Diamond Strip Detectors for Charged Particle Tracking

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Applied Diamond, Inc

DOE NP SBIR/STTR Exchange Meeting
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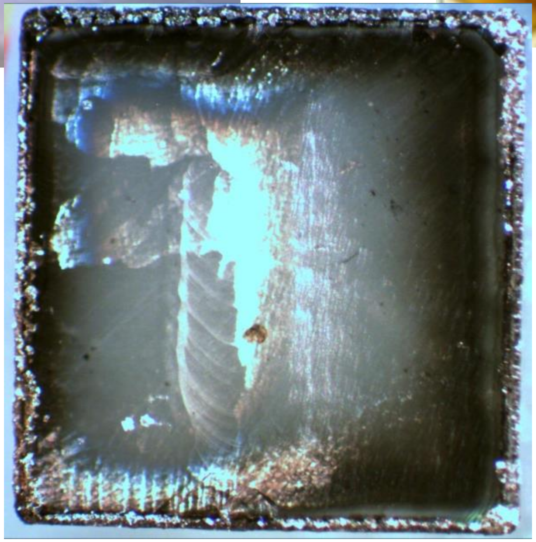
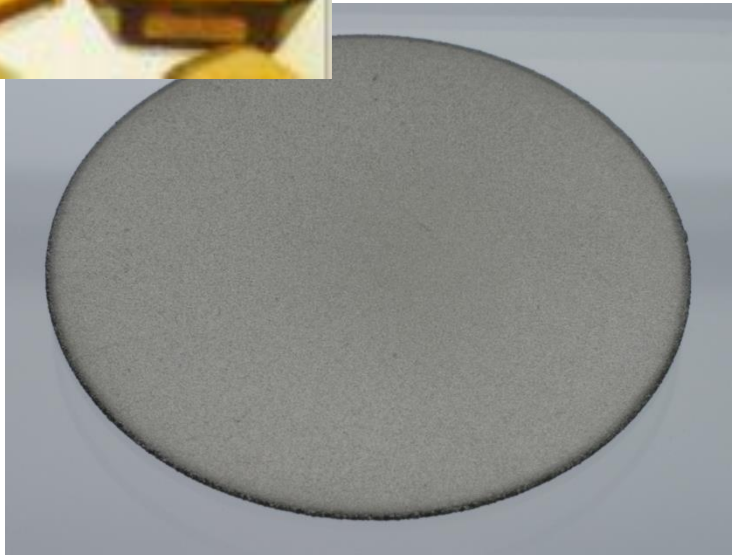
Outline

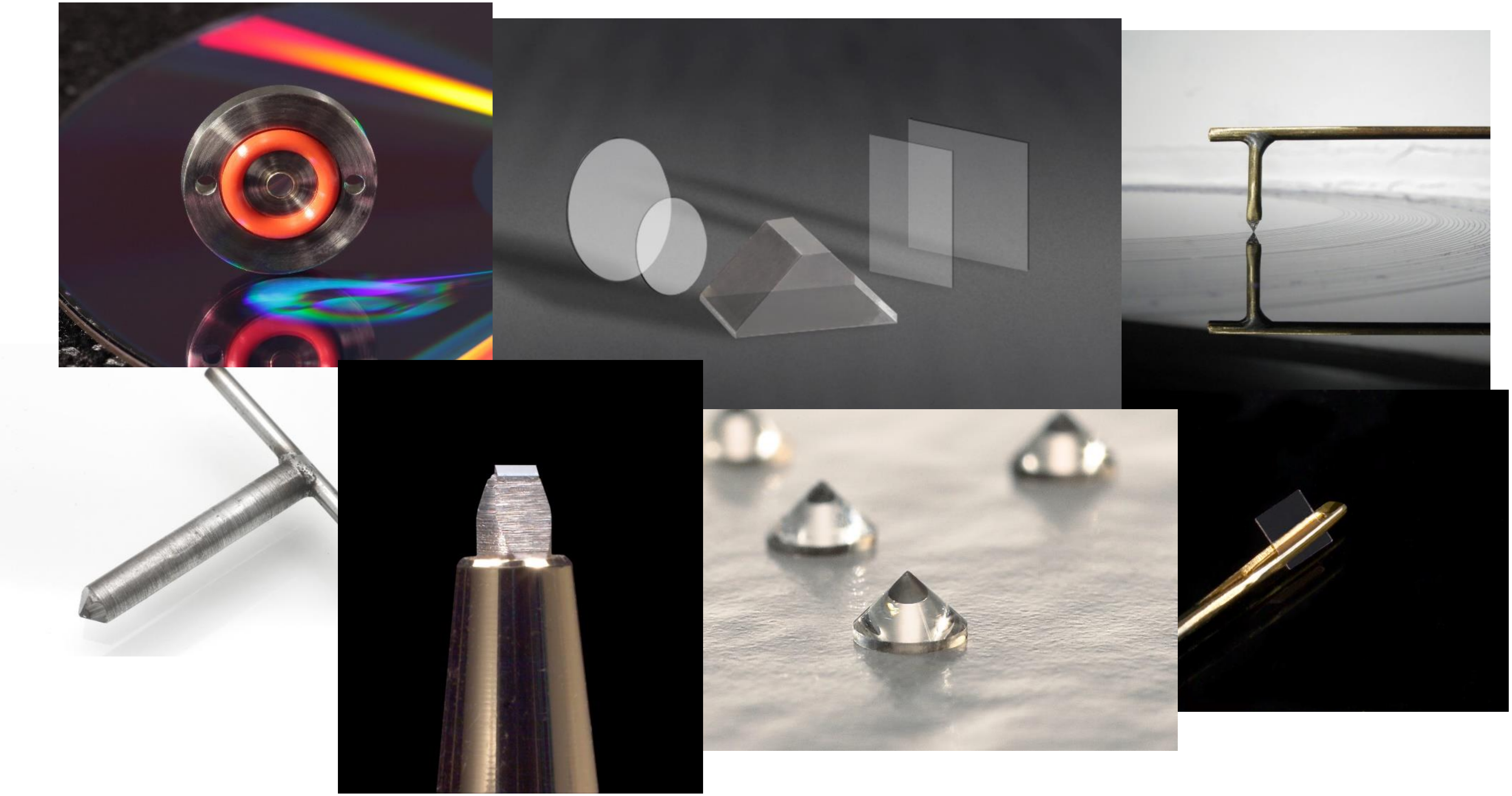
- A Bit about Applied Diamond
- Topic and Challenges
- Progress to-date
  - Diamond Growth
  - Material Uniformity
  - Material Removal
  - Packaging
- Commercialization

