Thin Diamond Time-of-Flight Detectors

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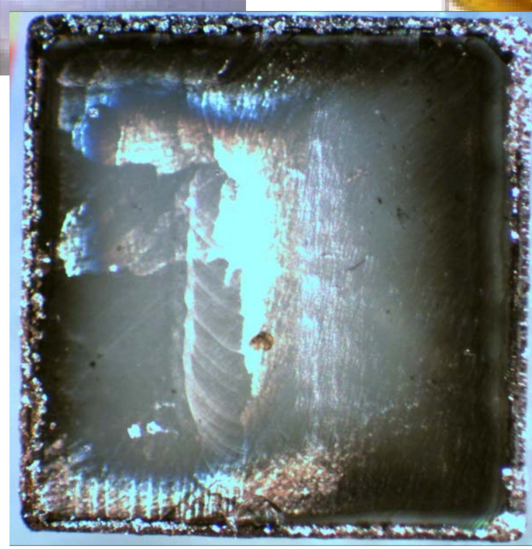
Applied Diamond, Inc

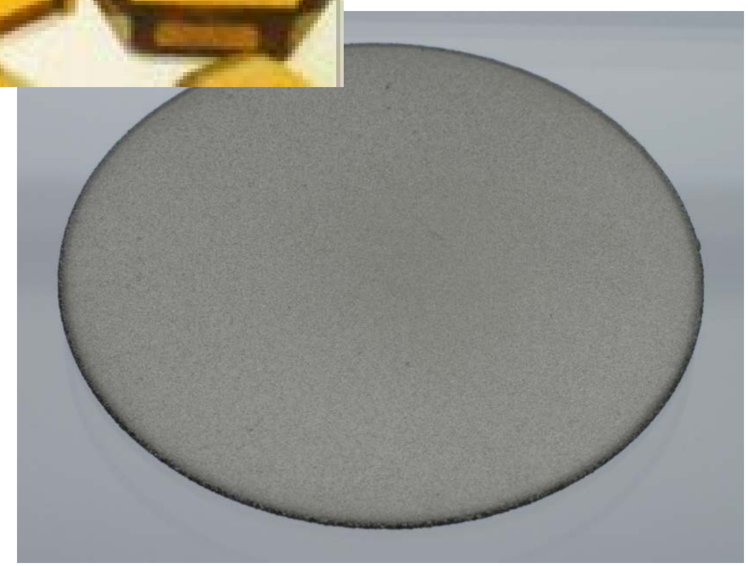
DOE NP SBIR/STTR Exchange Meeting
August 6 & 7, 2014

Outline

- A bit about Applied Diamond
- Topic and Challenges
- Progress to-date
  - Diamond Growth
  - Material Removal
  - TOF Testing
  - Characterization
  - Packaging
- Commercialization

Diamond – Types and Sources





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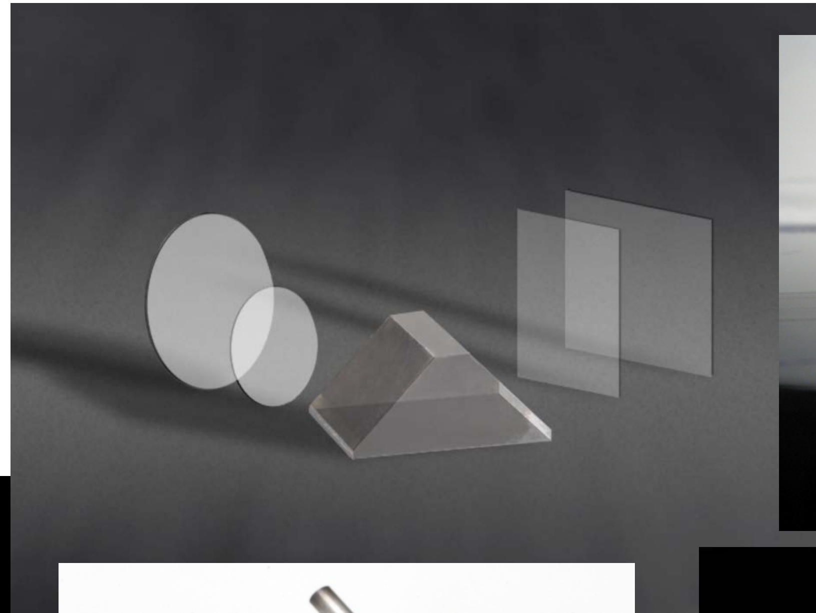
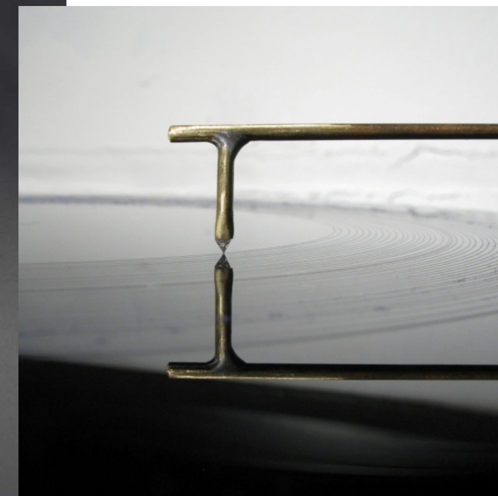
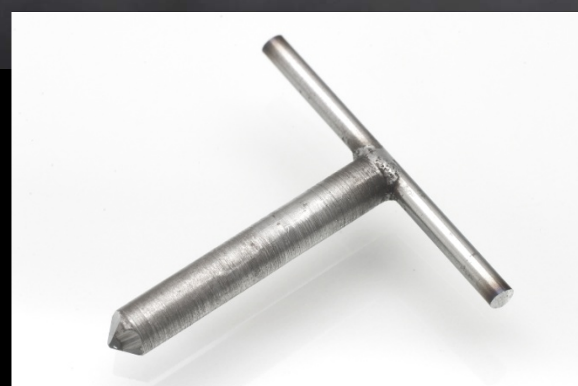
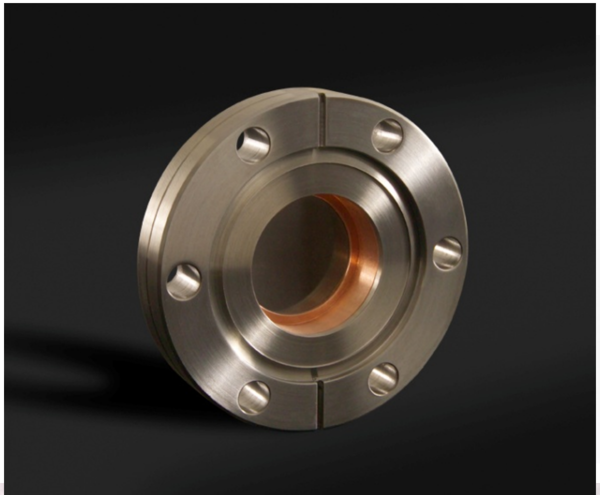
Diamond – Finished Products (single crystal)

