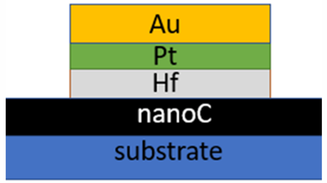
Hafnium Contacts for n-type Conducting Nanocrystalline Diamond

Carson Gockley
Mentor: Terry Alford, Associate Director and Professor
School of Electrical, Computer, and Energy Engineering

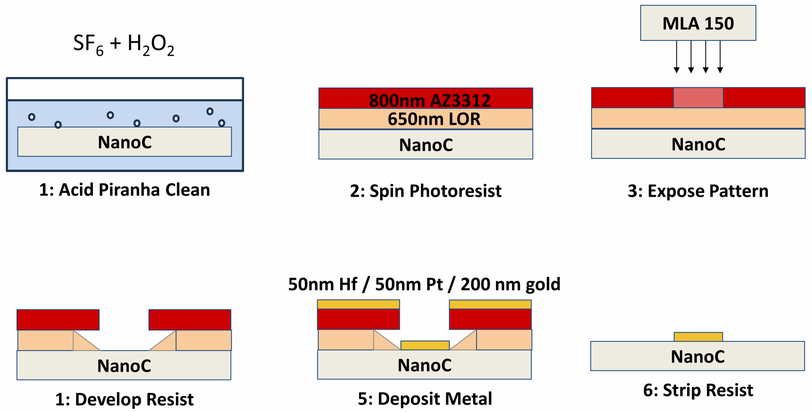
Research question



Previous work at ASU has shown Ti/Pt/Au to be an effective metallization for creating ohmic contacts on nanocarbon (nanoC)[1]. However, Hafnium has a lower work function than Titanium by 0.43eV and both metals have similar enthalpies of formation for forming carbides. This implies the ability to form strongly adhering carbides at the interface while lowing barrier height and contact resistivity compared to Ti.

[1]E. Amonoo, V. Jha, T. Thornton, F. A. Koeck, R. J. Nemanich, and T. Alford, "Ohmic contacts to nitrogen-doped nanocarbon layers on diamond (100) surfaces," *Diamond and Related Materials*, vol. 135, p. 109832, May 2023, doi: 10.1016/j.diamond.2023.109832.

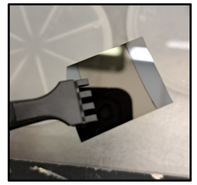
Metal Patterning Overview

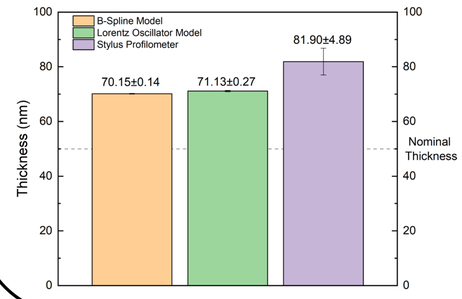


Process flow for depositing contacts by bi-layer lift-off process. An additional step performing a thermal anneal at 800C° in N_2 for 30 minutes is not shown.

Hf Evaporation Process Development

Left: Crucible with Hf pellets before slug melt.
Right: Hf witness sample deposited on bare Si



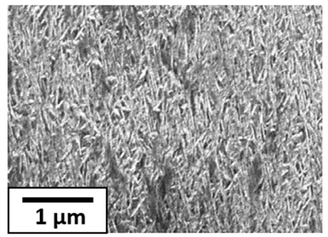


Thickness of Hf test sample measured by various methods. Used to calculate tooling factor for quartz crystal monitor in E-beam evaporator

Nanocarbon Characterization

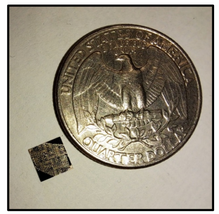
Parameter	Sample 22-048
Bulk electron concentration (cm^{-3})	1.69×10^20
Sheet electron concentration (cm^{-2})	5.08×10^15
Sheet resistance ($\Omega\square^{-1}$)	478
Resistivity (Ωcm)	1.43×10-2
Mobility ($cm^2V^{-1}s^{-1}$)	2.57

Hall parameters for NanoC sample extracted by Van der Pauw method

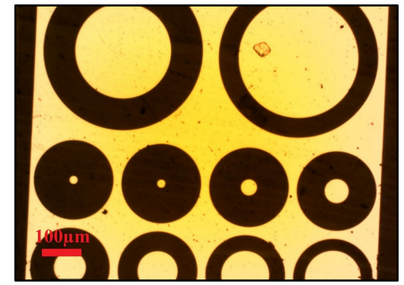


SEM image of NanoC surface.

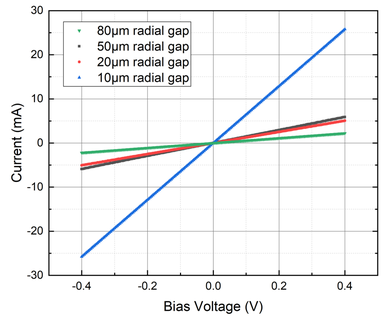
Contact Evaluation

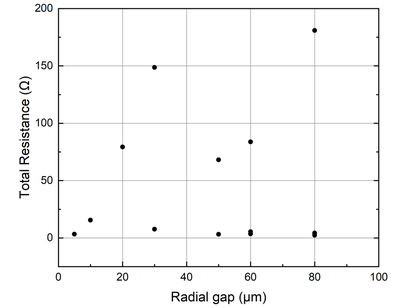


5mm x 5mm patterned NanoC sample



Optical microscope image of circular transfer length method (cTLM) structures.





Plots showing measured current-voltage curves and extracted resistances for different contact geometries.

Conclusions & Future Work:

- Contacts show ohmic behavior but are inconsistent. Contact resistivity cannot be extracted by fitting to cTLM equation.
- Future work is needed to study how thermal processing can control the interface and improve reliability of contacts

Acknowledgements:
Evangeline Amonoo for initiating the project, Eugene Hsu and Mihilat Fantu Manahile for providing the photolithography process used in the project, Professor Trevor Thornton for allowing me to use his probe station, Professor Robert Nemanich and his students for growing and providing the nanocarbon sample, and the staff of ASU Nanofab for training me on the equipment used to conduct the project..

FURI

Ira A. Fulton Schools of Engineering
Arizona State University