Diamond – Types and Sources





Diamond – Finished Products (single crystal)



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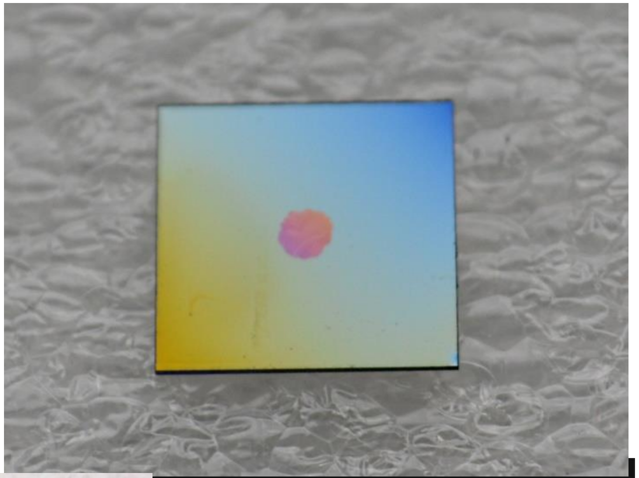
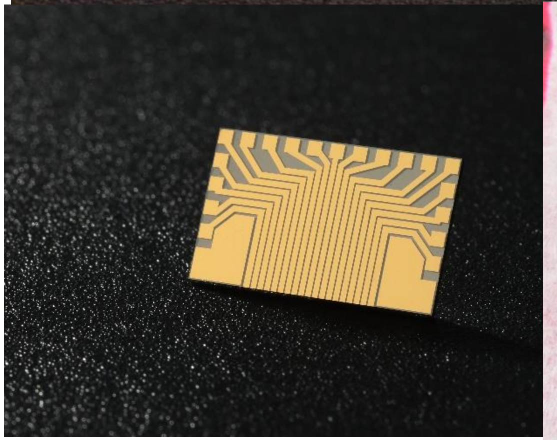
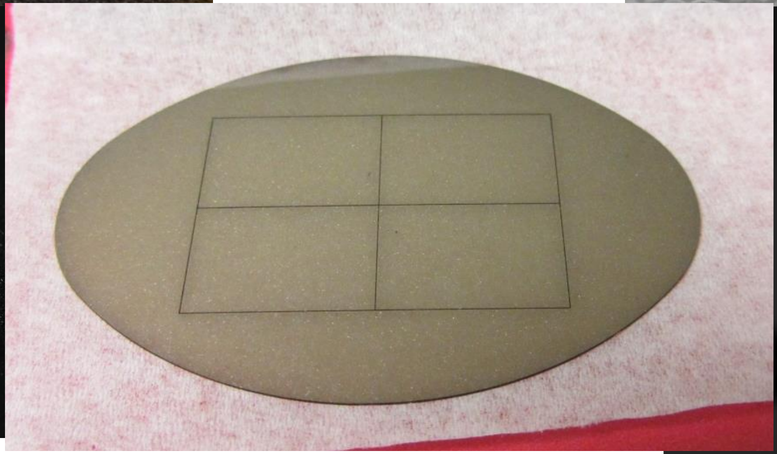
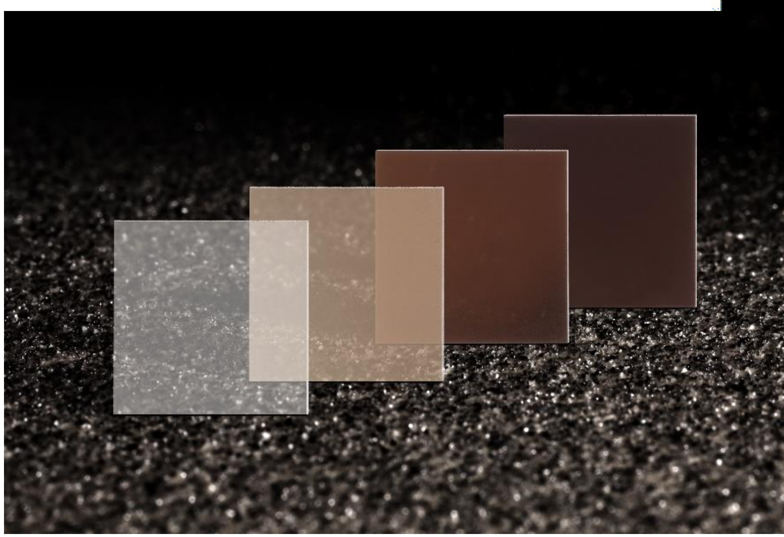
Diamond – Finished Products (polycrystalline)

