# Low-Z Thin Film Stripper Foils, Targets and X-Ray Windows

Contract # DE-SC0011287

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**nanoRANCH**
***UHV Technologies, Inc.***

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# Outline

- Overview of UHV Technologies/nanoRANCH
  - History and Core Competencies
- DOE NP Phase II SBIR Project
  - Free Standing Diamond-Boron Stripper Foils
  - Diamond X-Ray Windows for Low Energy Detectors
- DOE NP Phase I SBIR Project
  - Scalable

# UHV Technologies, Inc. (aka nanoRANCH)

- **23 year old high tech company with facilities in Lexington, KY and Fort Worth, TX**
  1. **New headquarters in Lexington, KY opened in 2016**
  2. **Over 20,000 sq. ft. combined Manu. & R&D Space**
  3. **Active collaboration with 10+ Universities**
- **3-Prong business strategy**
  1. **R&D in Advanced Thin Films, Diamond, Nano-Materials & Devices, X-Rays, Artificial Intelligence and Deep Learning, & Optical Fiber Coatings**
  2. **In-House Small Scale Manufacturing**
  3. **Commercialization through Subsidiaries and Alliances**
  4. **Various spin-offs including 1 IPO (NASDAQ) and > 22 million in Venture Capital**
- **Current Status**
  1. **20+ employees**
  2. **$2.5M revenue in 2016, $3.5M expected in 2017**
  3. **Multiple R&D contracts and products**


# R&D Facilities

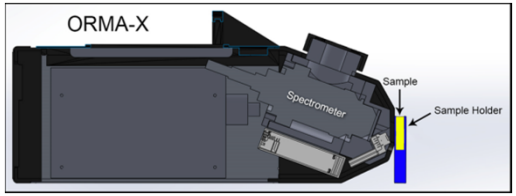

*UHV Technologies, Inc.*

# Current R&D Projects

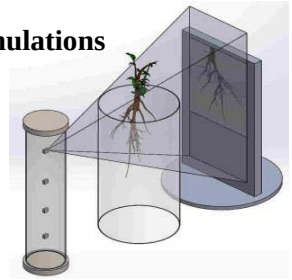
1. **Mercury Air Continuous Emissions Monitor (CEM) 2013-16**
   - US-DOE Phase II Project + Matching funds from KY
   - Spin-off: nanoRanch Environmental Systems, LLC in Lexington, KY

2. **In-Line High Throughput Scrap Metal Sorter 2014-19**
   - Funded by US-DOE ARPA-E Project and Commercial Partners
   - Uses advanced sensors and artificial intelligence; throughput ~ 100M lbs/year

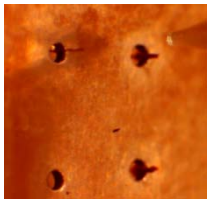
3. **On-Line Real Time Metal Analyzers for Pharma Industry 2015-18**
   - NIH Phase II SBIR Project and KY Matching Grant
   - Real time contamination detection in solid, liquid and gel formulations




4. **Stationary CT for *In-Situ* Imaging of Roots 2017-19**
   - US-DOE ARPA-E Project



5. **Nano-Crystalline Low-Z Thin Films for X-Ray Windows 2014-17**
   - US-DOE Phase II Project and KY Matching Grant



6. **A Scalable Additive Manuf. Technology for Large Area PCBs 2017**
   - US-DOE Phase I SBIR Project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# Product Photos


