Progress in Diamond Sensor Development for Use in LENR Experiments

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Schedule

- Recap of results presented at ICCF 17
- Developments in 2012-2013
  - Procedures
  - Experimental setup
  - Detection methods
- Results
- Conclusions
- Future work
If LENR phenomena are in fact nuclear, it is reasonable to expect nuclear products from their interactions

- Excess heat, neutrons, transmutation into unstable nuclei

Predominant in-situ neutron detector is CR-39

- Integrating detector provides no rate data
- Time delay between experiment and results
- Resolution and threshold energy depend on etching and counting processes
Recap – Motivation

- Useful to switch to diamond
- Real-time detector
  - 50 ps pulse rise-time
- Good energy resolution
  - $R = 2.35 \, N^{-\frac{1}{2}}$
    - $R$: resolution; $N$: # electrons produced
    - For 5.5 MeV alpha particle, $N \sim 4.2E5$
    - Minimum resolution ends up being .365%, 0.3 – 3% in literature
- Low noise
  - 5.47 eV bandgap
  - Insensitive to temperature and stray light
- Chemically inert, can be used in-situ cf. standoff detection modalities
- No easy intrinsic particle discrimination
Recap – ICCF 17

- Preliminary results last year
  - DLC/Pd (10nm/100nm)
  - DLC/Au/Pd (10/100/100nm)
  - Long detector prep time
- Trials using three gases
  - $\text{H}_2$ – contact peeled off
  - He – contact peeled off
  - $\text{D}_2$ – strange peaks
  - Need better deposition mechanisms
- MCNP results
  - Based on MCNP models, whatever caused the signal appears to not be monoenergetic
  - No narrow full energy peaks in observed spectra
Recap – Results

Energy (keV) vs Counts

- Peak = 658.5 keV
  FWHM = 134.5 keV
  Energy Resolution = 23.2%

- Peak = 881.7 keV
  FWHM = 12151.5 keV
  Energy Resolution = 17.2%

- Peak = 312.5 keV
  FWHM = 132.9 keV
  Energy Resolution = 42.5%
Interim Work

- More trials
  - Increase sample size
  - Look for reproducibility
- Using different materials
  - Improve contact robustness
  - Reduce fabrication time
- Single run, no interruptions
- Include SEM
Procedures

- Clean
- Coat
- Calibrate
- Experiment
Procedures – Clean

- 3x3x0.5mm single crystal diamond plate
- Prepare diamonds for deposition
- Alternate acid/base washes
  - Remove metal layers
  - Oxygen terminate the surface
- Interim washing with DI
- Final rinse
  - Acetone
  - Methanol
  - DI H₂O
Electrode materials
- Ti/Au/Pd
- Ti/Pd

Processes
- Argon plasma sputtering
  - 600 eV
- Thermal evaporation

<table>
<thead>
<tr>
<th>Sensor #</th>
<th>Ti (nm)</th>
<th>Au (nm)</th>
<th>Pd (nm)</th>
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<tbody>
<tr>
<td>1</td>
<td>50</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>50</td>
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<tr>
<td>3</td>
<td>50</td>
<td>-</td>
<td>130</td>
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</table>
Procedures – Calibrate

- I-V test
  - Linear between 0-300 V
  - 200 V yields 100% CCE
- Pu-239 calibration
  - First sensor failed calibration check – not used
  - Others showed
  - 2nd sensor used low-activity source for calibration
  - 2.4% resolution at 5.2 MeV
Connected diamond sensor to SHV connectors
Closed chamber
Placed in 3” thick lead cave
Evacuated with diaphragm pump
Load chamber with D₂ gas to pressure of 691 kPa; measured using MKS 722 Baratron Absolute Capacitance Manometer
Energy spectroscopy
- No high energy signal was previously observed
- Only used low energy amplification
- Plotted with GENIE2000

Count rate
- SCA fed into LabVIEW™ counter
Results – Sensor 2, Load 1

Graph 1: 
- X-axis: Time (sec)
- Y-axis: Count rate per 100 ms
- Data points spread out over time with a general trend.

Graph 2: 
- X-axis: Energy (keV)
- Y-axis: Counts
- Multiple data sets for different days, each represented by a different line color.
  - Day 1
  - Day 2
  - Day 3
  - Day 4
  - Day 5
  - Day 6
  - Day 7
  - Day 9
- The data sets show varying counts across different energy levels.
Results – Sensor 2, Load 2
Results – Sensor 2, Load 2
Results – Sensor 3, Load 1

5.0kV 9.8mm x40 SE(M) 6/4/13 23:14

10.0kV 14.1mm x1000 SE(M) 6/4/13 22:22

10.0kV 14.1mm x900 SE(M) 6/4/13 22:07
Results – Sensor 3, Load 1
Results – Sensor 3, Load 1
Counts only indicate that charge is being produced
  - Response is inconsistent with monoenergetic particles
  - Not yet reproducible
  - Current results inconsistent with ICCF 17 results

Possible causes
  - Small-scale delamination of films due to gas loading
  - Interactions between films
  - LENR events

We have a fast and consistent fabrication method to produce robust sensors

So what do we need to do in the future?
Future Work

- Even more trials
  - Consistent production method on a faster turnaround than initial diamonds
  - Improve chances of reproducibility
- Make additional control measurements
  - Number of controls so far is small; results are inconsistent.
- Prepare two sensors simultaneously
  - Expose one to inactive gases (H,He)
  - Expose other to deuterium
  - Ideally both experiments are isolated and run simultaneously
  - Distance between ideal and actual is measured in cost
Future Work

- Account for interactions at Ti-Pd interface
  - Separate Ti & Pd, swap with Au or
  - Determine lattice characteristics after loading
- Once we establish reproducibility conditions
  - Analyze all reaction and energy release mechanisms to correlate with measured spectra
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Questions?