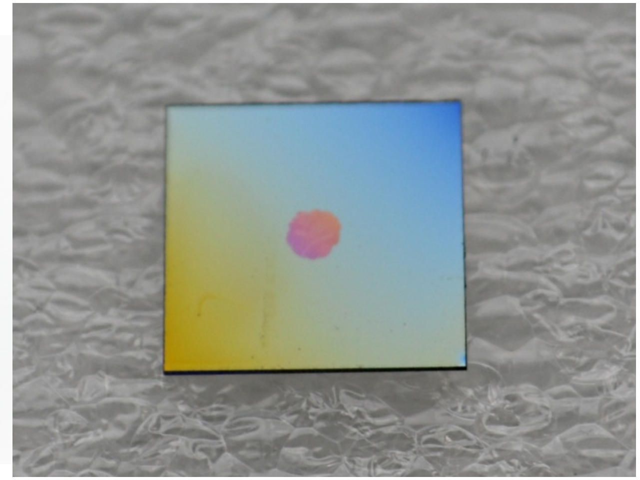


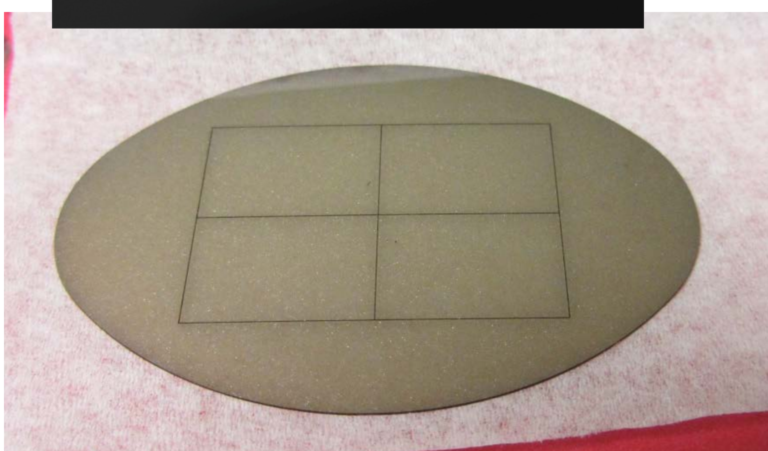


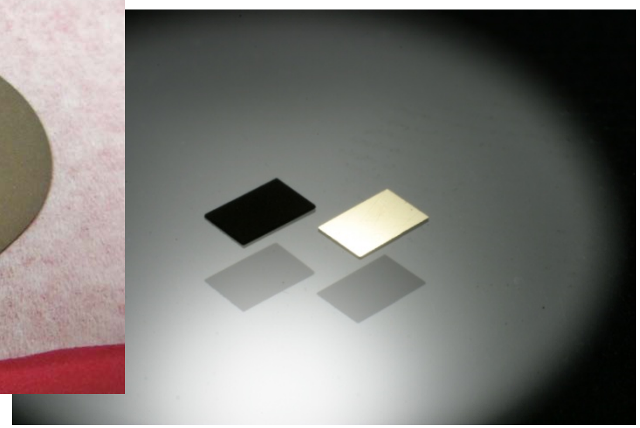


Diamond – Finished Products (polycrystalline)









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Solicitation Topic and Challenges

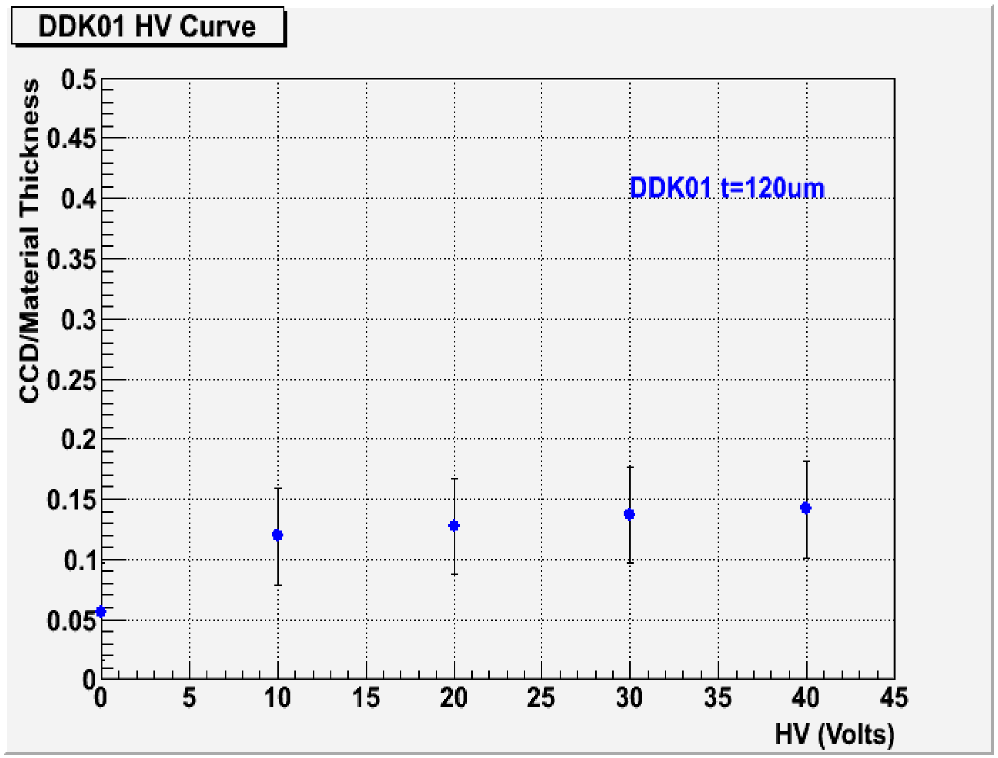
Future rare isotope beam facilities like FRIB will provide beams with unprecedented intensity, creating a challenge for single particle tracking and beam profile measurements. The development of position sensitive fast particle detectors for particle tracking/timing and with high rate capability would be desirable. Ideally these detectors would provide both position and timing measurements in a transmission mode and be radiation resistant and of very homogenous density and thickness.

Time-of-Flight Detectors – square cm, segmented
Focal Plane Array Detector – 20 cm x 2 cm, segmented

Uniform quality providing adequate S/N
Uniform mass (thickness and density)
Transmission mode = as thin as possible