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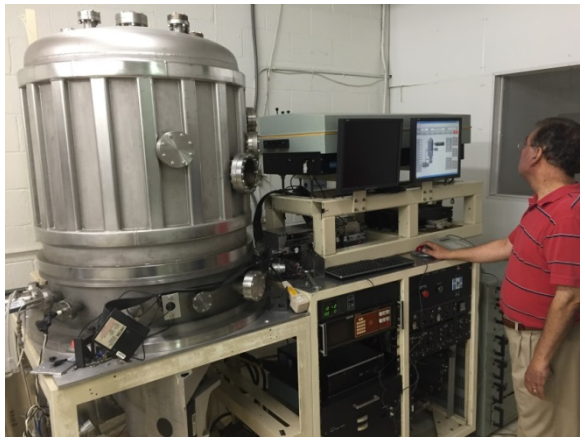
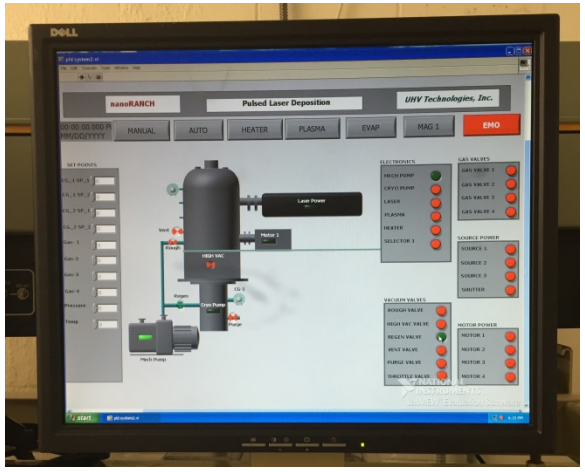
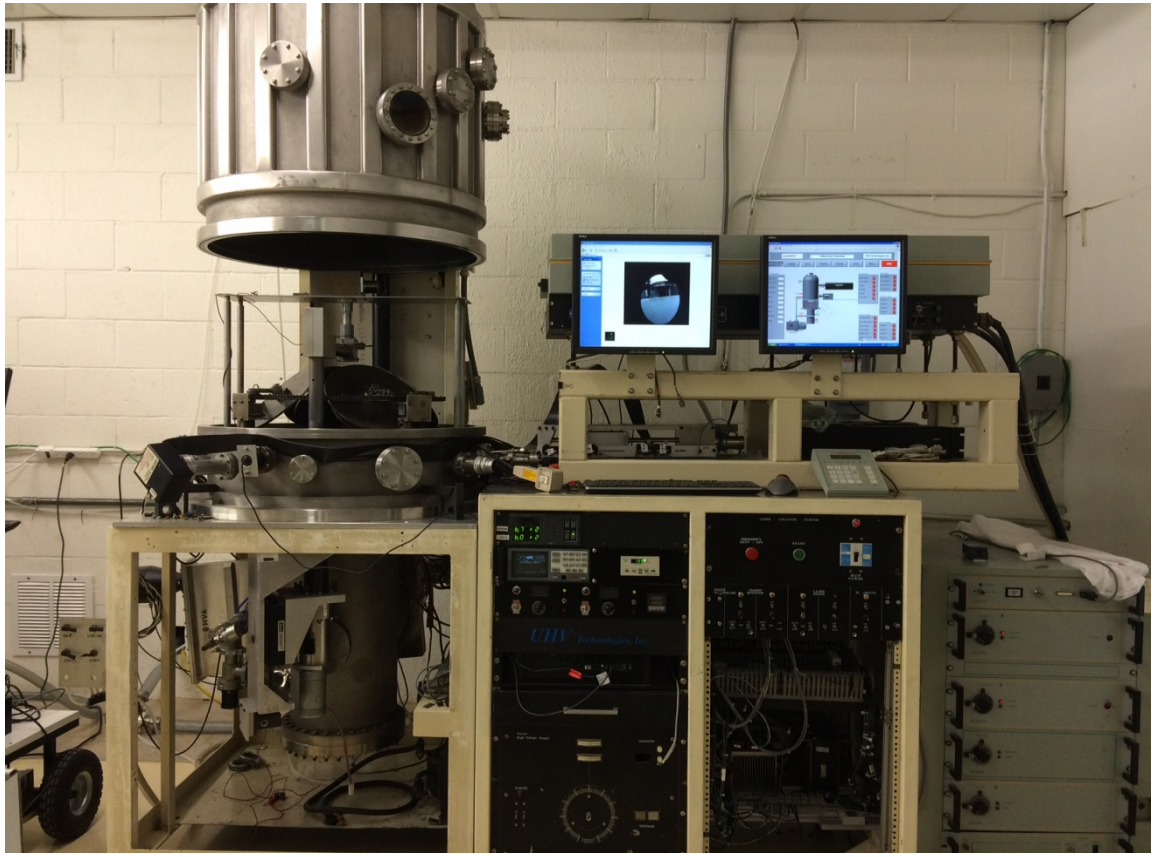
# NP Phase II SBIR
# Low-Z Stripper Foils, Targets and Windows

- **Team:** UHV and NSCL/MSU (Dr. Wolfgang Mittig)
- **Objective:** The goal of this project is to develop technologies for the production of **free standing low Z thin films** in the range from a few ug/cm$^2$ to over 100mg/cm$^2$ for applications as charge strippers and targets in heavy ion accelerators as well as x-ray windows for low energy x-ray detectors and gas ion detectors.
- **Key Technical Concept**: Free Standing Thin Films consisting of 10-100's of stress controlled nano-layers
- **Enabling Technologies:**
  - Fully automated nano-layer PLD manufacturing system
  - Instrumentation for *in-situ* measurement and control of stress in individual and multi-layer thin films
  - Computer controlled process optimization

# Automated Stripper Foil Manufacturing System





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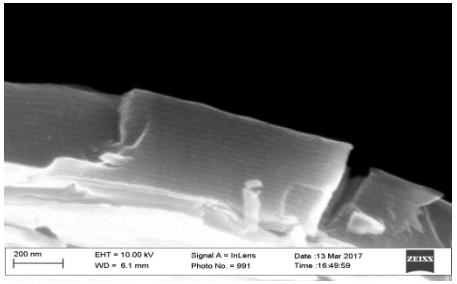
**nanoRANCH**

