ABSTRACT

Current gamma ray optics that rely on grazing incidence and Laue diffraction in crystals have low sensitivity, high costs, and a complex design. A research team here at UNH, lead by Dr. Peter Bloser in the Astrophysics group within EOS, has been developing an alternative approach via ~1^{o} curved multilayered structures of alternating low- and high- density materials to "channel" soft gamma rays with higher sensitivity and reduced background noise. The proof-of-concept design consists of alternating spin-coated poly(methyl methacrylate) (PMMA) and sputtered gold/palladium (Au/Pd) layers. My contribution to this project was to optimize process conditions of spin coating PMMA layers to create a multilayered (approx. 150 bilayer) structure. Uniformity of successive layer thickness and reduction of defects within the multilayer were successfully achieved.

Process Conditions of Spin-Coated Thin PMMA Films for Soft Gamma Ray Optics

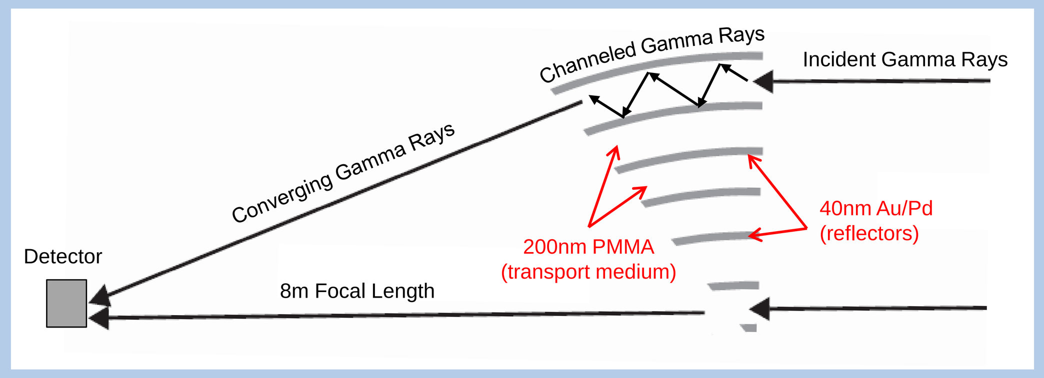
Emily Wong*, John Tsavalas**
*Department of Chemical Engineering
**Materials Science Program
University of New Hampshire, Durham NH, USA

University of New Hampshire

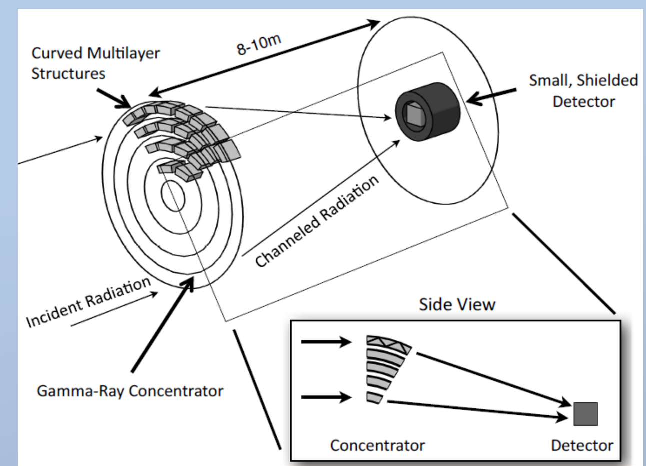
INTRODUCTION

The purpose of this project is to create a multilayered structure of thin PMMA and Au/Pd layers that can channel incident gamma rays towards a single-point detector. A series of comprehensive tests have been conducted to determine the optimal spin coating conditions that yield the desired thickness, overall uniformity, and maximum smoothness. Empirical correlations were used to investigate the effects of solvent type (pure or mixed), PMMA concentration *c*, and spin speed *w* on film thickness *h*. Measurements were taken via Alpha-Step 200 Profilometer and Scanning Electron Microscopy (SEM). The average arithmetic roughness *Ra* was measured via Atomic Force Microscopy (AFM) to determine the optimum concentration-spin speed combination for smoothness. Different fracture methods (room temp. vs cryogenic) were performed to ensure a clean entry pathway for incident gamma rays and to maintain the structure's integrity.