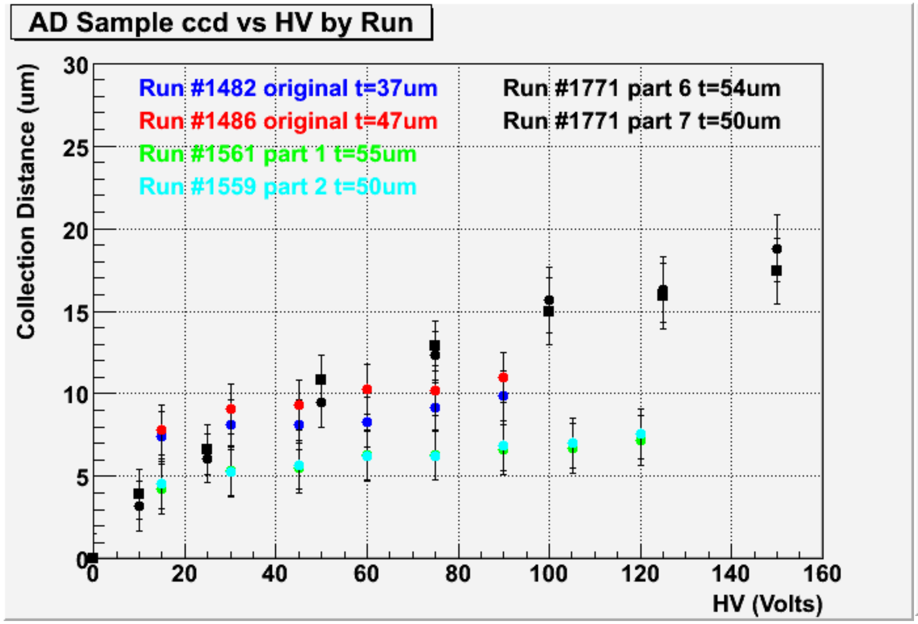
Diamond Growth Progress

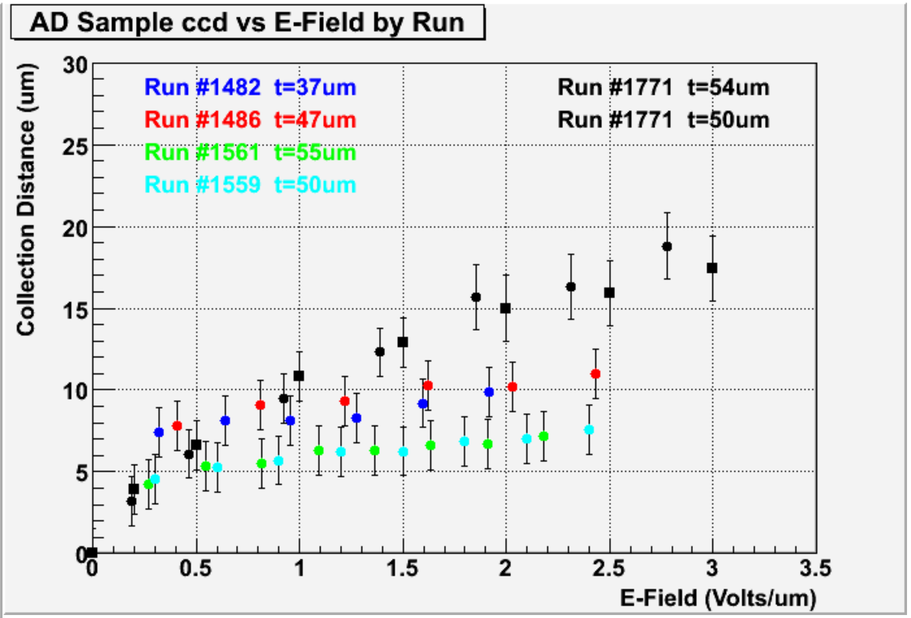
Early results on 100μm+ films



Diamond Growth Progress

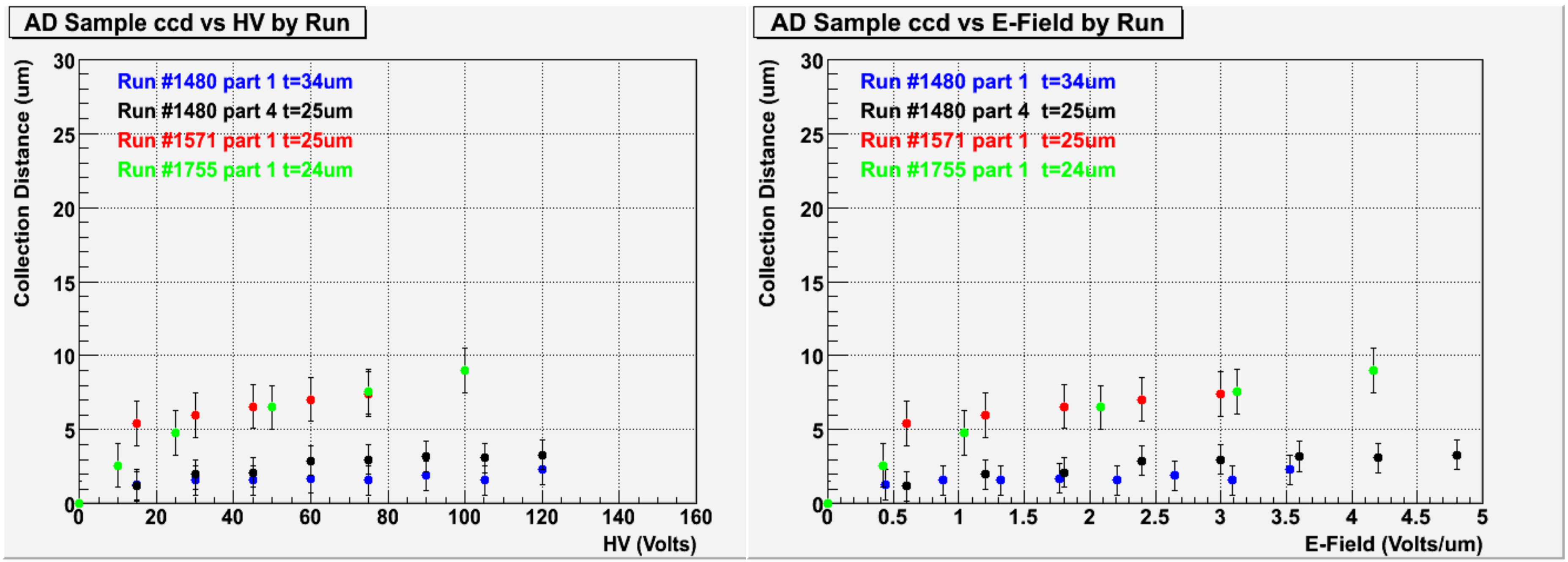
Early vs. current results on 50 – 60 μm films