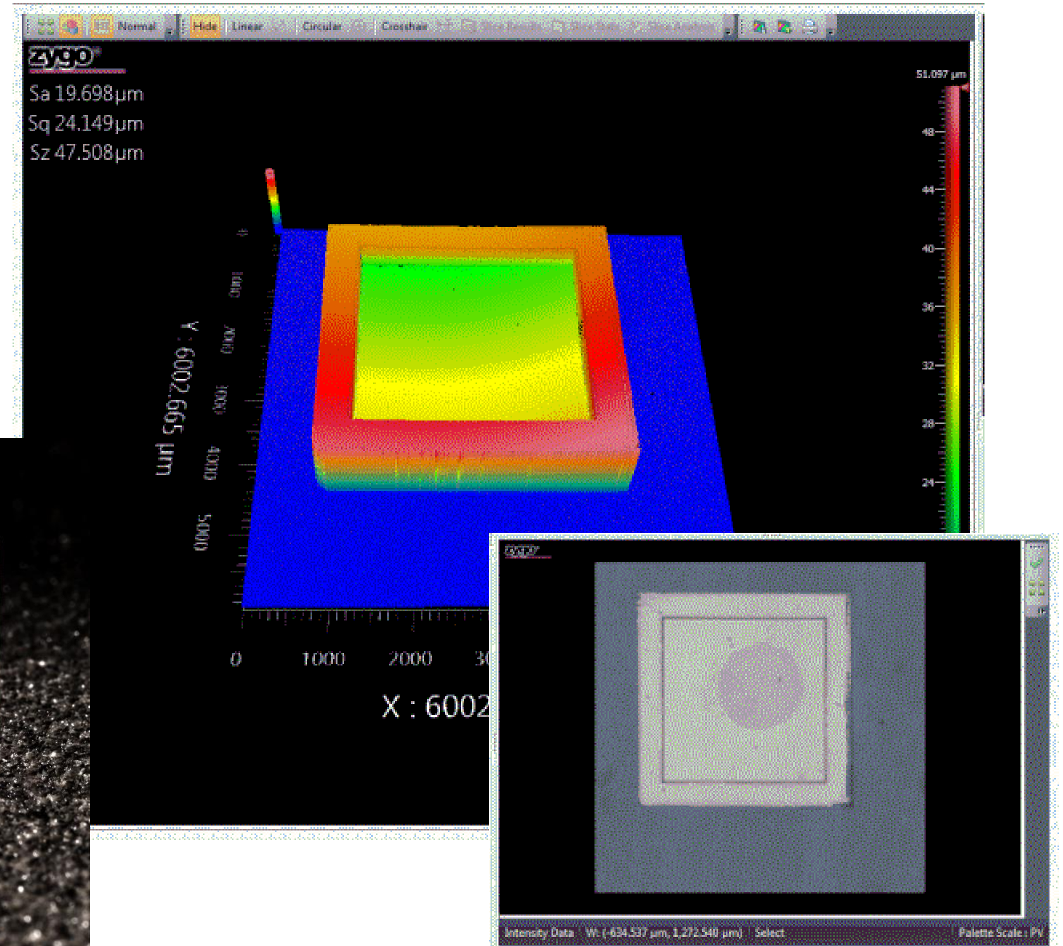



Diamond – New Capabilities

- Doping w/ boron, nitrogen
- Dry etching w/ RIE/ICP





Solicitation Topic and Challenges

24b. Grant applications are sought to develop advances in the general field of solid-state devices for tracking of charged particles and neutrons, such as silicon drift, strip, and pixel detectors, along with 3D silicon devices. Approaches of interest include:

…

5. Diamond detector or other radiation hard strip detector with strip size of 500 µm or less and at least 192 strip giving a total length of at least 4.8 cm long.

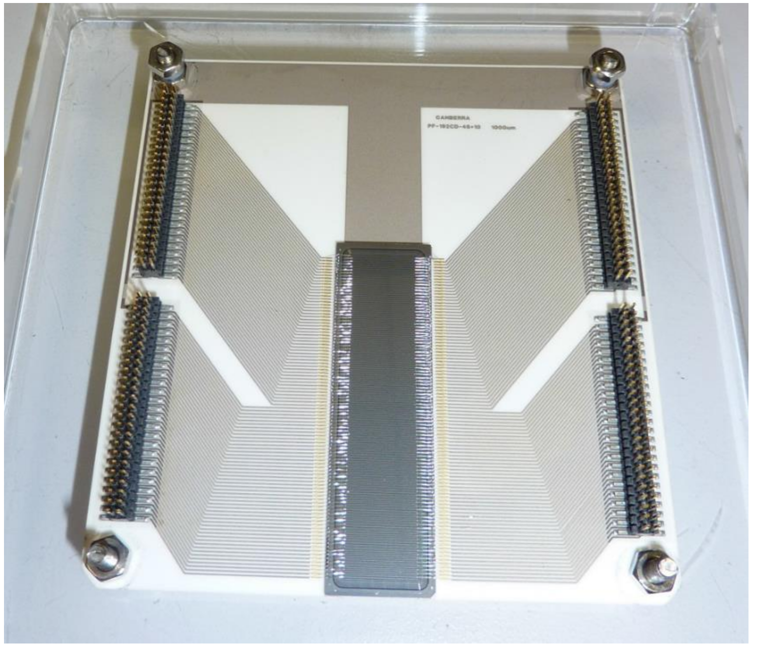
Monitoring electron beam polarization via Compton-scattered electron detection.

Distance from detector to electronics means more signal is needed:

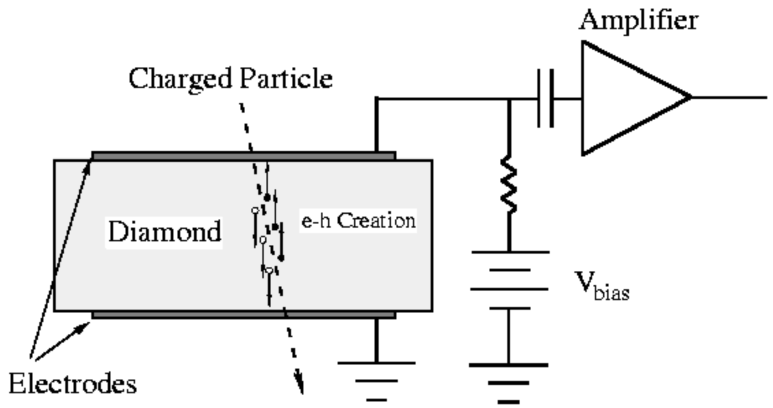
- thicker detector
- remove defect-laden nucleation layer

Uniform performance over larger area

Contact pitch of 240 µm – 220 µm wide / 20 µm spaces



Why Diamond?