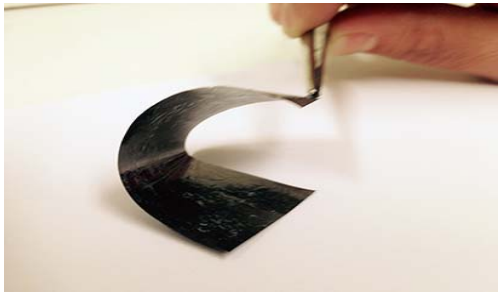
# 100+ Layer C-B Thin Film Design

| |
|---|
| PAD nano-Carbon Layer |
| PLD nano-Diamond Layer |
| PAD nano-Carbon Layer |
| PLD nano-Diamond Layer |
| PAD nano-Carbon Layer |
| PLD nano-Diamond Layer |
| PAD nano-Carbon Layer |
| Release Layer |
| Substrate |

| |
|---|
| **PLD nano -Diamond Layer** |
| **PLD nano -Boron Layer** |
| **PAD nano -Carbon Layer** |
| **PLD nano -Boron Layer** |
| **PAD nano -Carbon Layer** |
| **PLD nano -Diamond Layer** |
| **PAD nano -Diamond Layer** |
| **Release Layer** |
| **Substrate** |

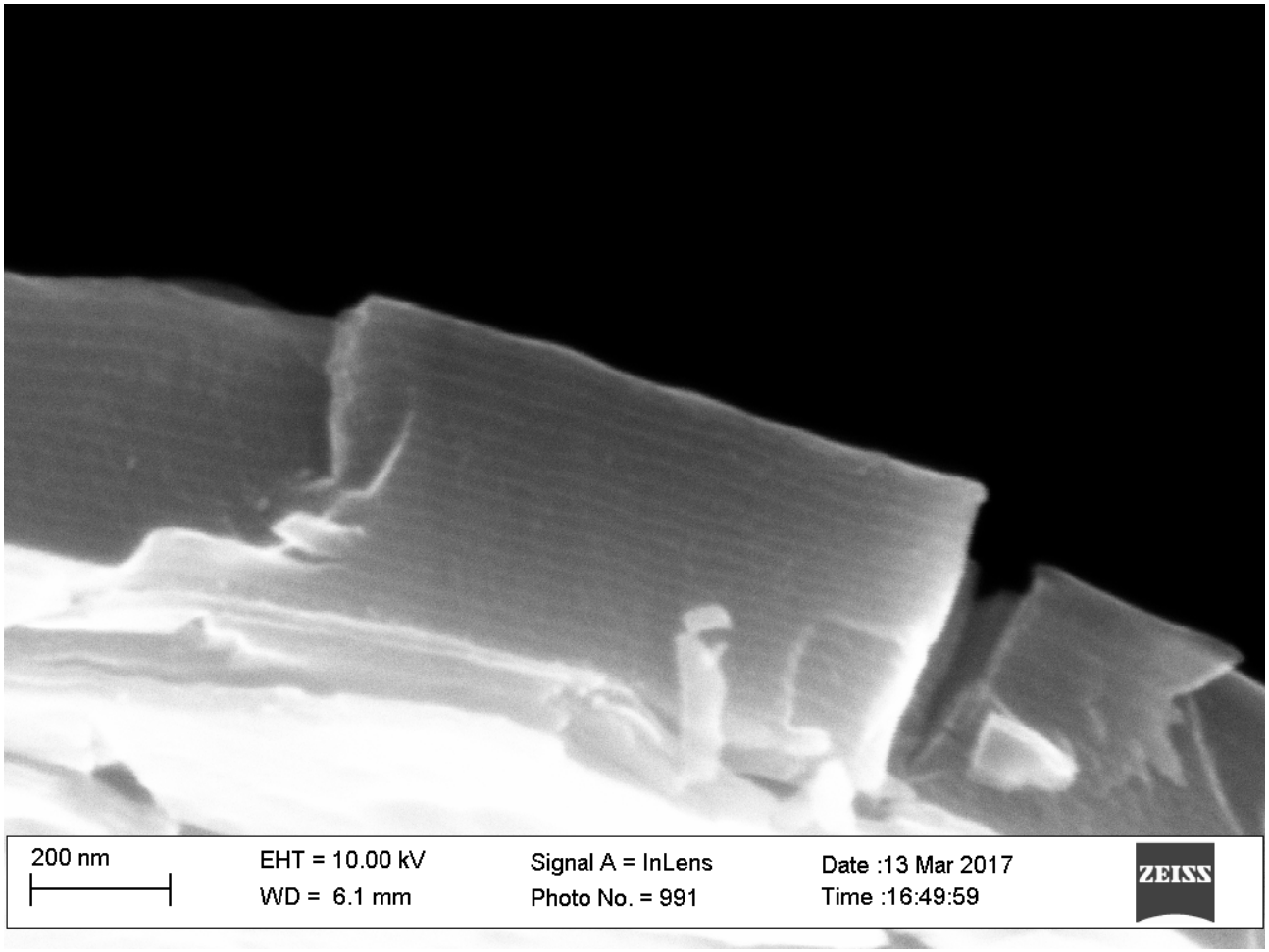
| |
|---|
| **PLD nano -Diamond Layer** |
| **PLD C-B Mixed Layer** |
| **PAD Mixed nano -Boron Layer** |
| **PLD C-B Mixed Layer** |
| **PAD Mixed nano -Boron Layer** |
| **PLD C-B Mixed Layer** |
| **PAD Mixed nano -Diamond Layer** |
| **Release Layer** |
| **Substrate** |