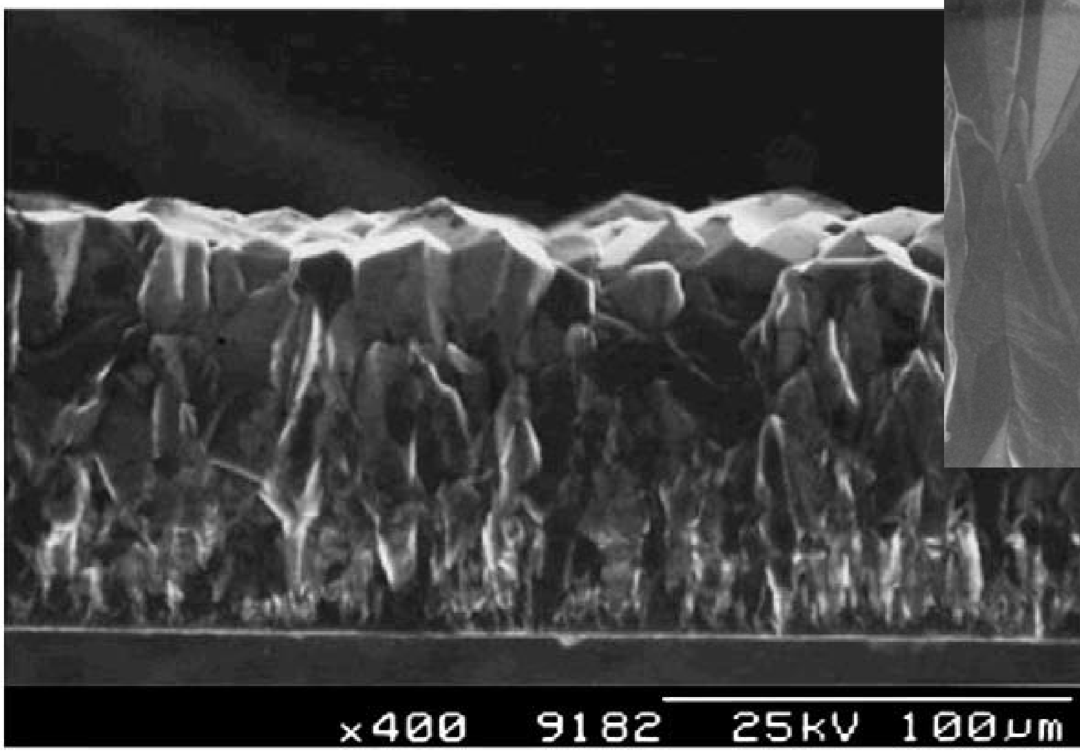
Diamond Growth Progress

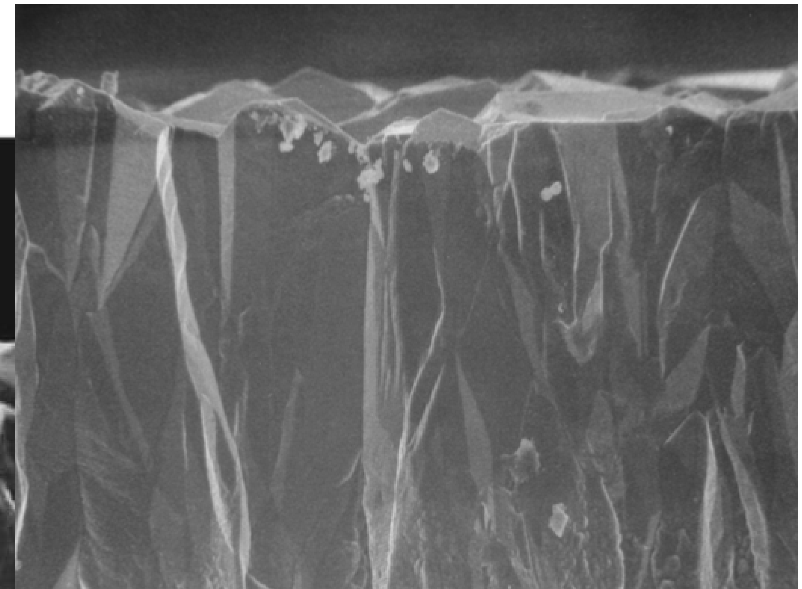
Early vs. current results on 25 – 30 μm films



Material Removal Progress

Why remove material?





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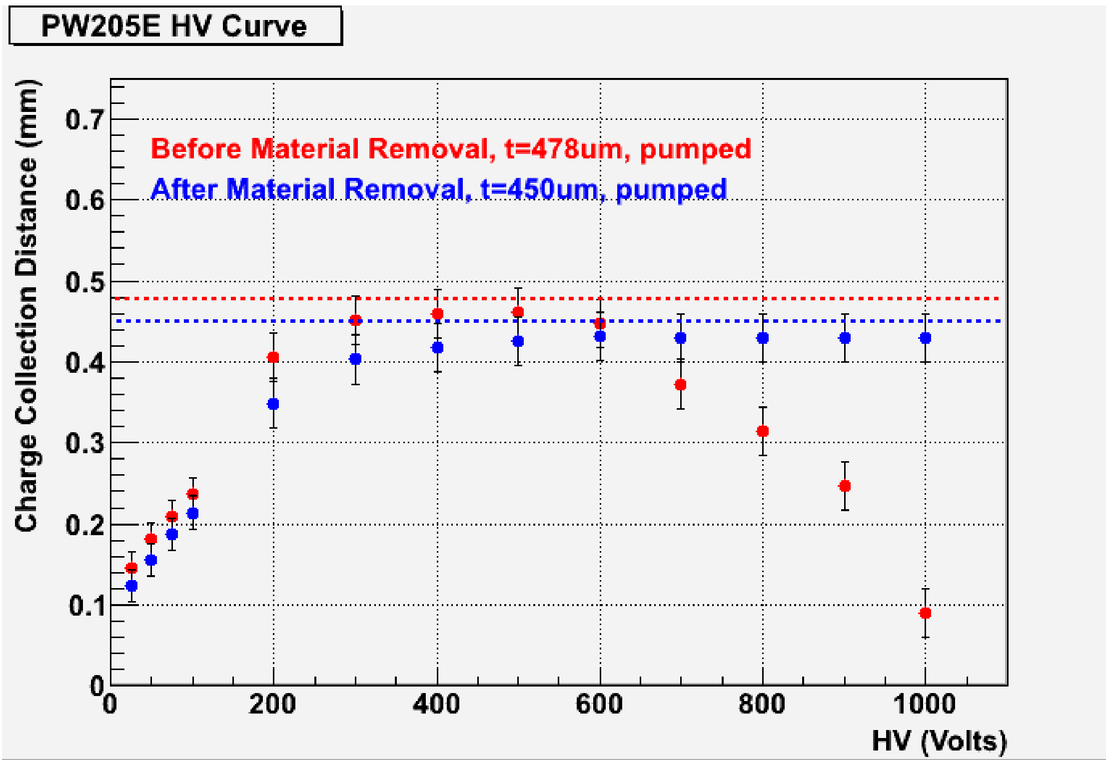
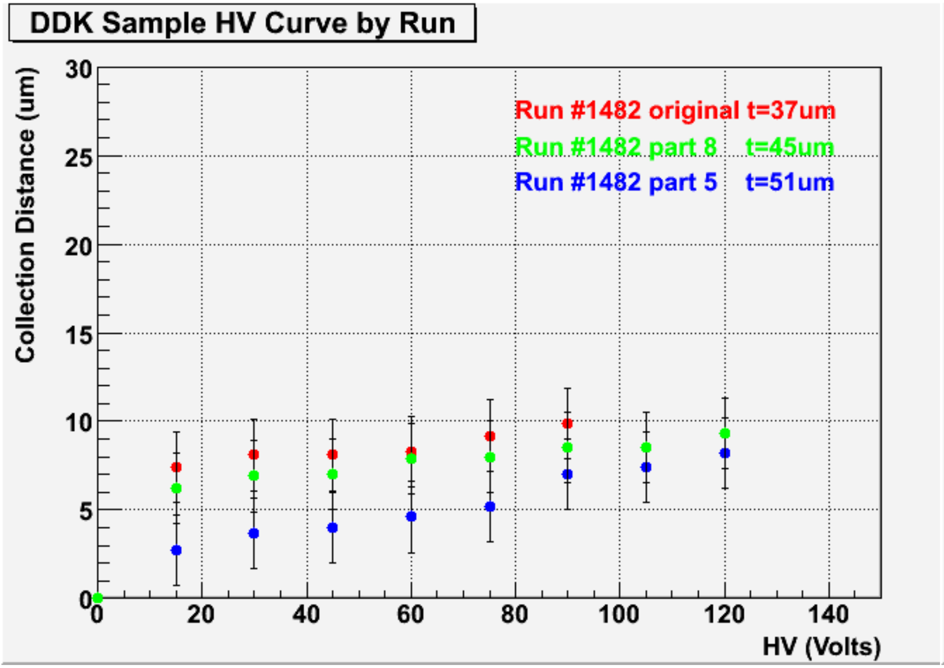
Material Removal Progress

