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

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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
- Other R&D Projects

UHV Technologies, Inc. (aka nanoRANCH)

- **First Full-time Employee in June 1998 (Dr. Nalin Kumar)**
- **Mission Statement: UHV will use state-of-the-art technologies to develop innovative products and rapidly commercialize them through subsidiaries and strategic partnerships.**
- **Raised $22 in venture capital in 2000 for Thin Film spin-offs**
- **Several Spin-offs:**
  - **International Delta Systems, LLC**
    - Turn Key Equipment and Vacuum Systems`
  - **LightMatrix Technologies, Inc.**
    - Components for the Fiber-Optic Networks
  - **Genome Data Systems, Inc.**
    - Genomics and Micro-Fluidics
- Combined CY2015 Revenue ~ $ 1.5 M
- 10,000 sq. ft Facility in Fort Worth, TX
- Opened new 6,000 sq. ft Headquarters in Lexington, KY in Jan. 2016

Core Competencies and Business Strategy

- Advanced Thin Films Materials and Devices R&D
  - Wide band gap cathodes (nano-diamond, and nanotubes)
  - Cathode based devices (x-ray sources, detectors, light sources)
  - Fiber Coatings (optical fibers and composite fibers)
- In-House Small Scale Manufacturing
  - DLC Stripper Foils (DOE Phase I project commercialization)
  - Diamond Cathodes and other coatings (NSF Phase II commercialization)
  - XRF Calibration Standards (nanoXRF)
- Commercialization through Subsidiaries and Alliances
  - Indel Systems
  - LightMatrix Technologies, Inc.
  - Genome Data Systems, Inc.
  - Stellarray, Inc.
  - TRIUMF/AAPS/MicroMatter, BC, Canada

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

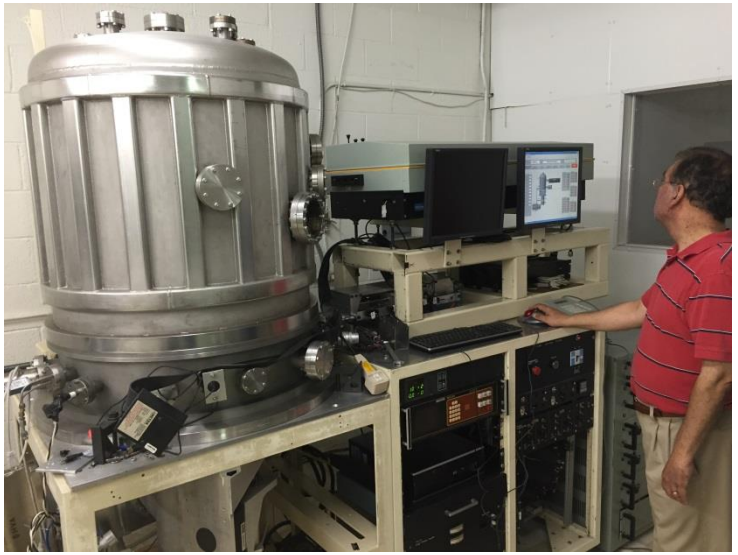
- **Team:** UHV and NSCL/MSU (Dr. Wolfgang Mittig)
- **Objective:** The goal of this project is to develop technologies for the production of **free standing low Z thin films** in the range from a few ug/cm^2 to over 100mg/cm^2 for applications as charge strippers and targets in heavy ion accelerators 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
  - Instrumentation for *in-situ* x-ray transmission measurement

DOE Funded Phase II SOW

Schedule: Low Z Thin Films-Ph II

Task	SA Name	Quarters 1 2 3 4 5 6 7 8	Milestones
1	Design & Assemble Full Automation		M1
2	*in-situ* Process Control Instrumentation		M2, M3
3	Develop Automated Thin Film Processes		
4	Fabricate Thin Films		M4
5	Evaluate Multi-layer Film Properties		M5
6	Evaluate Films for Stripper Foils		M6
7	Optimize Films for X-Ray Transmission		M7
8	Optimize Films for X-Ray Window		M8
9	Develop and Optimize X-Ray Windows		M9