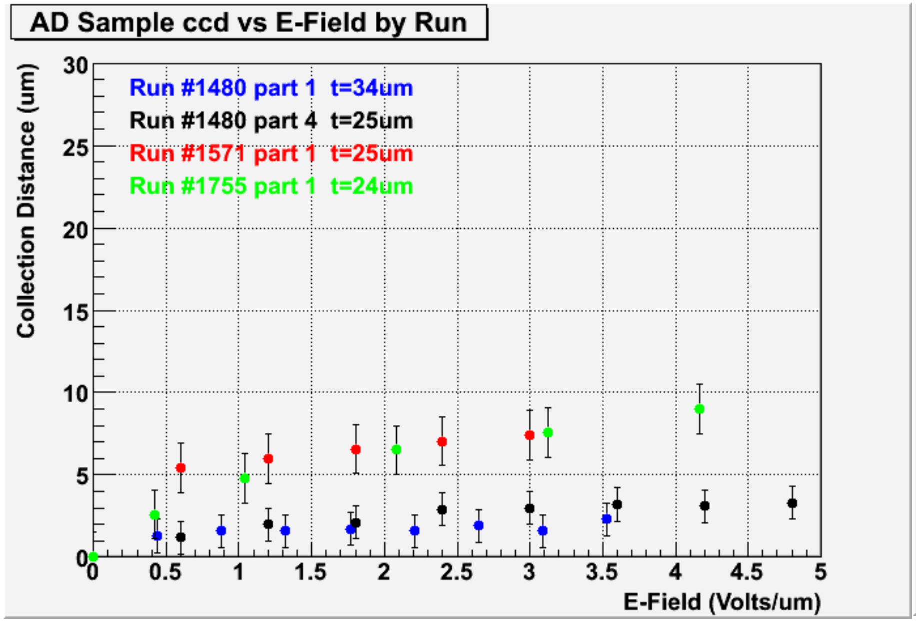
Solid-State Ionization Chamber

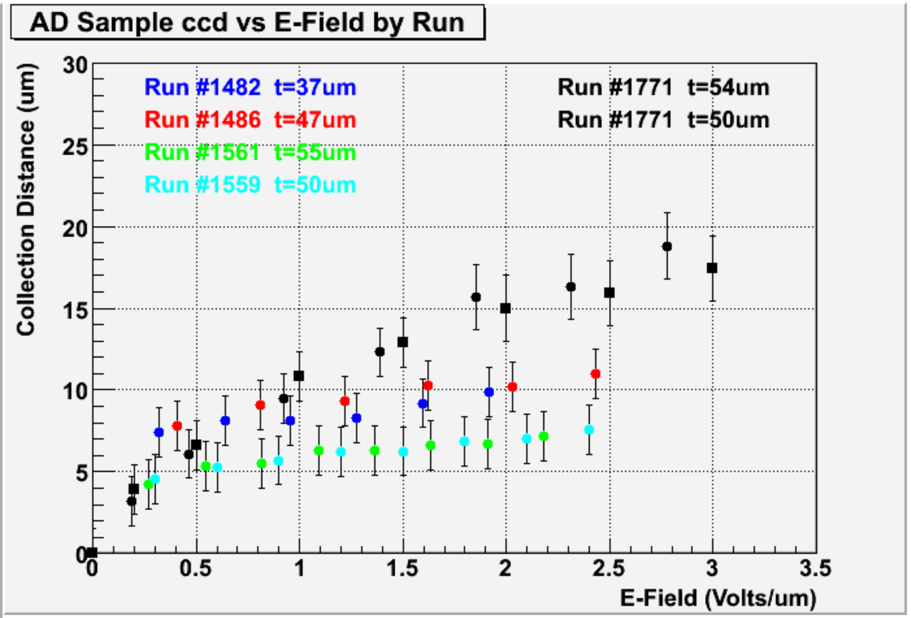
- 36 e-h pairs created per μm of diamond traversed per MIP
- Charges drift responding to bias voltage creating measured signal
- Trapped by defects in material so charge collection distance is average distance an e-h pair drift apart

- Radiation tolerance tested and found superior with wide range of particles/conditions.
- Smaller dielectric constant provides lower capacitance and lower noise.
- Excellent insulator so no leakage current even under high electric fields.