# SEM of Multi-Layer Foils

**C-B Foil**
**48 Layers**
**B/C= 10%**



# 2016 Stripper Foil Data

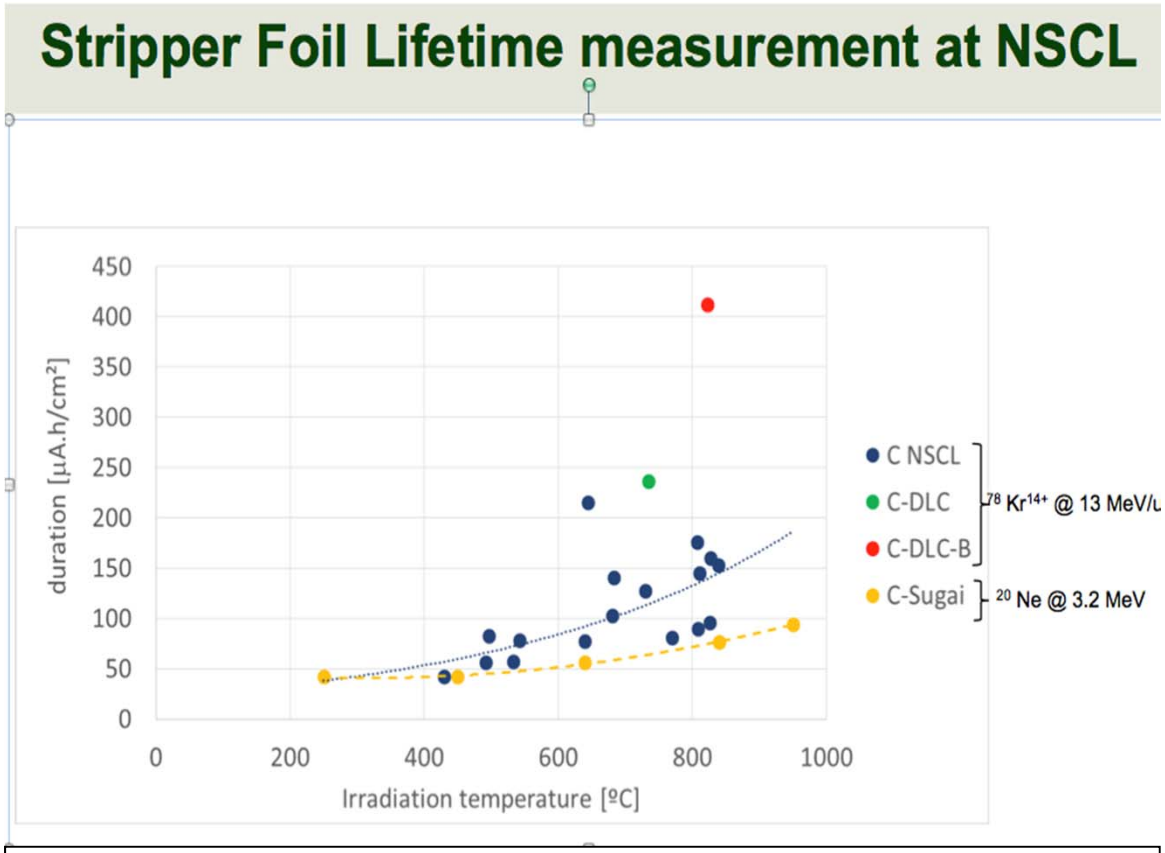


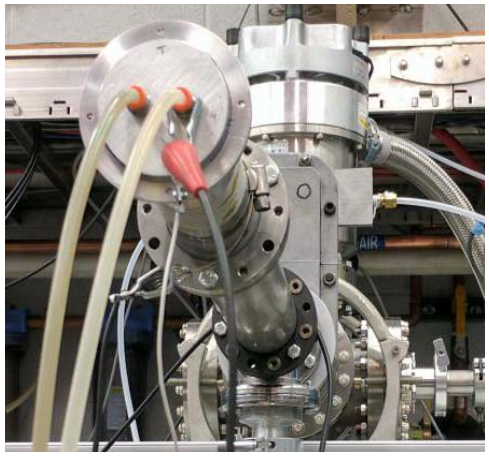

**Figure 10**: Lifetime result at the stripper injection system of the NSCL. The results are compared to results from Sugai with a Ne beam (I.Sugai et al., NIM B 269 (2011) 223)

# Foil Comparison Experiments

Comparison of 8 different types of stripper foils was performed by irradiating them with $Ar^{4+}$ beam under different intensities and fluences at the 5U accelerator of University of Notre Dame

