RIE Diamond Processing and Results

R. StoneRutgers UniversityB. HarropPrinceton University

Workshop on CMS Beam Conditions, Radiation Monitoring and Luminosity Systems

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Outline

Why do we want to change diamond processing?

What is RIE?

Charge Collection Comparison of RIE vs non-RIE processing

Motivation for new diamond processing

- PLT irradiation studies often show lower pulse height than RD42 predicts
 - PLT performance at P5 exhibits strange features (see Dean's talk tomorrow)
 - unexpected pulse height degradation
 - slower charge collection
 - rate can affect pulse height
- Why?

maybe related to surface defects or surface processing

• Our colleagues in Atlas diamonds have seen some of the above...

Irradiated sCVD from Atlas Bonn Group



Atlas Bonn reprocessing

- Used a combination of mechanical diamond-grit polishing and Reactive Ion Etching (RIE)
 - Removal of about 1.5 microns by polishing and 1.5 microns by RIE to both top and bottom surfaces side of diamond
- They are now involved in a study with an irradiated PLT diamond to find the optimal amount to remove
 - removing 1 micron from each surface per step, then test after each step
 - Haven't gotten any detailed results, but it appears that 5 microns is better than 1 so far.
 - (We plan to do the same study with another irradiated PLT diamond)

What is (**R**)eactive (**I**)on (**E**)tching?

- Use of various RF excited gases (SF6, CHF3, Ar, O2,Cl2 and BCl3 gases) to remove material from a substrates surface
- Totally clean and dry process:
 - <u>no need to chemically clean</u> surfaces before RIE or prior to metallization
 - we've found wet cleaning can leave residues that are very hard to see
- Much gentler and safer, with a smoother surface than using the traditional diamond grit polishing to remove material

Princeton's Fab "PRISM" Etch Process





- Currently removing 3 microns from both surfaces
 - takes about 2 hours per side
 - an additional variable 500W platen source allows for a final "soft bias" surface polishing step
 - can do RIE and metallization in one day
 - can RIE many diamonds together

Potential Difficulties of RIE for Diamond

- Note: etch rate for equivalent Silicon removal is a few minutes!
- 2 hours for diamond for 3 micron removal is a strain on vacuum seals, and other parts → ~\$25 K
- May have to rethink processing by RIE-only if we need much more than 3 microns removal; add mechanical polishing before RIE?

Results from RIE processing

- 1st RIE diamond was the non-Castor, unirradiated PLT S120
 - Before RIE was one of the lowest quality diamonds to pass acceptance
 - After RIE it was worse:
 - earlier voltage breakdown
 - but laser diagnostic showed lots of N in the bulk
 - so not a 'typical' sCVD?

• Next 7 diamonds after RIE show noticeable improvements!

PLT S49 (Castor) Large Side

Before RIE

After RIE



PLT S49 (Castor) Small Side

Before RIE

After RIE





RIE Data Summary: 3 Castor Diamonds

RIE diai	mond	run#s	1V/micron charge loss	% max V	level of rev-pol.% sig @ 0V sig @ 500V	lifetime(m) rev-pol.	source rate (Hz)
Before	39	20537/8	14/10	<500V/700V	38/63	3/6	4/3
After RIE	39	20540/1	18/12	1KV/1KV	53/31	6/3	3/3
After irrad.	39	20550/1	tbd/tbd	1KV/1KV	77/ 200	20/28	4/4
Before After RIE After irrad.	90 90 90	 10510/1 10516/7 <mark>(</mark>	0/0 55/tbd	1KV / 1KV 1KV / 1KV	73/29 130/137	>1/<<1 8 / 20	8/9 8/8
Before	49	20528/9	8/19	<500V/750V	67/83	2/2	23/21
After RIE	49	20533/4	0/4	1KV /1KV	19/31	<<1/<<1	2/2
After irrad.	49	20544/5	55/53	1KV/ 1KV	110/162	12 / 25	4/3

More charge loss than RD42 predicts (~40%) for LANL fluence of 10¹⁵ p/cm² Continued good HV performance after RIE and irradiation

RIE Data Summary: non-CASTOR Diamonds



Improvement in HV \rightarrow 1KV after irradiation (even those without RIE)

Questions:

- Would more RIE improve the post-irradiation CD of the diamonds?
 - Plan to do a 2nd RIE pass on one or more of these.
- Why is the charge loss of CASTOR diamonds higher than RD42 predicts?
 - Needs more RIE?
 - What about 'red' light effect? (see Dean's talk tomorrow
 - Longer pumping needed?
- Do RIE Pixels provide more uniform charge collection across all the pixels?
 - Have recently produced one pixel detector after RIE, in test now
- Does RIE fix the pulse height dependence on rate? (rate effect)
 - Will take several RIE pixel planes to high rate beamtest (at PSI) in mid May

Summary

- Castor and non-Castor diamonds show clear improvements after RIE.
 - more symmetric charge collection
 - full charge collection seen for 2 out of 3 Castor sensors
 - more stable I_{hv} currents; can go to 1 KV without any erratic currents
- Question 1: would more RIE on these diamonds show further improvement?
 - Starting a study to remove 1 micron at a time from an irradiated diamond and measuring the performance after each micron of removal to find optimum amount to remove
 - H Kagan at OSU is doing the same
- Question 2: Does RIE fix the rate effect?
 - Need to RIE then pixelate irradiated diamonds; test with hot source (next week)
 - Ultimate test is to take RIE pixels to PSI for high rate beamtest (mid-May)