Automated Stripper Foil Manufacturing System

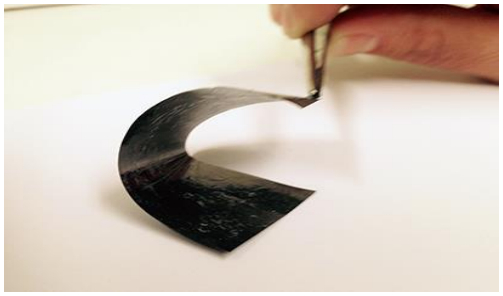


Thin Film Design

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



Preliminary Stripper Foil Data

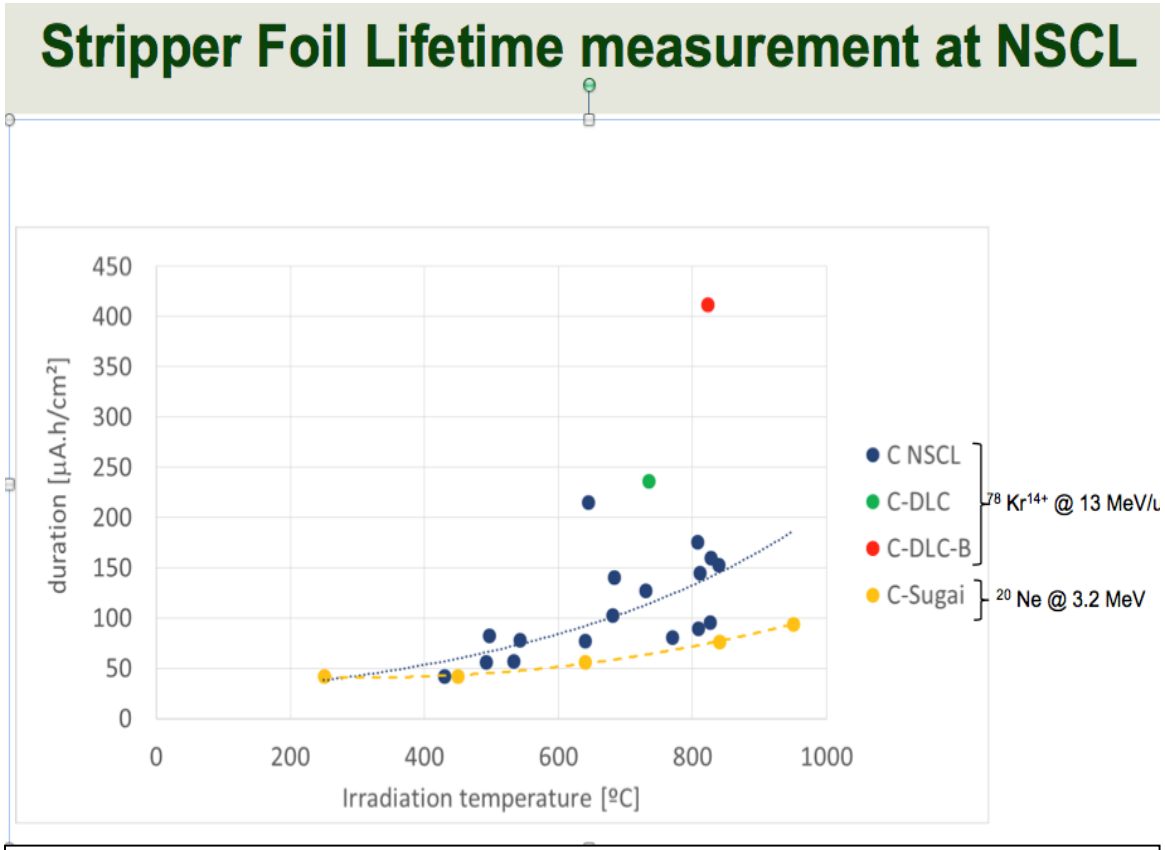


Figure 10: Lifetime result at the stripper injection system of the NSCL. The results are compared to results from Sugai with a Ne beam (I.Sugai et al., NIM B 269 (2011) 223)