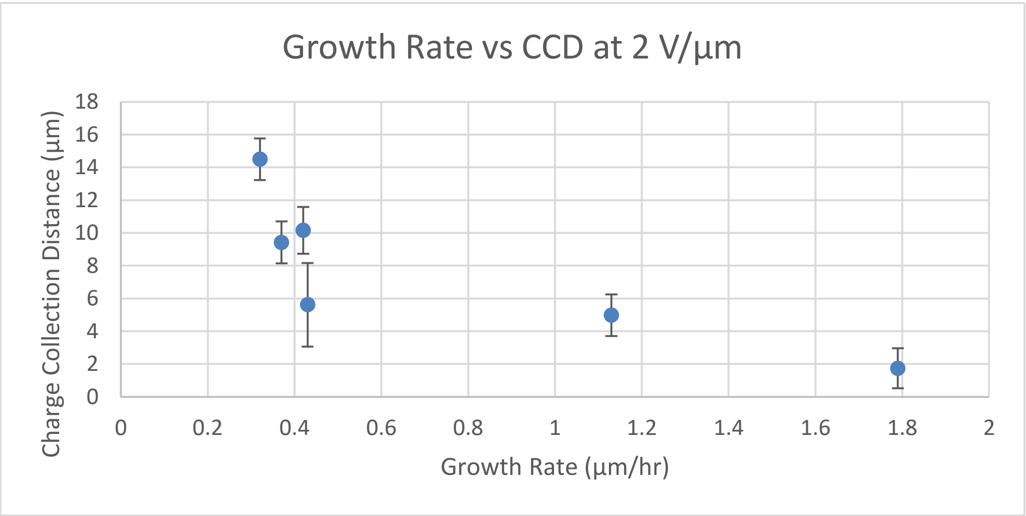
Diamond Growth Progress

Results on thin films





Diamond Growth Progress



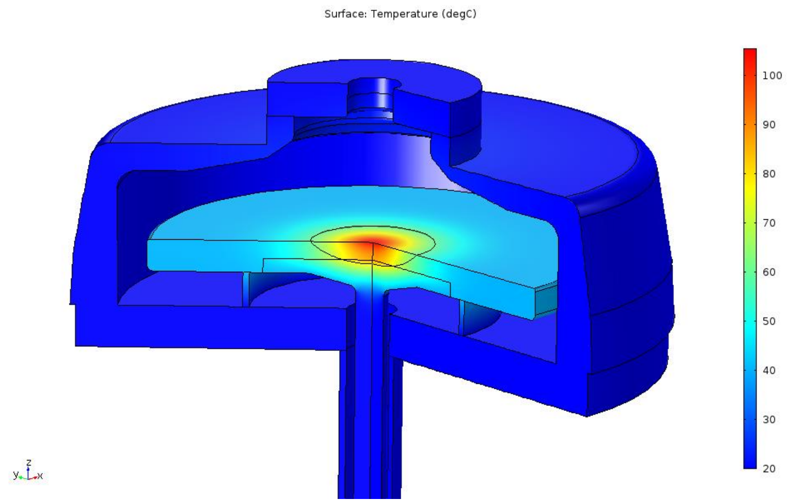
- All samples are 100 µm thick
- Slower is better

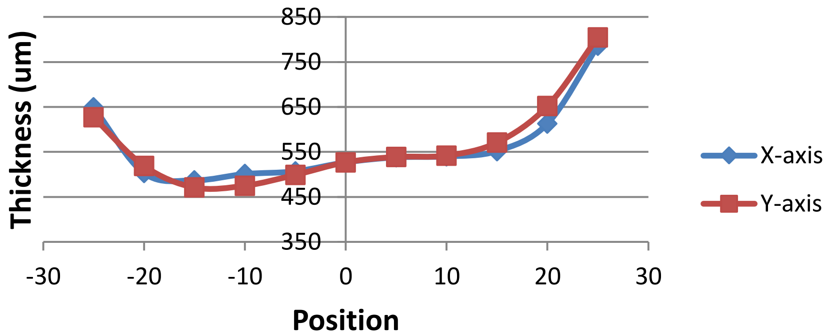
- Despite problems in growth, thicker is always better
- 500 µm at 0.33 µm/hr = 1500 hrs!!!

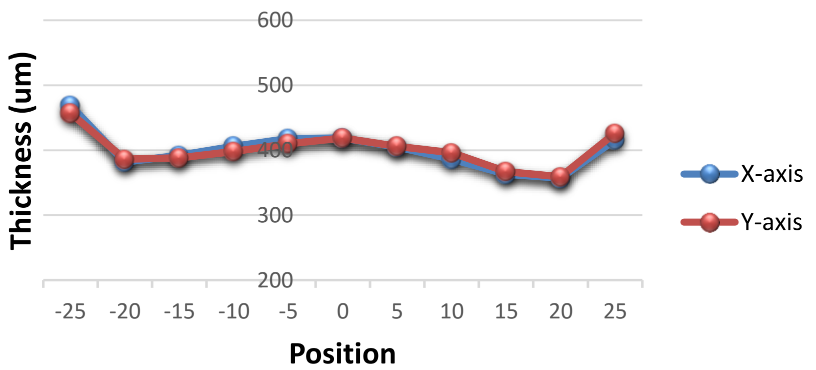
Uniformity of Performance

Rotating Stage

Substrate Holder Design







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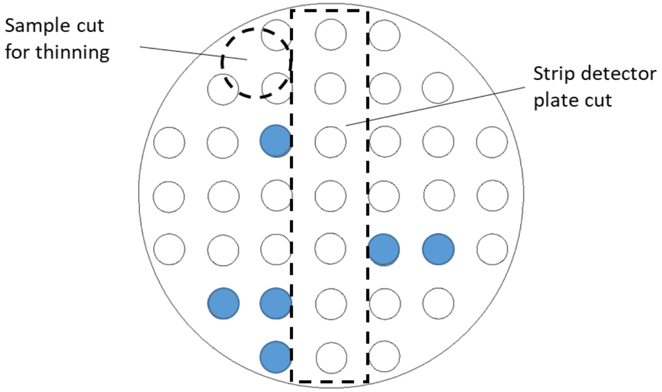
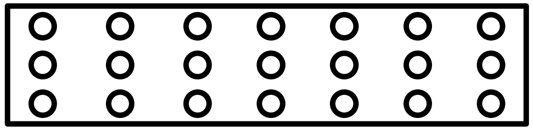
Area Dependence of CCD