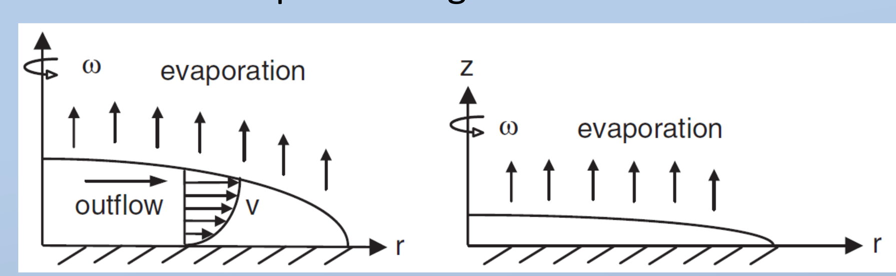
Design Parameters



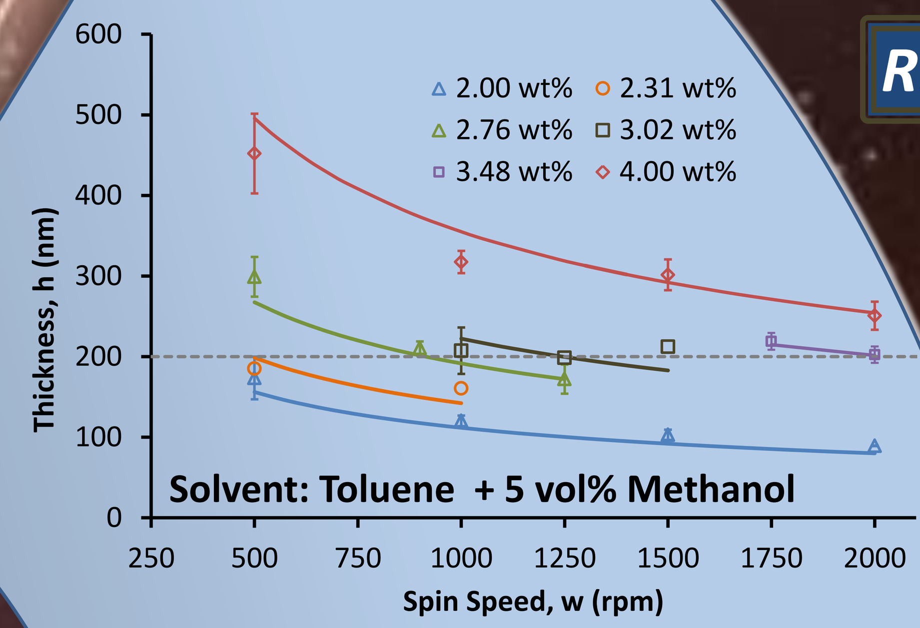
Proposed Apparatus

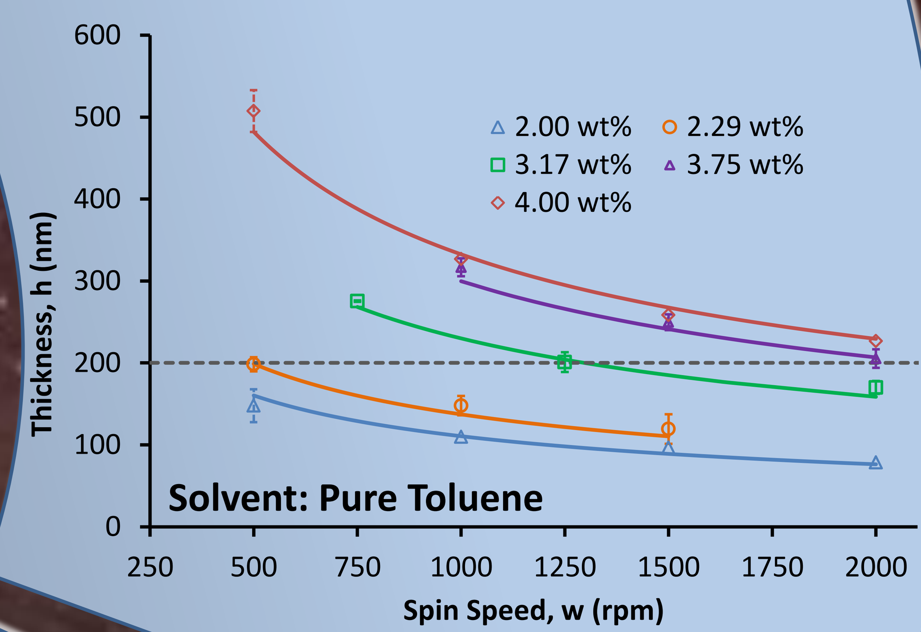


Spin Coating Process



Pure toluene gave a more reliable empirical correlation.