Low Energy Window Design

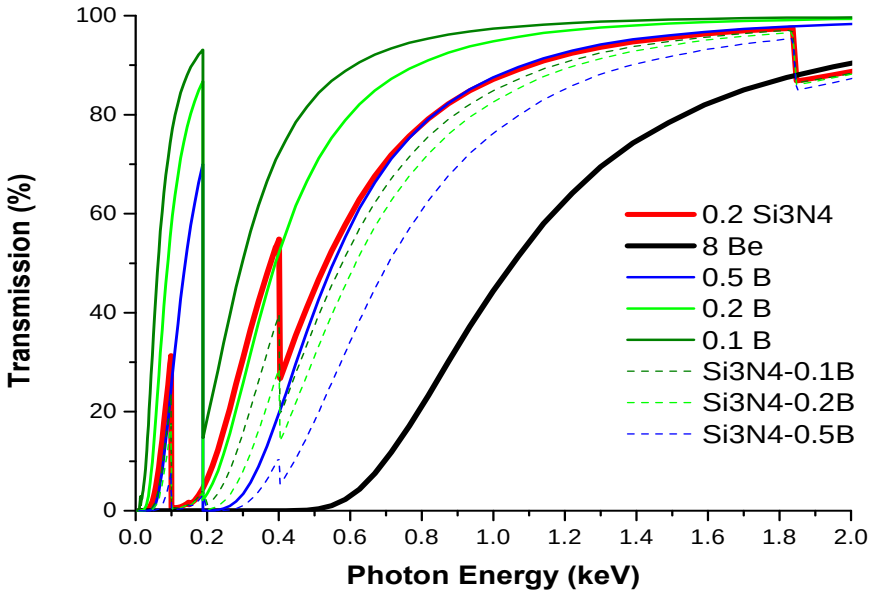


Figure 1: A comparison of low energy low energy x-ray transmission of diamond (C) and boron (B) windows of different thicknesses in comparison with standard Be window.

