Graphene Backing for Radioisotope Targets

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Outline

- Who is Applied Nanotech (ANI)?
- Prior effort using graphene
- Problem – need for radioisotope targets
- Approaches for using graphene foils to make targets – description of results
- Commercialization
About ANI

- Located in Austin, Texas
- Founded 1988, publicly traded
- In 2014, merged with Nanofilm (Cleveland, OH), both are now subsidiaries of Nano Magic Inc. (OTC:NMGX)
- Technology emphasis:
  1. Graphene foils and films
  2. Isotope Targets
  3. Printed Electronics (Ink and pastes of Cu, Ni, CuNi-alloy, Al, Ag, custom formulations)
  4. Sensors
- Nano Magic has 20+ employees, ANI has staff of 4
- ISO 9001:2015 Certified Quality Management System
Prior ANI Effort Using Graphene

- Graphene Stripper Foils for FRIB (Facility for Rare Isotope Beams).
  - DoE grant DE-SC0000852: The goal of this program was to develop a high thermal conductivity, rigid, large area, uniform carbon foil for charge stripping in accelerators, capable of having long lifetime.
  - Fabricated by filtration of reduced graphene oxide (rGO). Size up to 25 cm diameter (typical 12.5 cm diameter), typical thickness 0.1 to 1.0 mg/cm², can be cut per order.
  - Longer lifetime (up to 2x) in charge stripping applications compared to conventional vapor-deposited carbon foils.
Prior ANI Effort Using Graphene

- The foils are smooth and have a metallic luster
- Foils are robust, easy to handle and survive express shipping
- Lifetimes exceeding 7,500 µA-hrs routine in GE PETtrace cyclotrons
- Can be cut to size (customer specs)
- Several foil mounting options
- Thermal conductivity measured at 1480 W/mK (laser flash method) = similar to HOPG
Carbon Nanotech (CNT) + Graphene Foils

- Developed new stripper foil with 50:50 mixture of CNT and graphene.
- CNT-enhanced foils:
  - Are stronger and stiffer than graphene-only foils.
  - Are rougher with higher porosity – leading to higher number of nucleation sites for plating.
  - Have a greater ability to hold nanoparticles and micropowders of target materials
  - Can layer the target with carbon-rich and target-material-rich surfaces.

![SEM image of CNT-Graphene foil](image1)
![SEM image of standard graphene foils at same magnification for comparison](image2)
Problem

A variety of thin isotope targets are needed in NP research

- Need for robust backing made of a low Z material

- Targets of interest: refractory metals, targets with limited amounts of isotopes available (mg quantities), both stable and radioactive isotopes, B-11, etc, that are difficult to make thin (0.5 -10 mg/cm²).

- Effective, efficient methods of thin target fabrication are needed

  This program: Graphene Backing for Radioisotope Targets

  DoE Grant DE-SC0017208, Phase II completed

  (Topic 26(e) - Specialized Targets for Nuclear Physics Research)
Target fabrication approaches

- Use thin graphene backing films for target fabrication by magnetron sputtering:
  - Demonstration – deposit enriched $^{11}$B$_4$C boron carbide

- Spin-coating target material onto graphene substrates

- Use graphene foil as a cathode for electroplating of isotopes:
  - Demonstration – plated natCr and $^{52}$Cr on graphene target

- Use graphene or CNT+graphene as a matrix for composite targets where the target material is in nanoparticle or few micron powder format. Can load 2:1 target:carbon.
  - Demonstration – Targets of rhenium, hafnium, tungsten, bismuth, chromium, boron, boron-10, iridium
  - Works as easily for metals, oxides, carbides, and other compounds
Sputter deposition

- Graphene backing for target material deposition
  - Fabricated 4” enriched Boron-11 carbide sputtering target
- Prepared graphene substrates
- Deposited 200nm $^{11}\text{B}_4\text{C}$ on 0.1mg/cm$^2$ graphene: electrostatically attracted to substrate holder
- Deposited 200nm $^{11}\text{B}_4\text{C}$ on 0.5mg/cm$^2$ graphene: substrate survived the film deposition in plasma
Sputter deposition (Cont.)

- Made two $^{11}\text{B}_4\text{C}$ sputter targets
  - 1/4” thick target cracked under heat load during sputtering
  - 1/8” thick target made but untested.
- Created better mounts for thin foil substrates to sputter $\text{B}_4\text{C}$ coatings.

Four 20mm x 20mm graphene foil substrates mounted for B4C sputter deposition. Left – foils on wafer. Right – foils under Kapton mask.
Spin-coating on graphene substrates

- Spin-coating works
- Made W and Re targets
- Not efficient use of expensive materials
Plating of targets

- Developed plating solutions for $^{52}\text{Cr}$
- Electroplating on graphene is difficult
  - Works best if there is a very thin sputter layer of natural Cr.
  - Plating much easier on CNT+graphene foils. Foils are stiffer and high nucleation site number.
  - Plating targets is difficult and labor extensive – not an easy or efficient approach.
Graphene and CNT-enhanced graphene (preferred) foils made from dispersion after filtering through a membrane.

Can add other materials to the dispersion that will be trapped in the carbon matrix when filtered.

Process is easy and compatible with many materials (not compatible with material that dissolves or reacts with water).

Process is highly efficient – all material in dispersion is in target.

Examples include:
- $5 \text{ mg/cm}^2 \text{ Re} + 2 \text{ mg/cm}^2 \text{ carbon}$
- $9.4 \text{ mg/cm}^2 \text{ }_{10}\text{B} + 5 \text{ mg/cm}^2 \text{ carbon}$
- Others, $\text{nat} \text{HfO}_2$, $\text{nat} \text{WO}_3$, $\text{nat} \text{Ir}$

Preferred method of making a target!

125mm diameter, 250mm diameter possible
Commercialization

- Sold $5,900 in 2019
- Sold $5,900 in 1\textsuperscript{st} half of 2020 (end of Ph2)
- Exploring other opportunities to leverage this technology for medical-relevant isotopes.

- Questions?
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- Thank you!!!