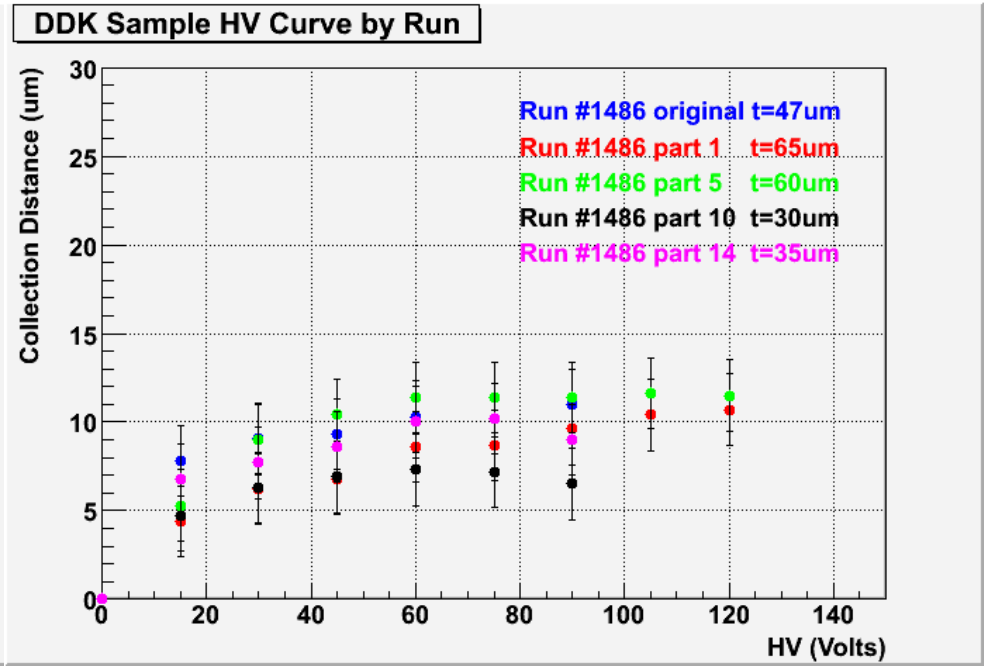
Early results - scCVD



Material Removal Progress

Various methods on polyCVD – cont.





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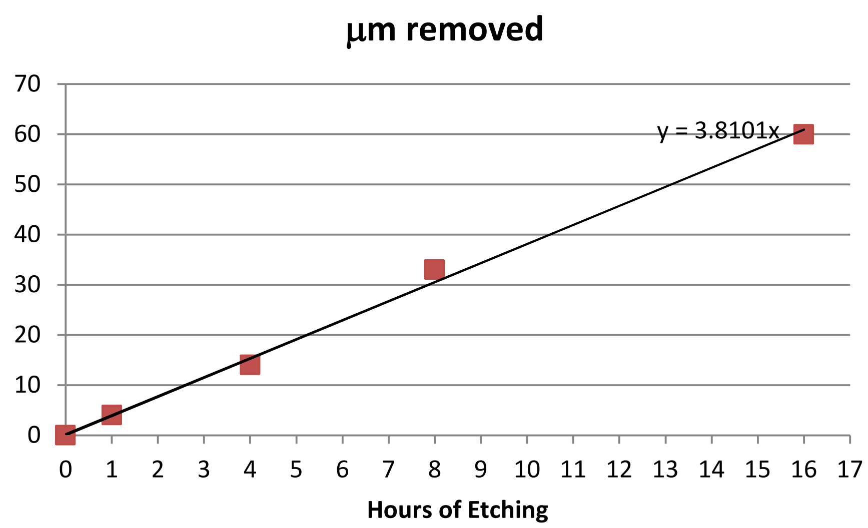
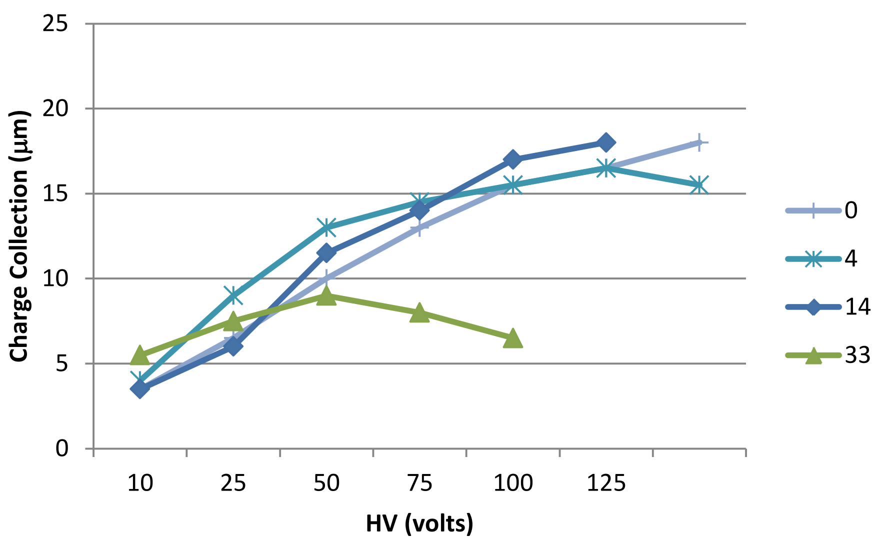
Material Removal Progress

Thickness control by subtraction



Fine control of thickness …



… without affecting performance

Time-of-Flight Results

^{232}U alpha particles with energy of 5.3MeV.

Bias = 100V

Leakage < 1 nA

Rise time ~ 0.8 ns

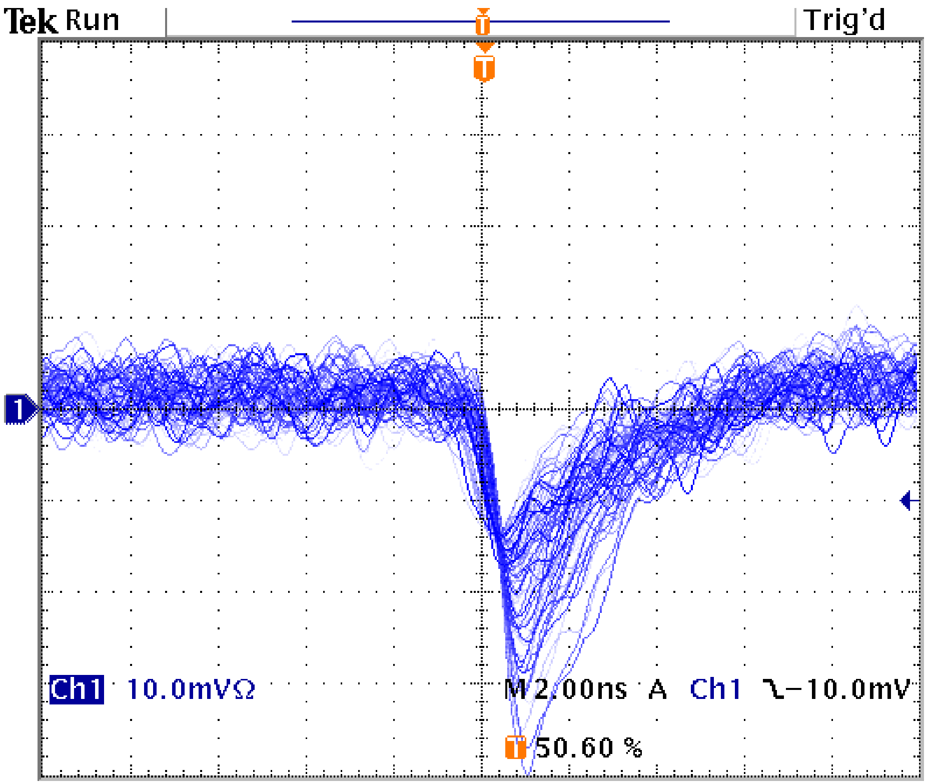
Decay/rise time ~ 3:1

S/N ~ 5

With 100 MeV/u particles, energy loss of:

11.4 MeV with ^{20}Ne

798 MeV with ^{238}U

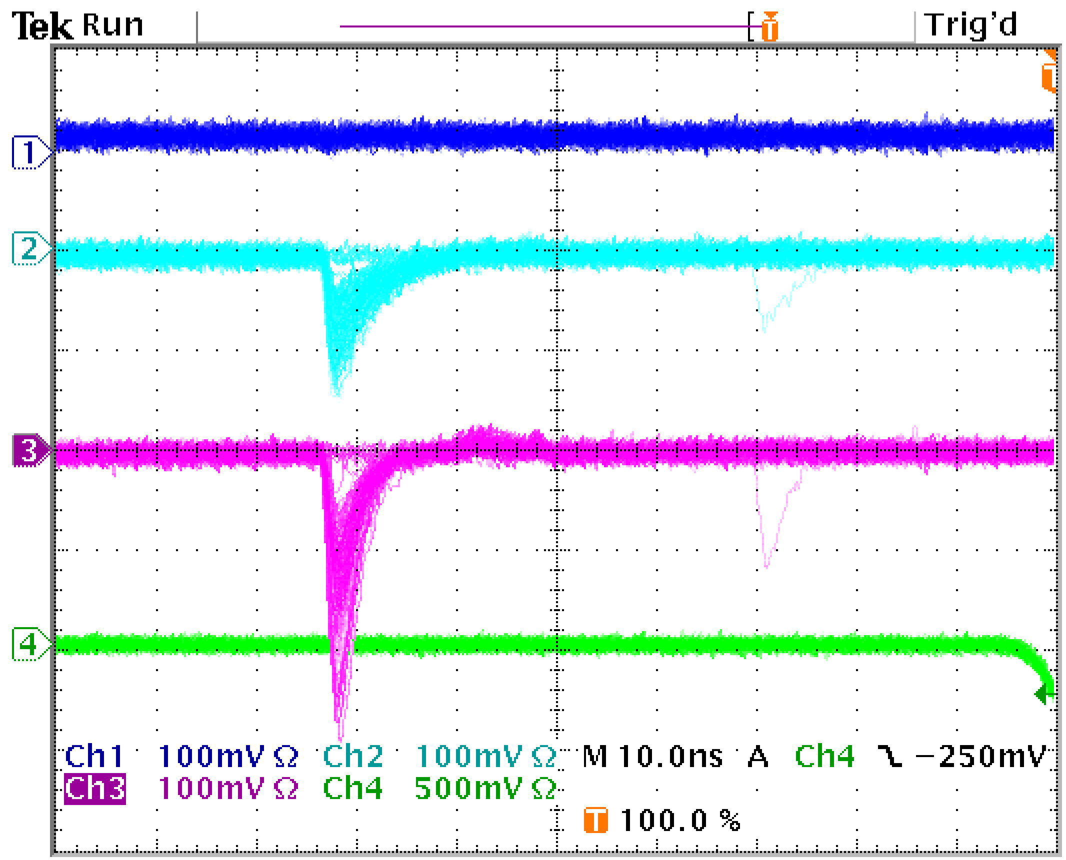


Time-of-Flight Results

^{40}Ca beam with energy of 140MeV/u.

1 – 65 μm thick
2 – 60 μm thick
3 – 50 μm thick

Sample 3:
E_{loss} = 36 MeV
trigger eff = 81% @ 100V bias



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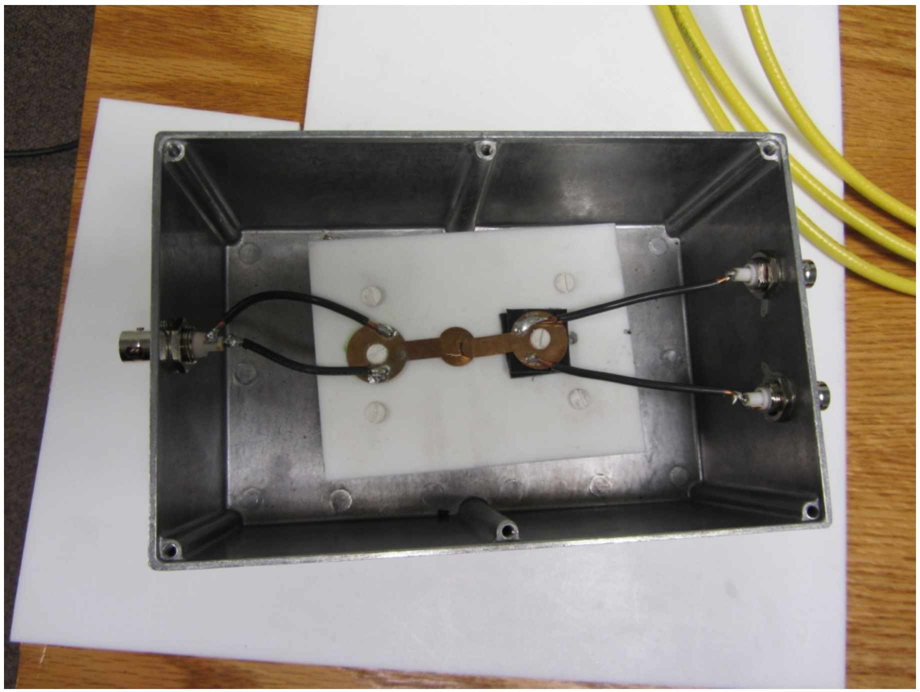
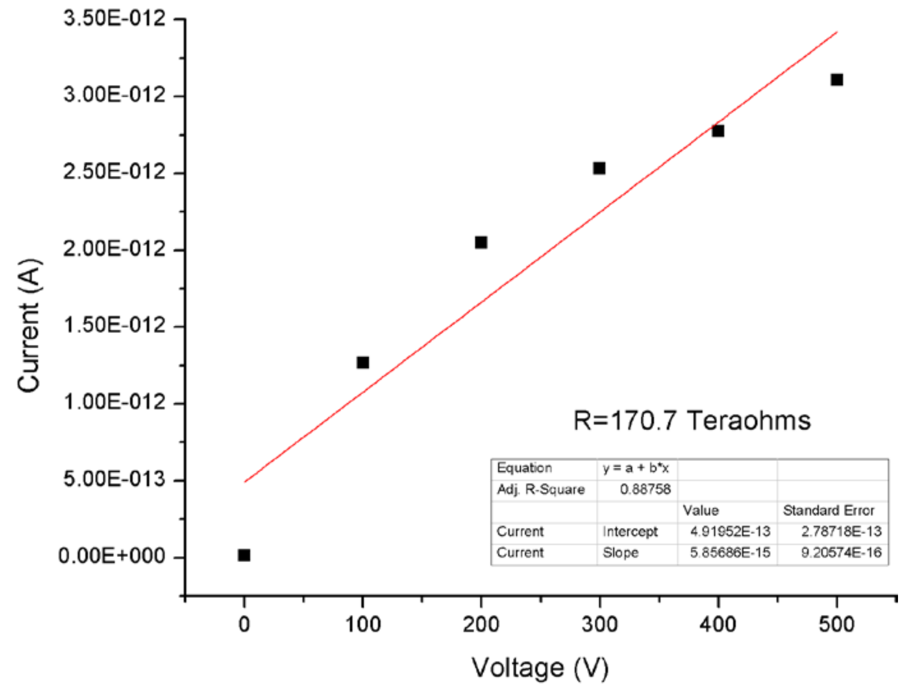
Characterization Progress