Low Energy Window Design

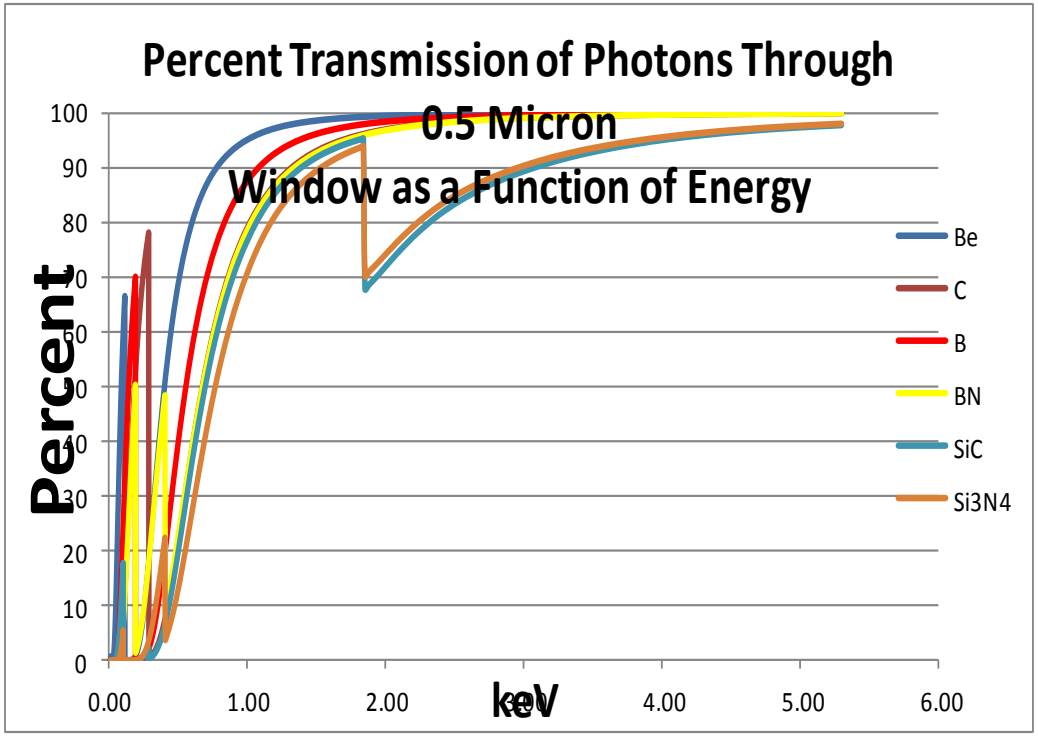


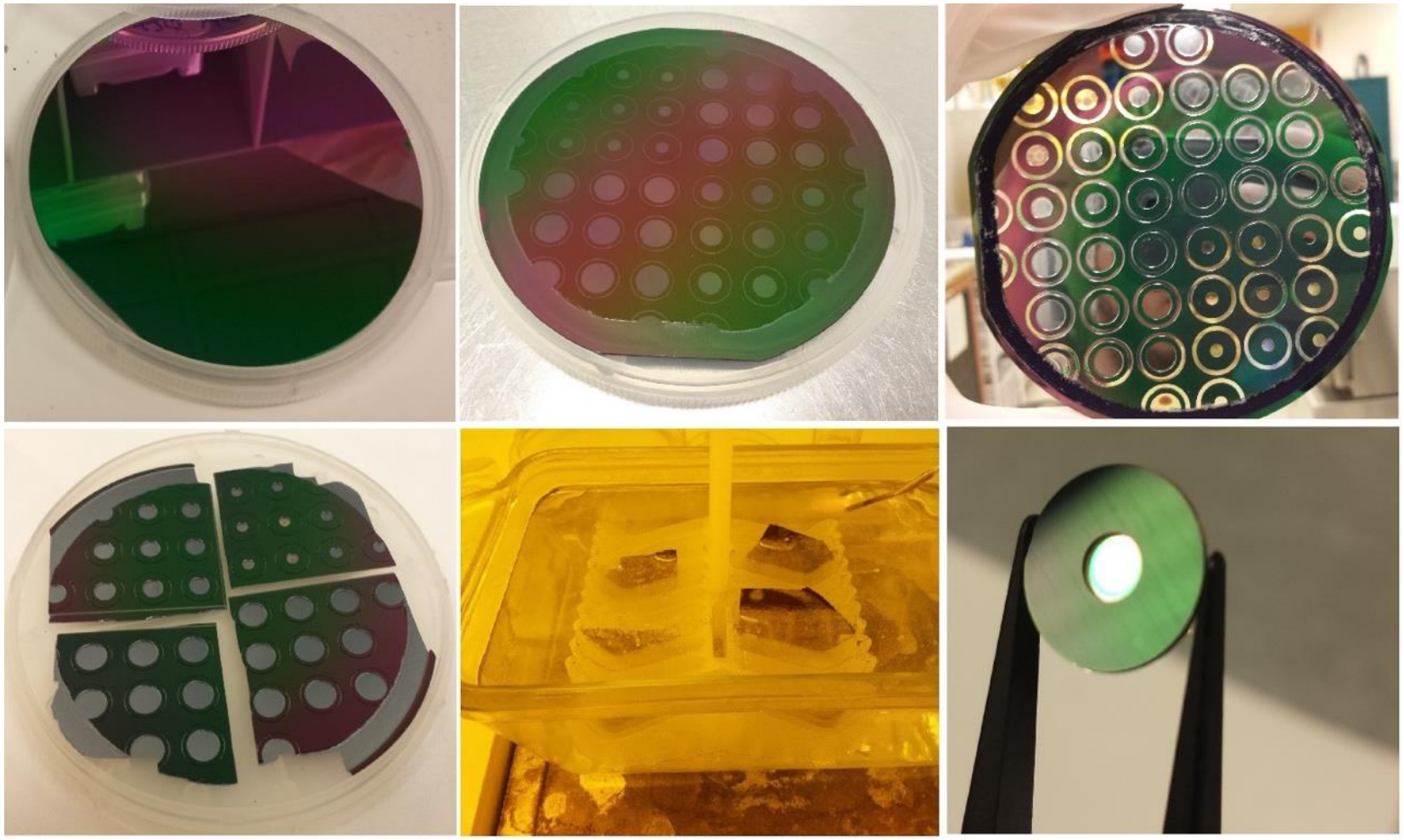
Figure 2: Calculated x-ray transmission curves for 0.5micron thick films of various materials at UHV. Please note that even though 0.5 micron thick Be has the best transmission, films/foils thinner than 8 microns cannot be used due to pin-holes and poor strength, which is why we need ceramic films.