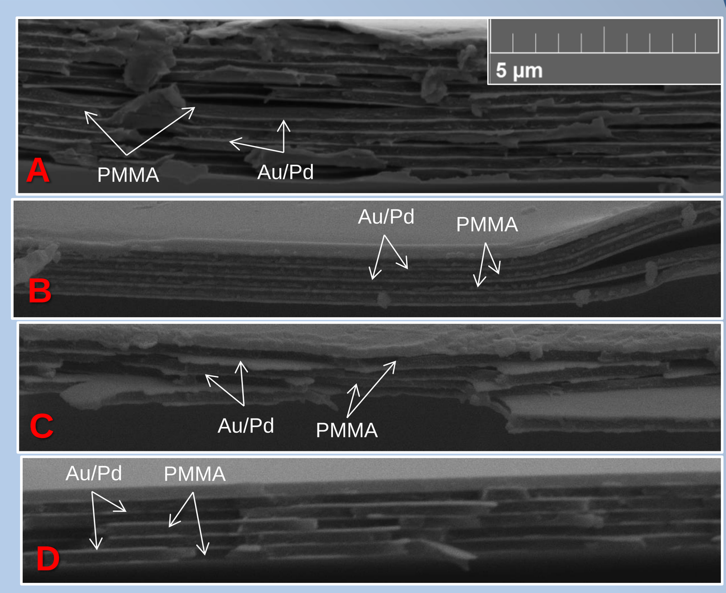


RESULTS: PROCESS PARAMETERS

- Best-Fit Correlation:

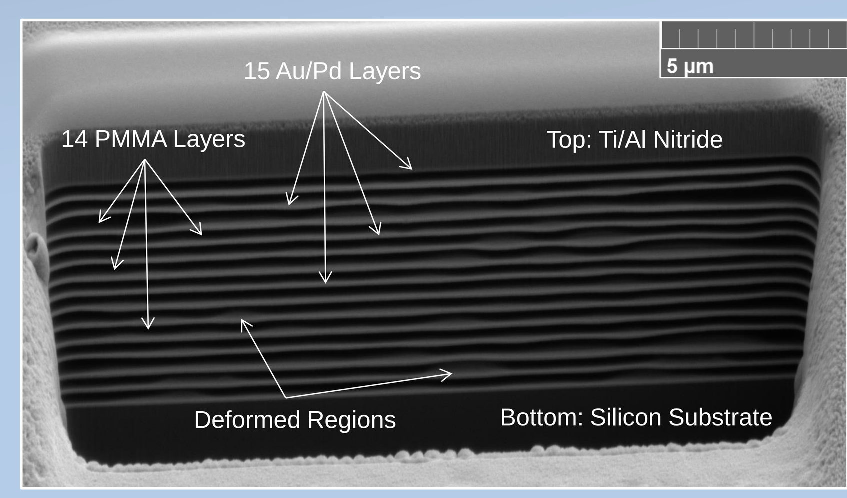
$$h = 1489.5c^{1.589}w^{-0.536}$$

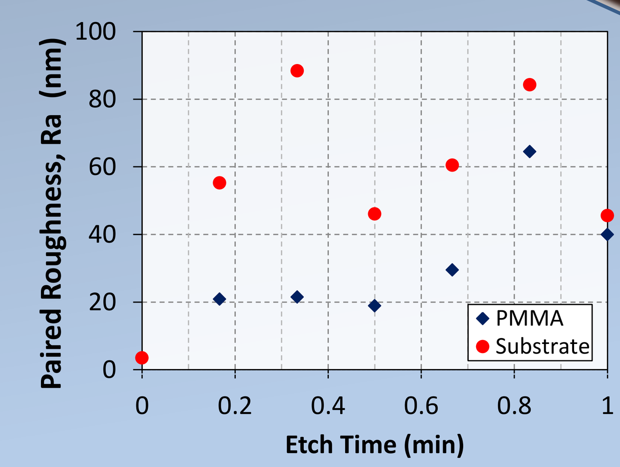
- Solvent Components: Solutions of pure toluene had more predictable results than that of toluene/MeOH mixture
- Desired thickness achieved (200 ± 11nm) for three different concentration-spin speed combinations at 500, 1250, and 2000 rpm
- Uniformity; Spin coating process was modified to reduce dust exposure and defects caused by particle debris in layers
- Injection volume and spin time did not affect film properties.
- Minimum roughness was obtained for higher spin speeds. Also, edge effects at substrate edge were visibly reduced at higher spin speeds
- Spin coating on rougher substrates did not compromise PMMA roughness