48x15mm diamond plate with metal contacts



CCD, relative %

114	97	91	103	98	102	95
111	92	97	93	113	105	95
112	88	93	90	99	114	99

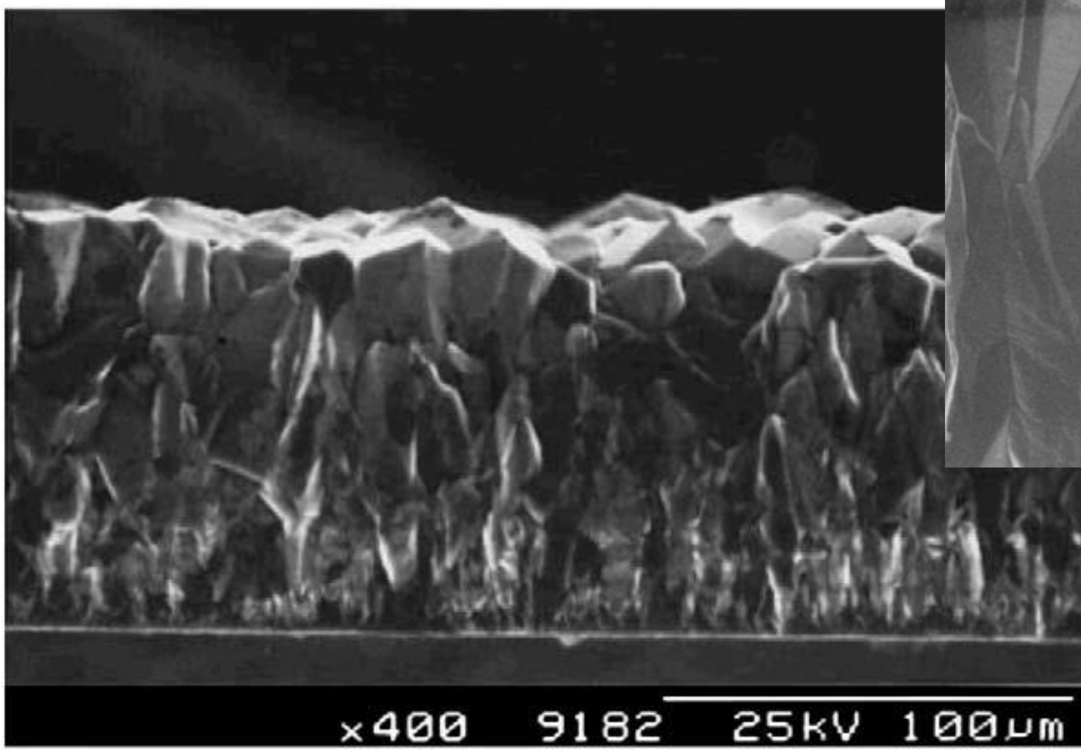
- Raman showed few locations with NV centers – cut samples avoiding those spots.
- Added contacts and measured CCD vs. location on strip detector blank.

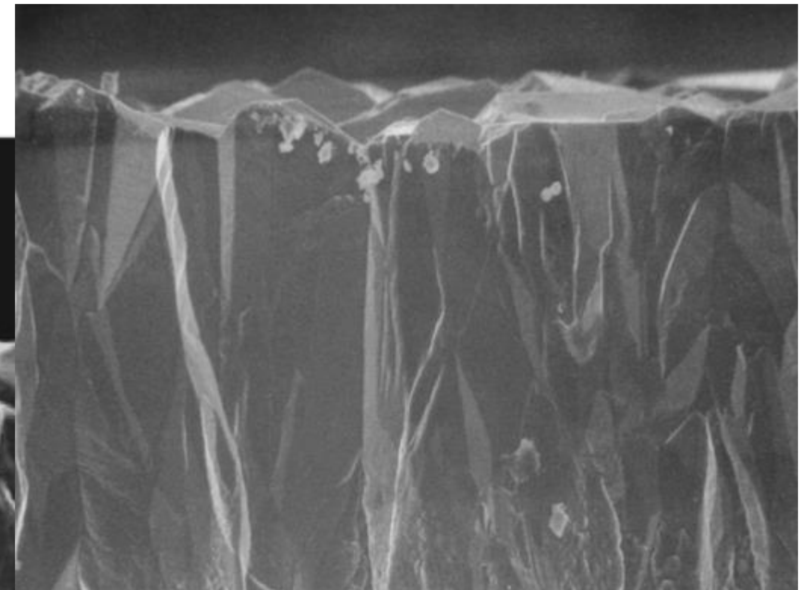
Thickness, relative %

110	108	105	102	100	97	94
108	106	103	100	98	95	92
105	103	100	97	95	92	90

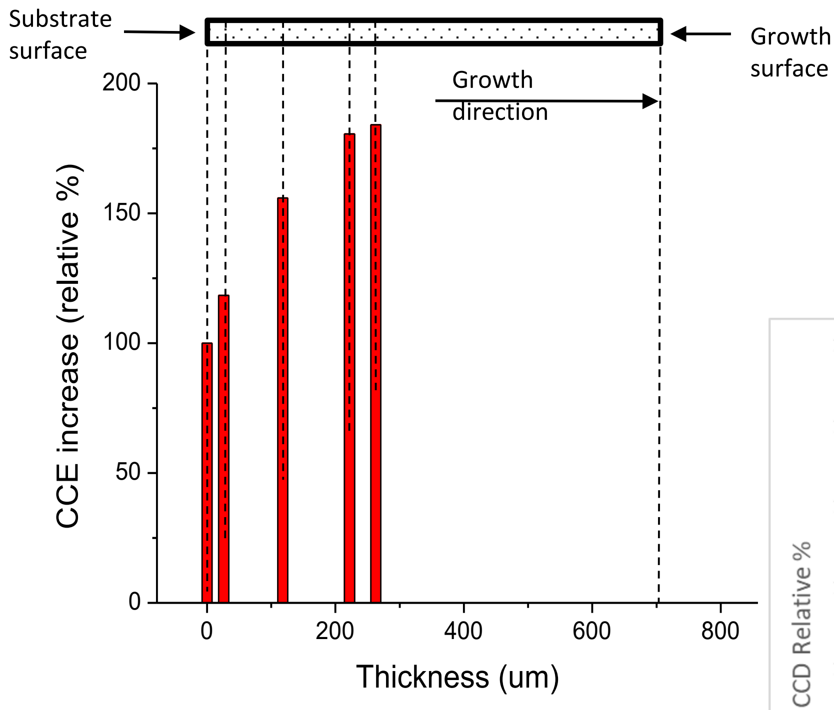
Material Removal Progress

Why remove material?