Low Energy Window Design

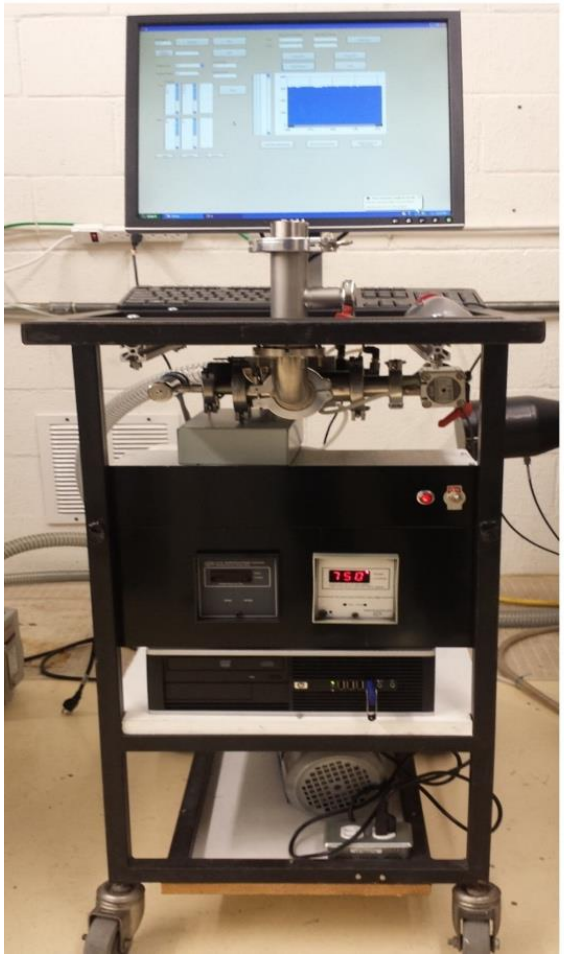
Figure 4: A photograph of a 9mm diameter 200nm thick Si_3N_4 window made by UHV.

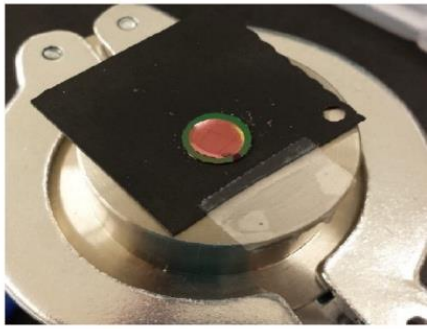
Figure 5: Photograph of a sealed x-ray detectors made by Ketek using 9 mm diameter Be window.

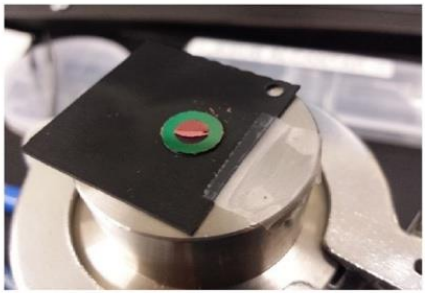
Wafer Fabrication

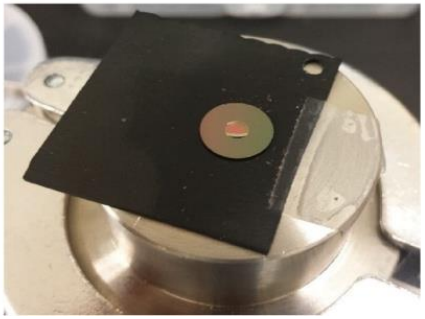


Window Testing









Window Results

	3 mm	5mm	7mm
Si_3N_4 (500 nm thick) **Dry + Wet Etching** **09/18/2015**	-Passed: 7 of 8 -Minimum Pressure: 122 mTorr	-Passed: 6 of 8 -Minimum Pressure: 128 mTorr	-Passed: 1 of 10 -Minimum Pressure: 232 mTorr Broken after 3 cycles.
Si_3N_4 (500 nm) **09/25/2015**	-Passed: 2 of 7 -Minimum Pressure: 132 mTorr Dry Etching	-Passed: 4 of 11 -Minimum Pressure: 150 mTorr Dry + Wet Etching	-Passed: 1 of 11 -Minimum Pressure: 138 mTorr Dry + Wet Etching
	-Passed: 7 of 8 -Minimum Pressure: 142 mTorr Dry + Wet Etching		
UNCD (1um) **Dry + Wet Etching** **10/05/2015**	-Passed: 2 of 4 -Minimum Pressure: 131 mTorr	-Passed: 1 of 8 -Minimum Pressure: 130 Torr.	-Passed: No one
Si_3N_4 (500 nm) **11/02/2015** **Dry Etching**	-Passed: 7 of 8 -Minimum Pressure: 125 mT	-Passed: No one Broken ~400 Torr.	-Passed: No one
Si_3N_4 (500 nm) **11/16/2015** **Dry Etching** **New mask**	-Passed: 7 of 8 -Minimum Pressure: 123 mTorr	-Passed: No one Broken almost immediately	No windows