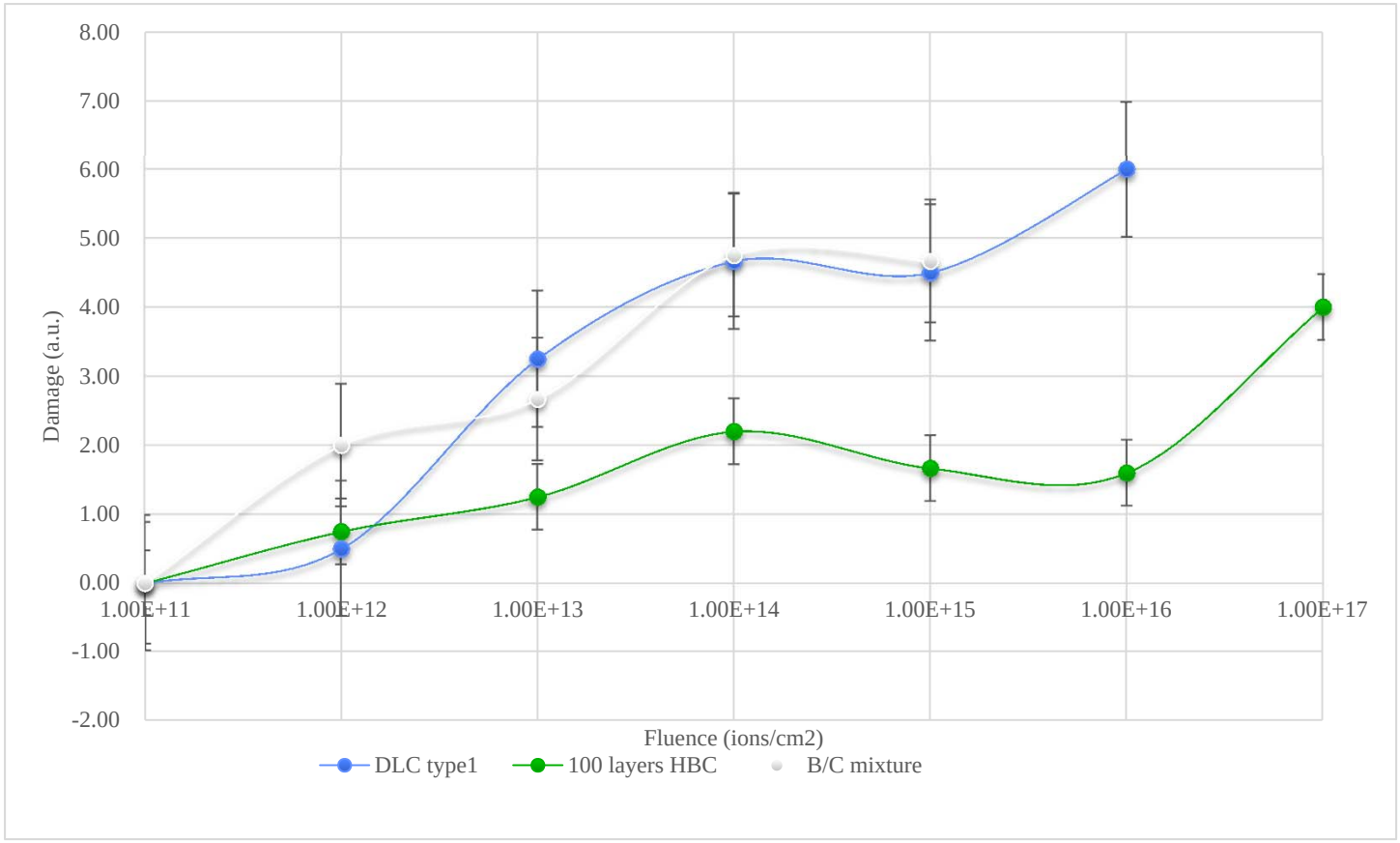
| Code | Foil type |
|---|---|
| 1 | One layer DLC, type 3 |
| 2 | One layer DLC, type 1 |
| 3 | 7 layers HBC, 4B+3C |
| 4 | 9 layers HBC, 5B+4C |
| 5 | 17 layers HBC, 9B+8C |
| 6 | 48 layers HBC, 24B+24C |
| 7 | 100 layers HBC, 50B+50C |
| 8 | One layer 10%B+90%C mixture |

