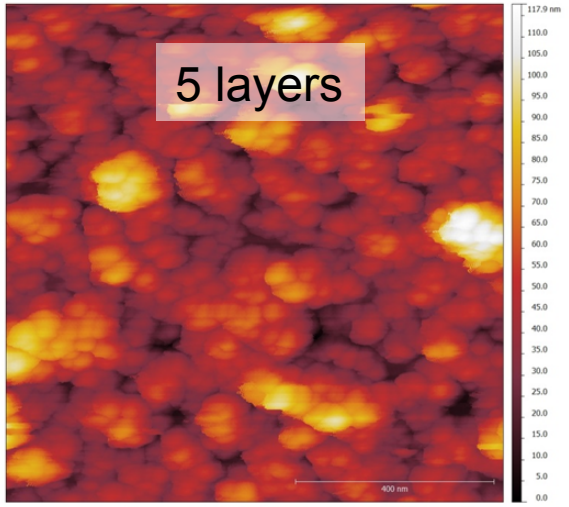




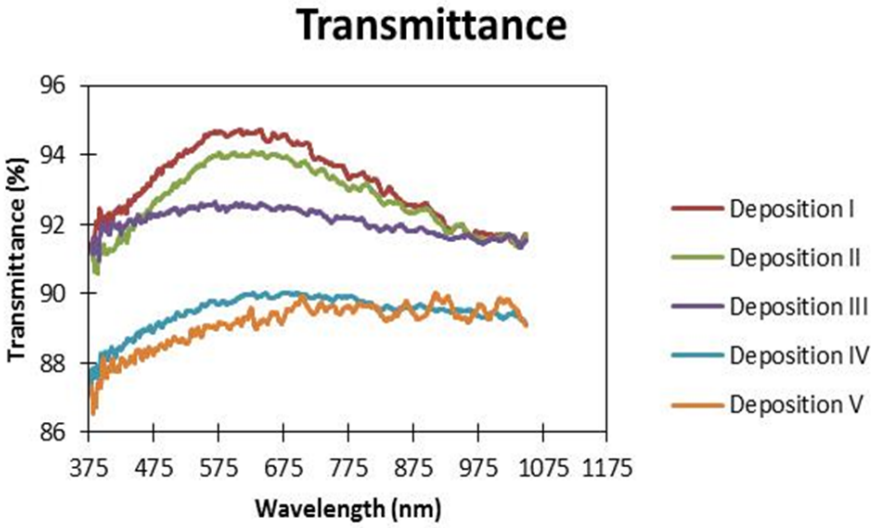


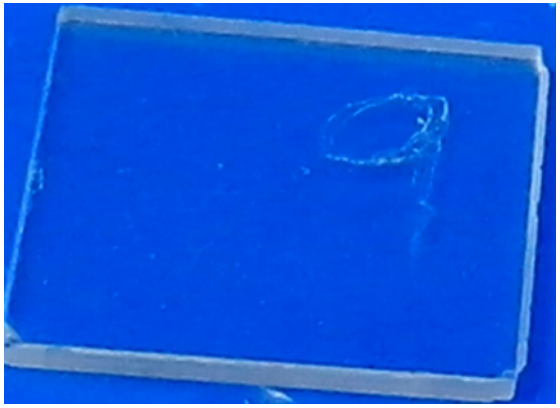
Atomic Force Microscopy

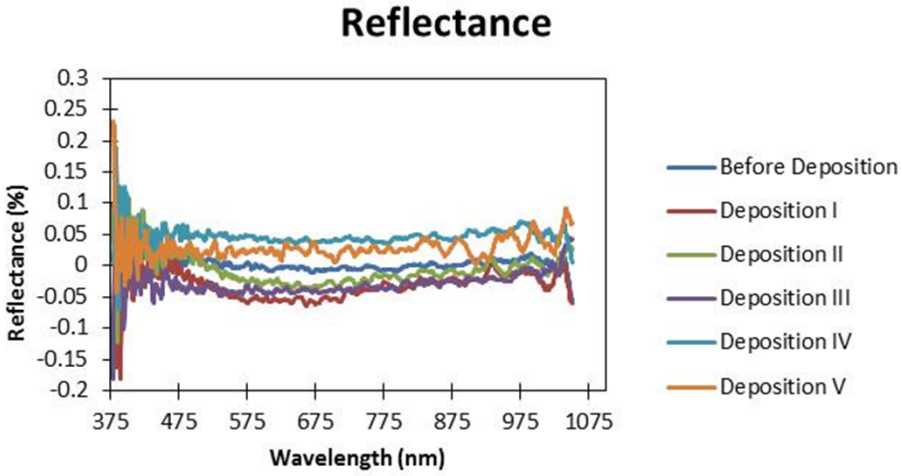




Results


Transmittance
Transmittance (%)
96
94
92
90
88
86
375
475
575
675
775
875
975
1075
1175
Wavelength (nm)
Deposition I
Deposition II
Deposition III
Deposition IV
Deposition V




Reflectance
Reflectance (%)
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
375
475
575
675
775
875
975
1075
Wavelength (nm)
Before Deposition
Deposition I
Deposition II
Deposition III
Deposition IV
Deposition V

Conclusion

- Successful attachment of nanodiamonds to substrates (both glass and silicon).
- Increasing surface coverage as layers are building up.
- Average surface roughness about 50 nm for 5 layers.
- 4% decrease in optical transmittance.
- Electrical characterization performed with inconsistent conductivity of the films.
- Examination of chemical structure as future work.

Acknowledgement

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