Fabrication Equipment

Fabrication Equipment

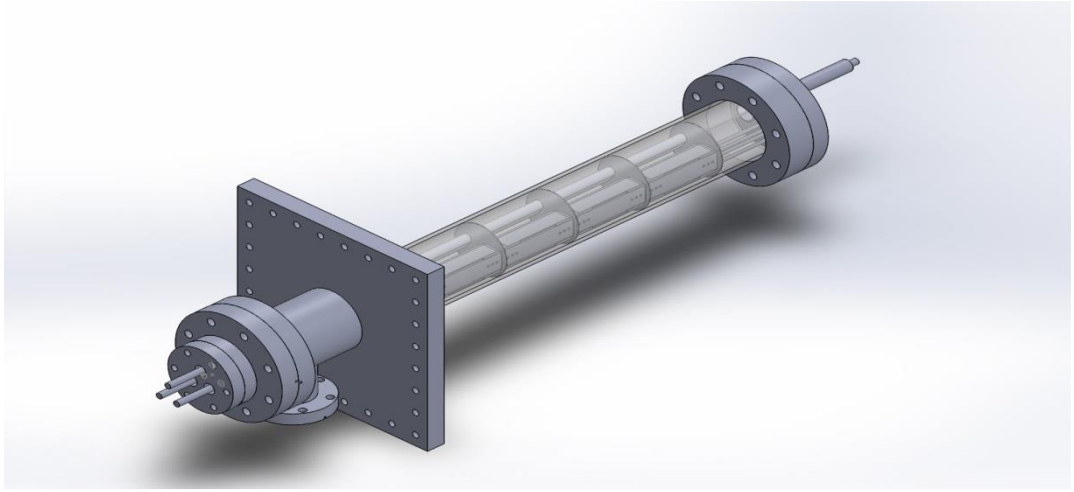
Fabrication Equipment

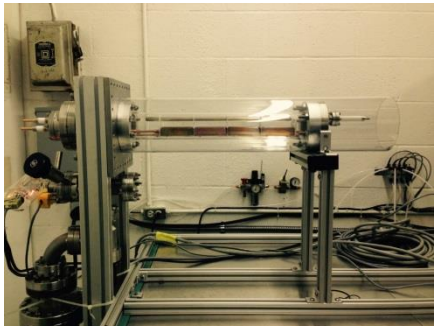
Fabrication Equipment

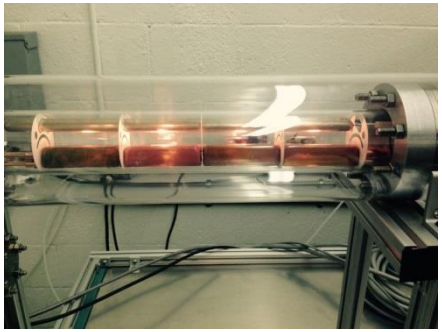
High Throughput Scrap Metal Sorter

Funded by US Dept. of Energy ARPA-E ($ 2M in 2014-16), Partnership with OmniSource
Objective: Develop a commercial scale aluminum scrap sorter (30-100 million lbs/year).
Current Status: Successfully installed a 30M lbs/year capacity sorter installed at OmniSource

Low Cost High Power Linear X-Ray Tube







FEATURES:

1. **Ideal for Industrial IL-XRF**
2. **Low Cost & Long Life**
3. **Demountable**
4. **Repairable in Field**
5. **Scalable to 36+ inch long***
6. **High Power (> 5KW)****

OTHER APPLICATIONS:

1. **Metal/Electronic Sorting**
2. **Isotope Replacement**
3. **Blood Irradiators**
4. **Industrial Irradiators**
5. **Wastewater Treatment**
6. **Water Purification**
7. **Diamond Mining**
8. **Food Sterilization**
9. **Medical Sterilization**
10. **Baggage Scanners**

*** 18” long tube built in Phase I with 4 x-ray beams**

**** Tested at 2kW (500W per beam) for >100 hours so far**

Continuous Emissions Monitor for Mercury from Coal Power Plants

Funded by US Dept. of Energy Office of Science SBIR Phase II (2013-16)
Objective: Develop an ultra-sensitive mercury instrument for real time measurement and control.
Current Status: Successfully developed prototypes ready for installation at two power plants.