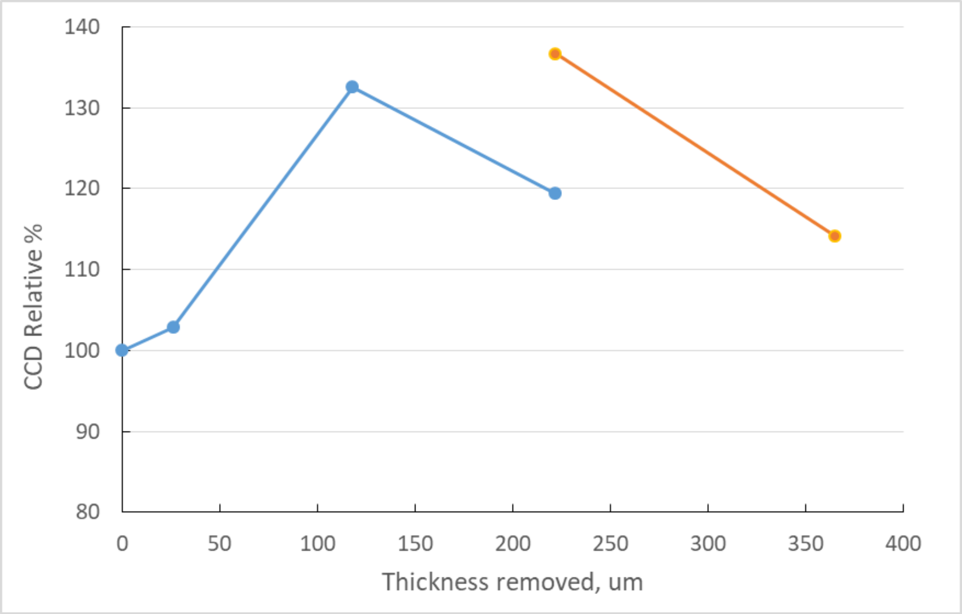




Material Removal Progress



Charge collection improves as back-grinding progresses but…



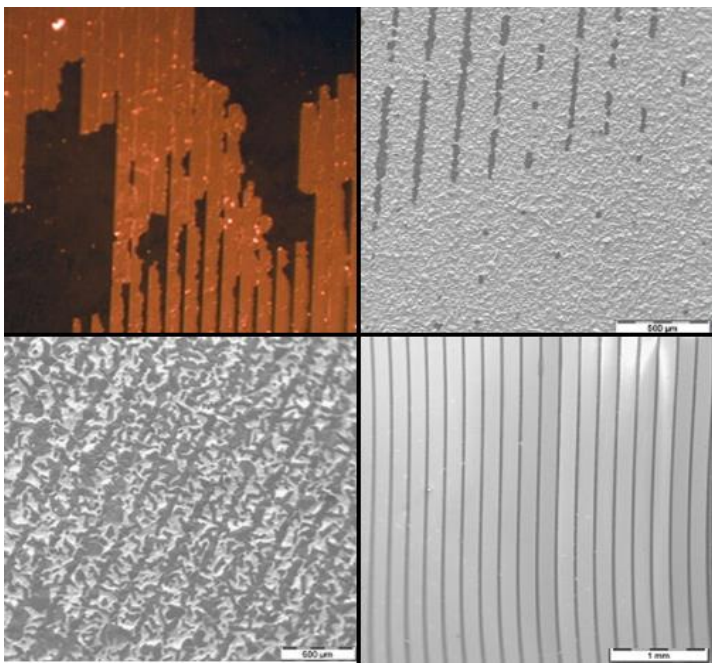
… reaches a maximum as larger grains begin to be removed.

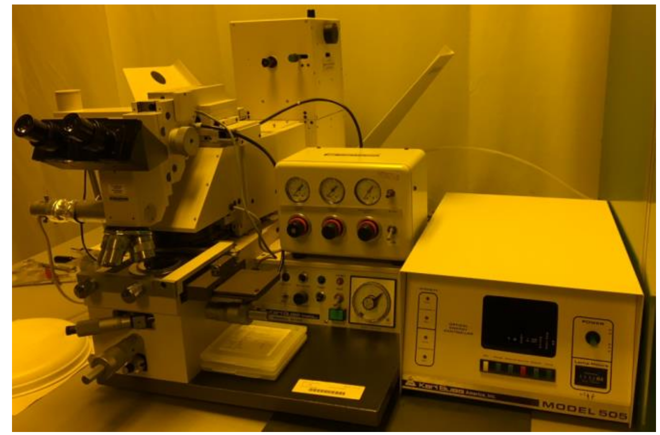
Packaging Progress – Lithography

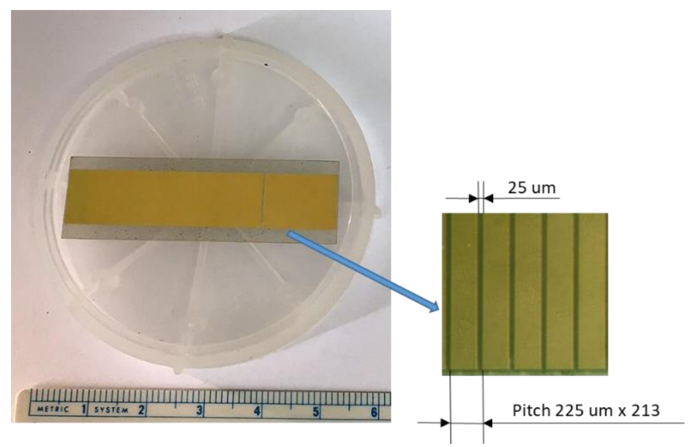
Various lithography methods attempted.

– negative or etch process gives desired results.