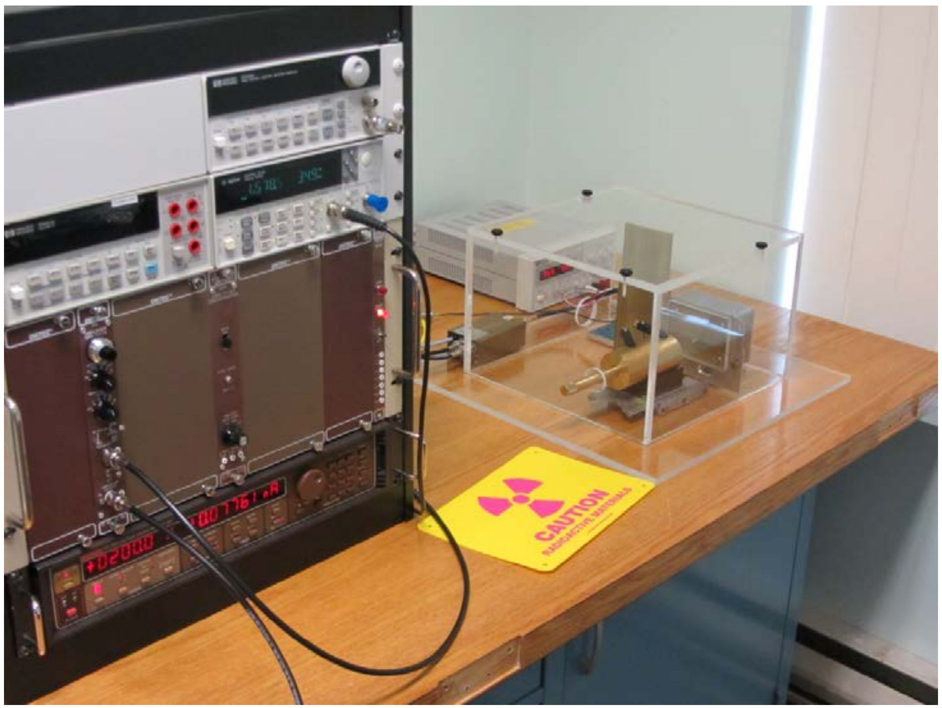
I-V Testing

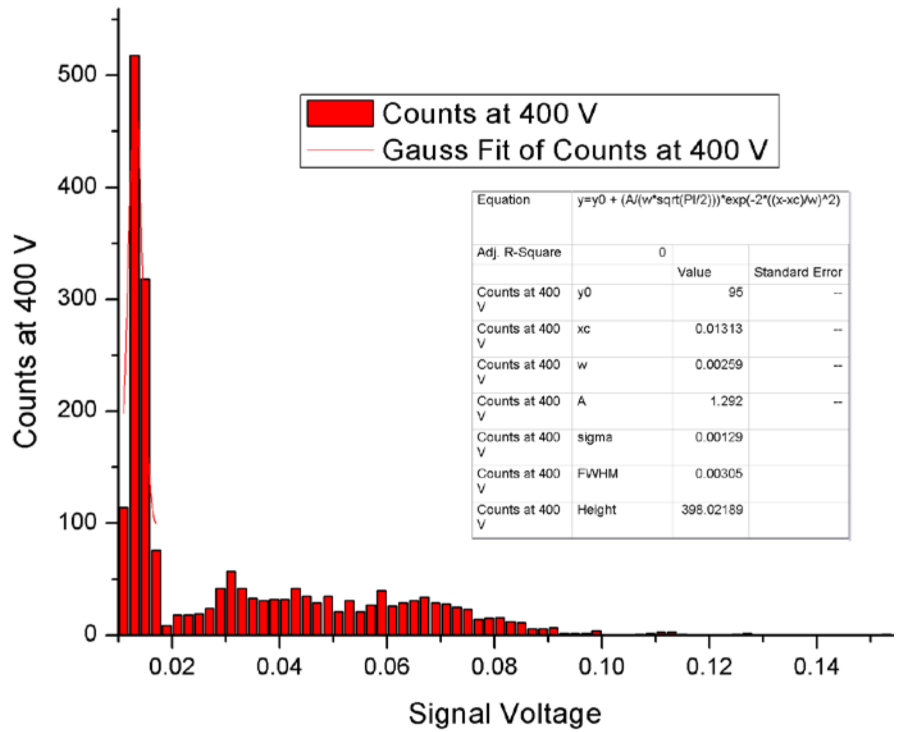




Characterization Progress

Charge Collection Testing

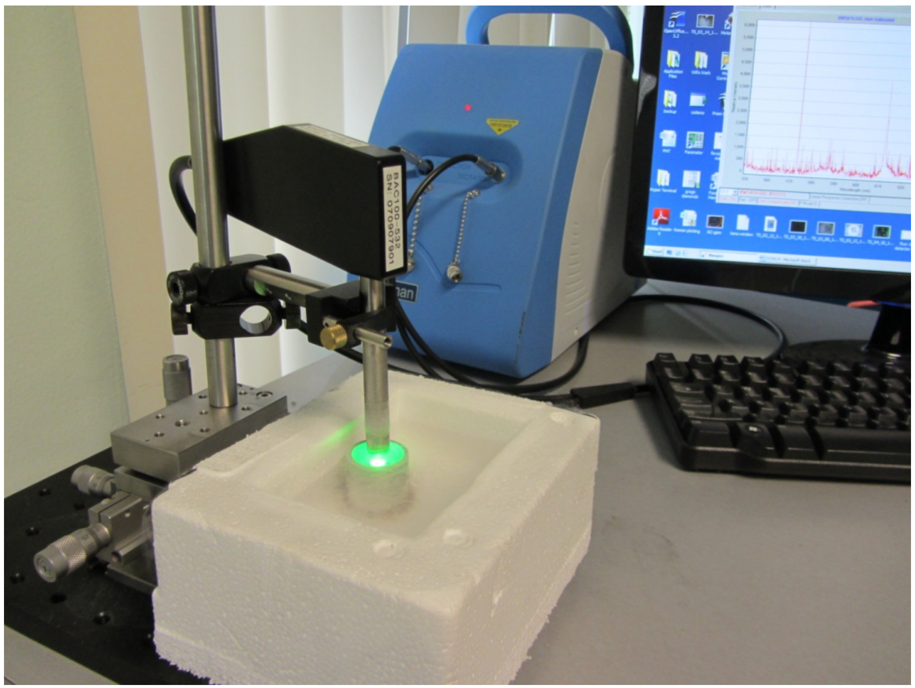


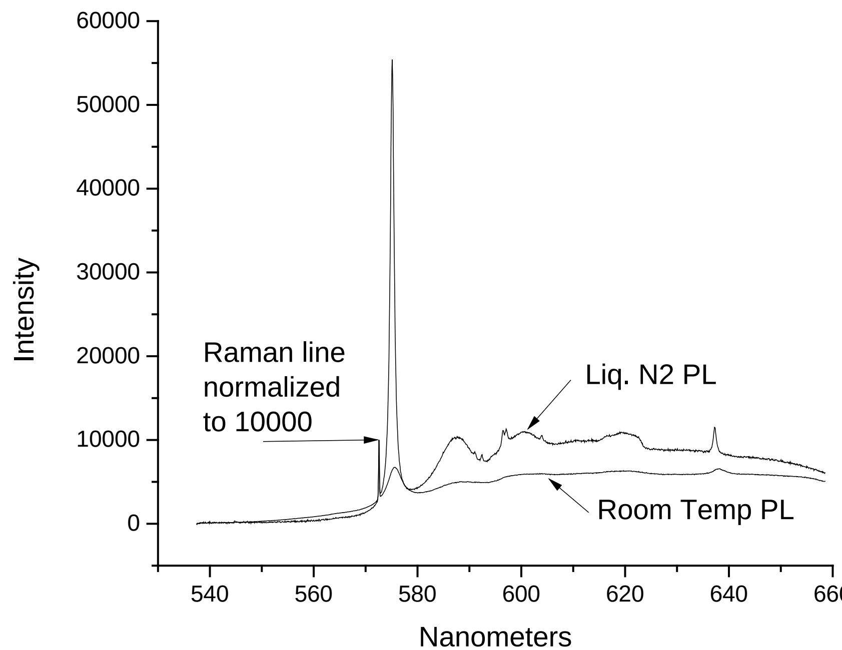


Equation	y=y0 + (A/(w*sqrt(PI/2)))*exp(-2*((x-xc)/w)^2)		
Adj. R-Square	0		
		Value	Standard Error
Counts at 400 V	y0	95	--
Counts at 400 V	xc	0.01313	--
Counts at 400 V	w	0.00259	--
Counts at 400 V	A	1.292	--
Counts at 400 V	sigma	0.00129	
Counts at 400 V	FWHM	0.00305	
Counts at 400 V	Height	398.02189	

Characterization Progress

cryoPL Testing

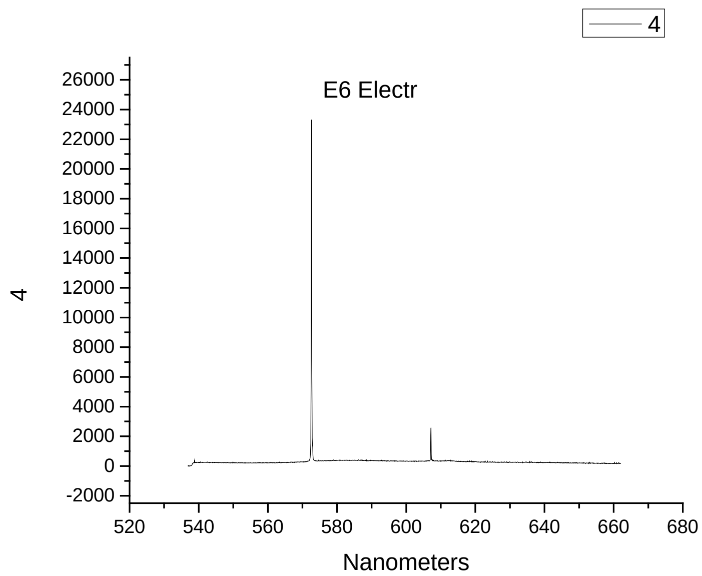


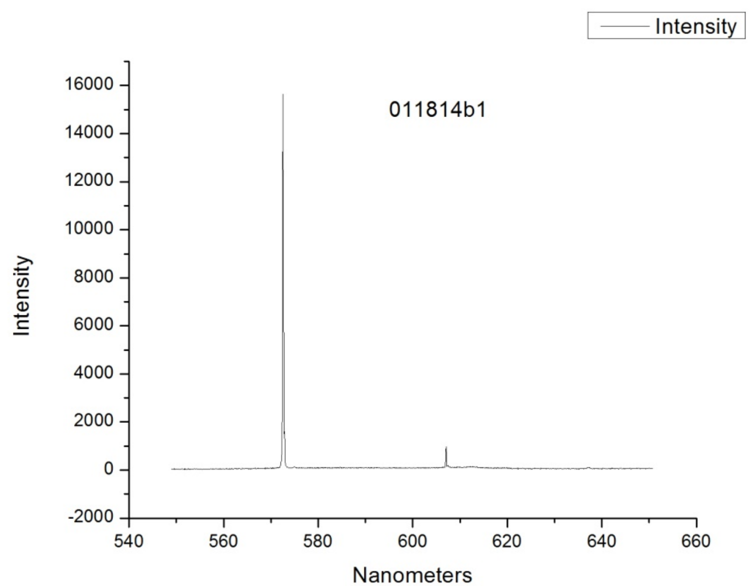


Characterization Progress

scCVD growth progress

- cryoPL shows NV^0 and NV^- approaching benchmark levels





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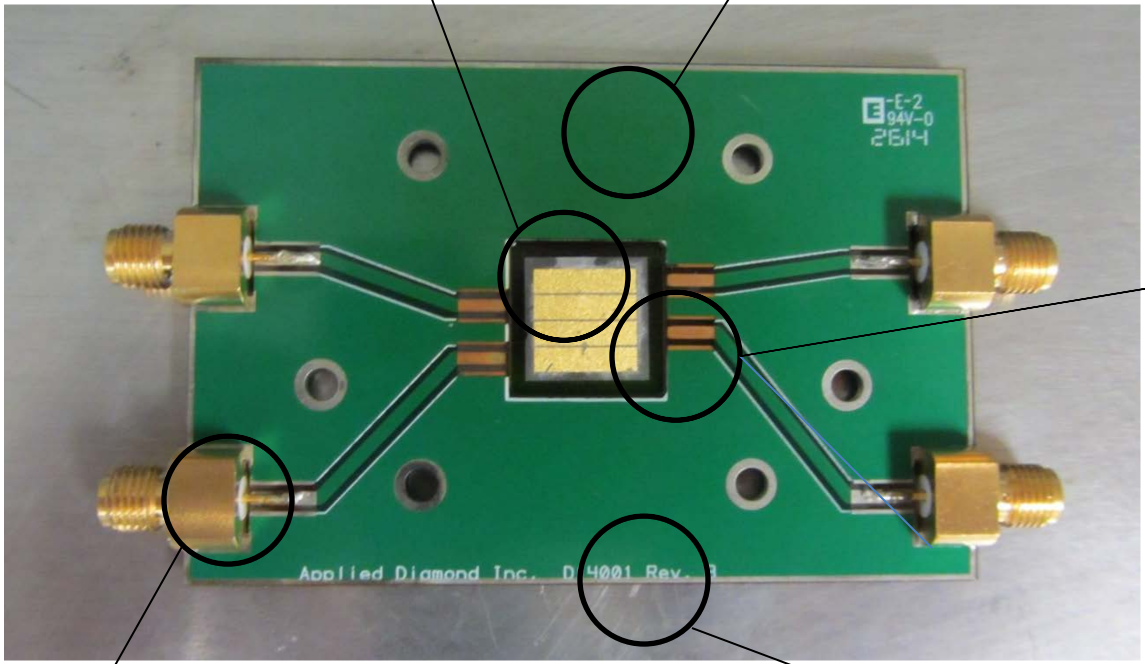
Packaging Progress

PCB design
and build

Lo-res lithography
CrAu contacts



Wire
bonding

Industry-standard
Connectors

Edges sealed with high
vacuum-compatible epoxy

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

Conclusions

- Have a process for growing thin diamond films with predictable charge collection properties.

- Have an analytical method that can reliably predict product performance in customers' applications.

- Have a process for modifying thin diamond coupons to have uniform predictable thickness coupon-to-coupon.

- Soon will have an in-house low volume custom packaging capability.

- Sales of diamond material have started and prototyping of a detector with an industrial partner has started.

Acknowledgements:

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