# Irradiation Damage to Foils

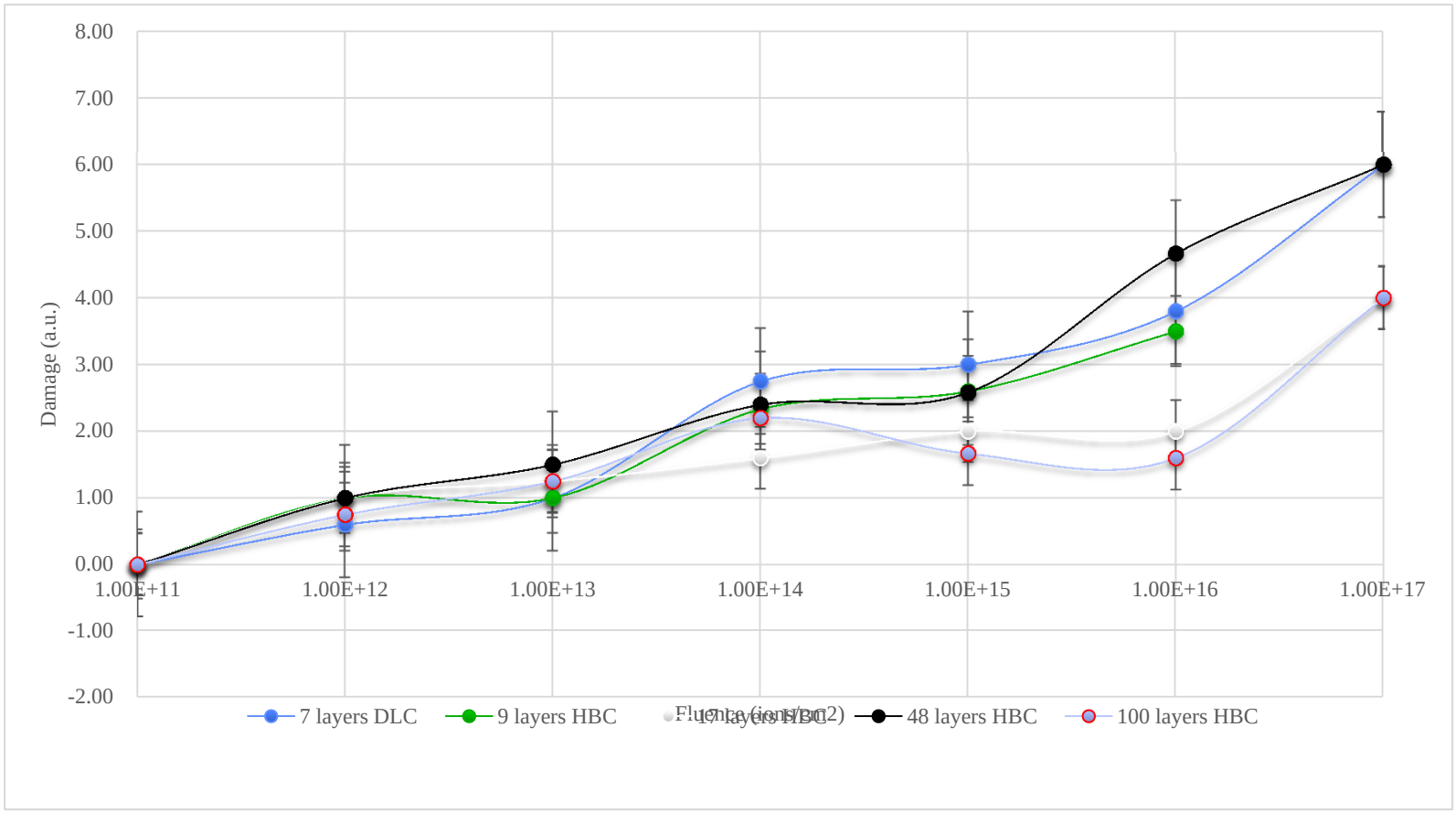


| | BEFORE | AFTER |
|---|---|---|
| 7-Layer HBC |  |  |
| 100-Layer HBC |  |  |

# Damage for Various Types of Foils



# Damage vs Number of Layers




**CONCLUSION: 100 layer foils are better than all others foils tested**

# Low Energy X-Ray Window Development

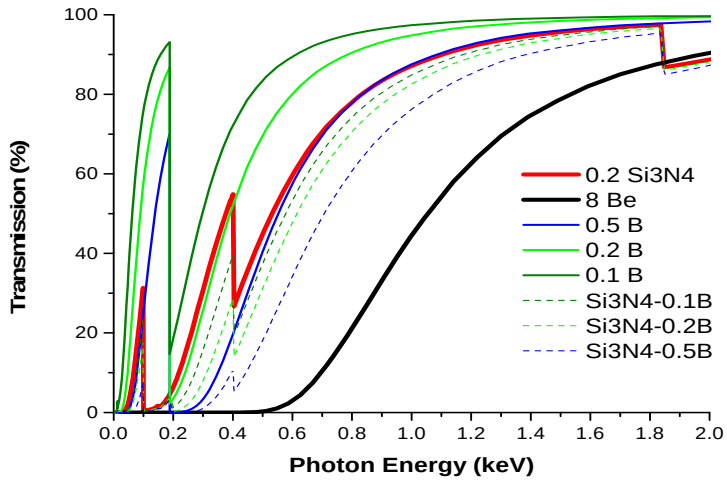



**Figure 1:** A comparison of low energy low energy x-ray transmission of diamond (C) and boron (B) windows of different thicknesses in comparison with standard Be window.