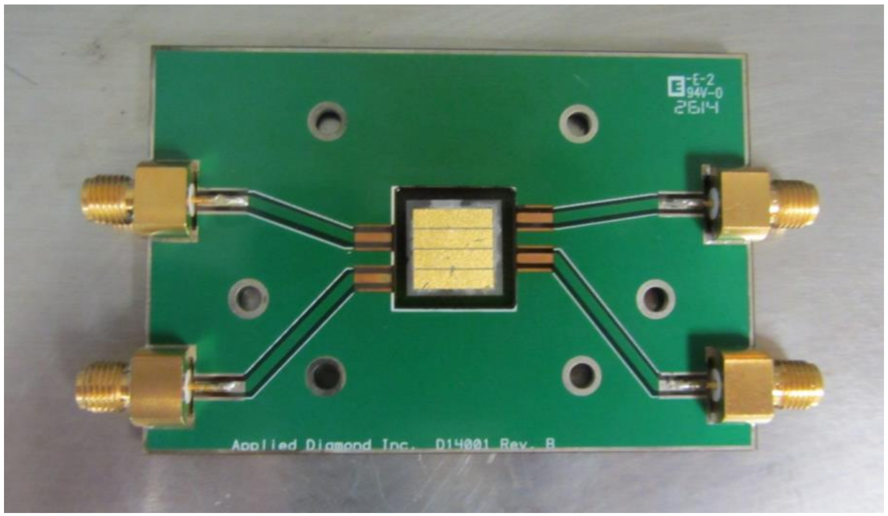
– expanded process to larger areas.



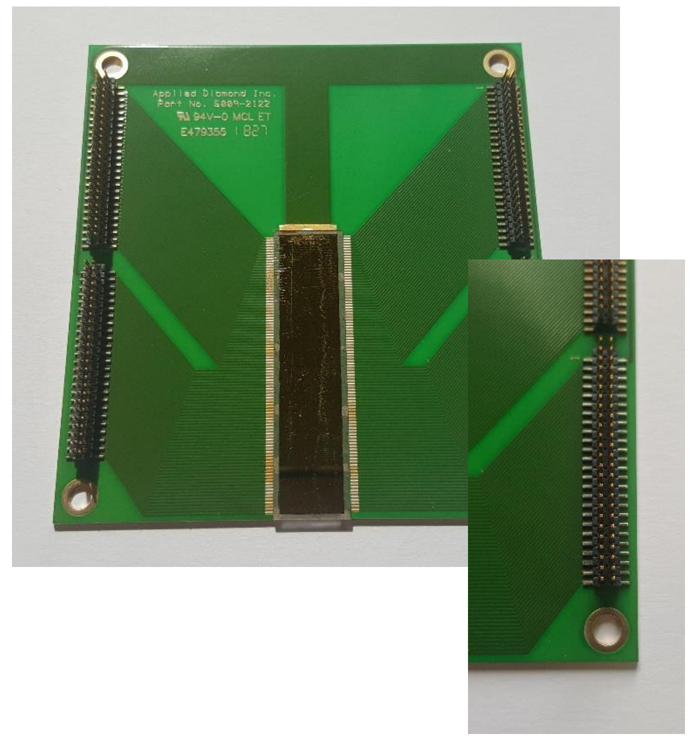




Packaging Progress



- Board Materials
- Soldering Improvements
- Wirebonding Challenges



Incorporation of passives, preamp circuit?

Commercialization Strategy

For scientific customers:

- Offer both poly and sc CVD diamond for detector applications
- Develop credibility with results of characterization testing
- Provide standard and custom packaging options
- Partner in development of new detector products

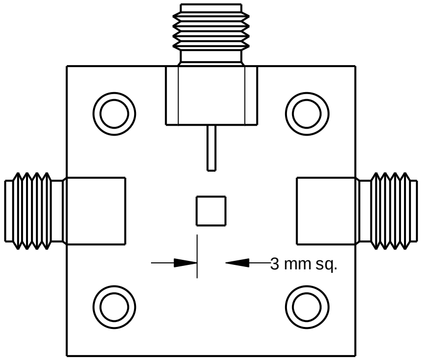
For industrial customers:

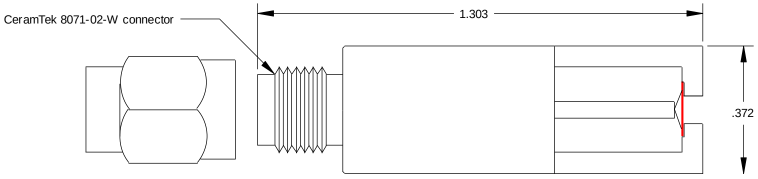
- Provide resource to educate and ease adoption of diamond
- Develop one-stop source for detectors using diamond

Current Commercialization Projects

Packaged Detectors

- Charged particle detector
  (in heavy neutron/gamma flux environment)
- Mosaic delta-E detector for slow, heavy ions
  (time-of-flight, intermediate-energy relativistic ions)
- Protons/Tritons/Alphas
  (in fusion energy research)
- X-ray fluorescence microscope
  (intensity indicator, normalization of signals collected from samples)
  - 10^{11} photons/sec at 4.5 - 25 keV





Current Commercialization Projects

Material Sales

- INFN – 100 electron bunches with 0.5 GeV energies
  - 2 cm sq / 50 μm thick / 5 – 10 μm CCD
- BNL beam position monitors
  - 4.5 mm sq / 50 μm thick / single crystal
- GSI
  - 2 cm sq / 100 μm thick / 15 – 20 μm CCD

Processing Services

- Contact deposition on customer-supplied materials
  - ESRF – high energy particle detectors
- Selective thinning of customer-supplied materials
  - BNL, GSI, Synchrotron Soleil – beam position monitors

Conclusions

- Have a process for growing thick diamond films for detector applications.

- Have quantitatively evaluated removal of defective substrate-side material to maximize CCD.

- Have actively begun work to improve performance uniformity across larger detector areas.

- Have demonstrated required contact pitch and spacing.

- Have an in-house low volume custom packaging capability.

- Have sales of diamond material, services and packaged detectors.

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