Other R&D Projects

- Room Temperature **3D Printing of Copper on Plastics** for Large Area Circuit Boards
- Radiation Hard UHV Components such as **Rotary Seals**
- Optical Fiber Coatings for **Rad Hard Sensors** & Optical Interconnects
- High Performance Glass Sealing and Brazing to support Linear X-ray Tube Manufacturing

Key Personnel (UHV)

Dr. Nalin Kumar

- 30+ years of experience in advanced materials, electronic instrumentation and thin film coatings/equipment development.
- **62 issued US Patents**. More than 10 pending patents.
- BS in EE from Thapar Intitute of Engineering and Technology, India
- MSEE and Ph.D. in Microelectronics and Thin Films from Drexel University
- Microelectronics and Computer Technology Corp. for 5 years
- VP/Director of R&D at SI Diamond Technology, Inc., Austin, TX for 4 years
- Sarnoff Corporation, Princeton, NJ for 1 year
- President/Founder of UHV Technologies, Inc. 1997-to-date
  - President of Indel Systems, LightMatrix (subsidiaries of UHV) 2000-2002
  - Co-Founder of Genome Data Systems (2000)
  - CTO of Stellarray (2009-2012)
  - Raised over $60 million in private and venture funding over the last 20 years

Commercialization History-1

1. **Nano-diamond field emission cathodes and Displays (1989-1996)**
   - Based on 30+ patents by Dr. Kumar in early 1990's
   - Commercialized through a start-up company (SI Diamond Technology) with funding from angel investors, venture capitalists and NASDAQ. Dr. Kumar helped take the company public, raise over $40 million in funding for flat panel display screens
   - Patents and technology licensed to a consortium of Japanese companies. SIDT is currently known as Applied NanoTech Holdings (APNT). These patents are being used by several Japanese companies to manufacture flat screen displays and televisions. **The total payments on these patents have already exceeded $10 million to APNT and MCC (original owner of Dr. Kumar's patents).**
2. **Equipment and Instrumentation Manufacturing (1997- to-date)**
   - Launched another 100% owned spin-off Indel Systems in 1998 to rapidly commercialize the high risk technologies developed at UHV
   - Sold capital equipment (over $5 million in 2001) to fortune 100 companies. These included: Ford ($500,000), Nortel Networks ($600,000), Dupont (1.24M), Boston Laser (1.2 M) and GE ($510,000) among others.

Commercialization History-2

3. Optical Fiber and Telecommunications Devices (1999-2003)

- Based on 5+ patents on fiber coatings by Dr. Kumar during 1985-95
- Won a SBIR Phase I contract from DoD in 1998 for UHV
- Spun off LightMatrix Technologies in 1999 and raised **$22 million in venture capital**
- Grew Company to over 70 employees by 2002 and developed several products. For customers such as Corning, Lucent, Nortel, Cisco and Agilent.
- Company was shut down due to the telecommunications downturn/bust.

4. High Throughput Screening Equipment (2000-to-date)

- Founded Genome Data Systems with his brother, Dr. Rajan Kumar, MD, Ph.D.
- Developed a high throughput cell based assay equipment and technology using apoptosis screens with funding from NIH. The equipment developed during this project is located in UHV's facility is being used for HTS assays and noanobiotechnology
- Currently exploring commercial opportunities for drug discovery and assaying in DFW area.

Commercialization History-3

5. Stripper Foils (2006-to-date)

- Based on DOE Phase I SBIR funded free standing diamond like carbon (DLC) stripper foils for high energy cyclotrons for manufacturing of radio-pharmaceuticals for cancer treatment
- Manufactured two systems to TRIUMF of Canada for manufacturing DLC foils for their 29MeV cyclotrons for supplying radio-pharmaceuticals to most of western North America.
- Currently commercially sales of foils through www.nanoranch.com. Supplying to Cardinal Health in Texas.

6. Medical Devices (2009-2012)

- Took over at CTO of SMD (partly owned by Kumar) and its subsidiary Stellarray to develop an X-ray Based Blood Irradiator with NIH and TX funding.
- Currently going through FDA approvals
- NK and MG own approx. 48% of SMD.

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Thank you very much for your time!