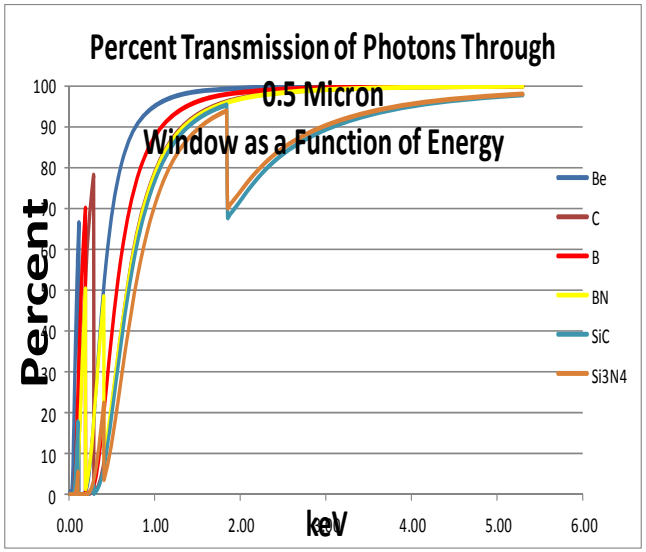


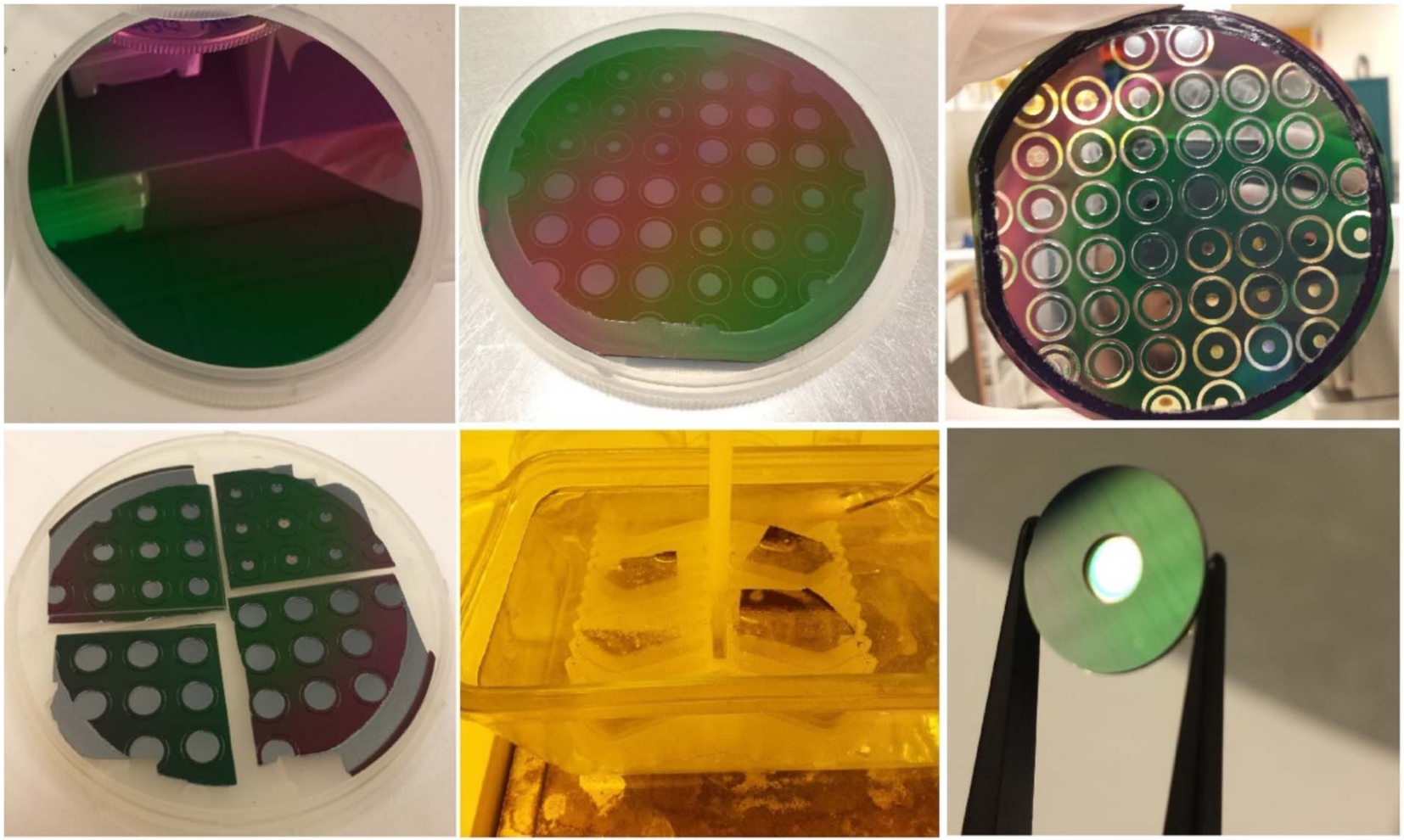

**Figure 2**: Calculated x-ray transmission curves for 0.5micron thick films of various materials at UHV.

# Low Energy Window Design

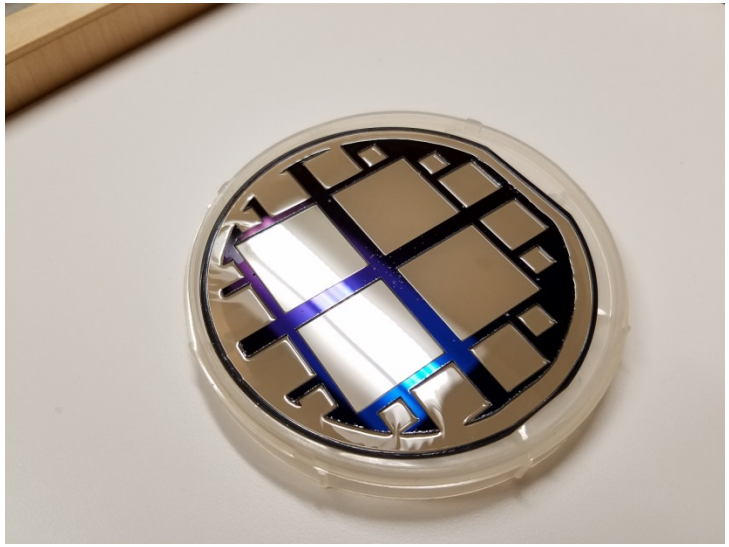
**Figure 4:** A photograph of a 9mm diameter 200nm thick $Si_3N_4$ window made by UHV.

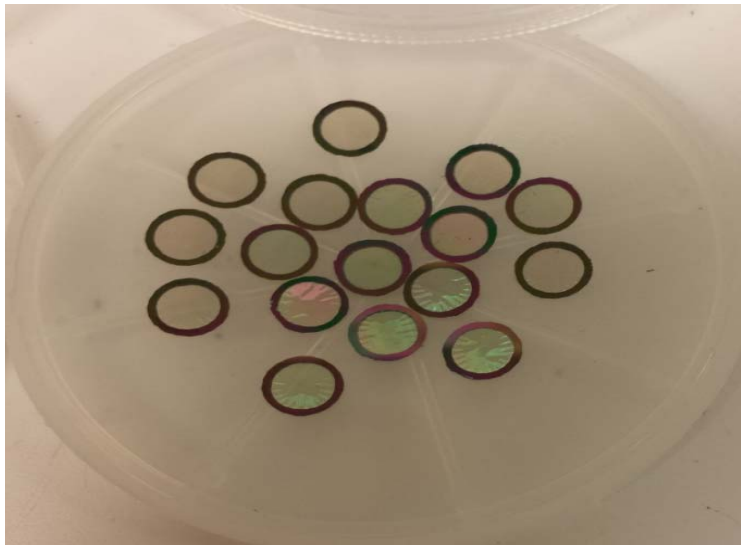
**Figure 5:** Photograph of a sealed x-ray detectors made by Ketek using 9 mm diameter Be window.

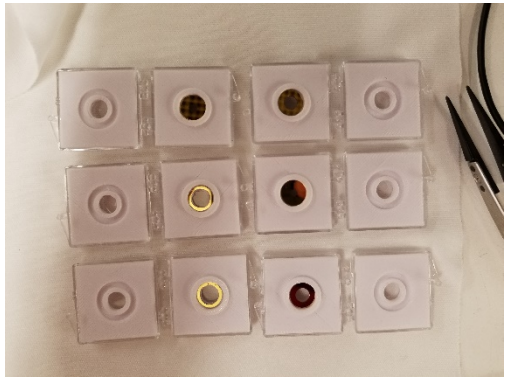
# Wafer Fabrication

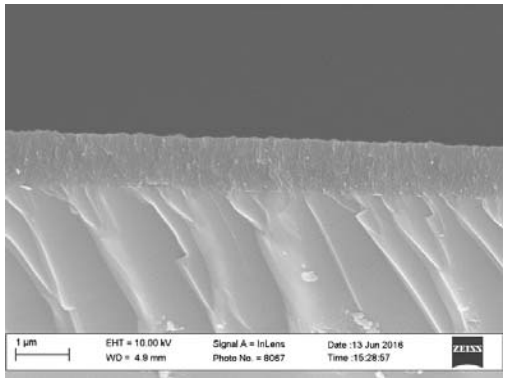


# Photographs of Various X-Ray Windows










# Phase II & Commercialization Plans

- Currently in No-Cost Extension until 10/17. May ask for another NCE if NSCL-MSU needs more time for further testing
- Fabricate and evaluate 200 and 400 layer foils, different thicknesses
- Explore other nano-crystalline multi-layer thin films
  - High brightness field emission cathodes
  - Magneto-electric bi-layer films
  - PZT-BFeO3 strained piezoelectric films
- Currently seeking partnerships with x-ray detector manufacturers to integrate x-ray windows in their spectrometers.
- The Stripper Foil Manufacturing facility is ready and is already providing foils to NP Community

**CALL US WITH YOUR REQUIREMENTS**