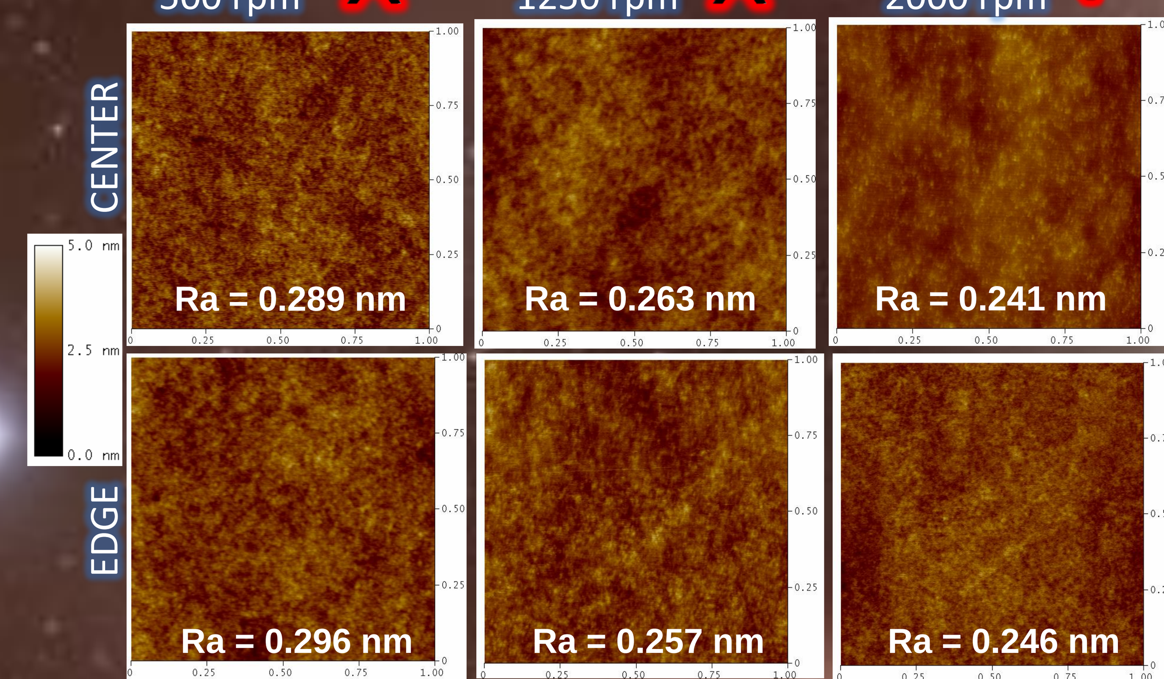
SEM images of cross areas from following fracture methods:
A) room temperature (RM)
B) RM, perpendicular ion polish
C) RM, parallel ion polish, and
D) liquid nitrogen (LN_2).

FIB/SEM image of 14-bilayers prototype.





PMMA roughness does not exceed respective substrate roughness.



Roughness values from AFM images of single layer 200 nm PMMA films.

REFERENCES

- Hall et al. (1998), *Polymer Eng. and Sci.*, (38) **12**, pp 2039-2045.
- Miller-Chou, B., Koenig, J. (2002), *Progress in Polymer Science*, (28), pp 1223-1270.
- Tippo et al. (2013), *Thin Solid Films*, (546), pp 180-184.

ACKNOWLEDGMENTS

- Dr. Peter Bloser (PI), EOS Space Science Center
- Prof. John Tsavalas (Co-I), Materials Science Program
- Prof. James Krzanowski (Co-I), Materials Science Program
- Paul Aliotta, Physics Department
- Nancy Cherim, University Instrumentation Center
- Mark Townley, University Instrumentation Center
- Prof. Todd Gross, Mechanical Engineering Department
- Background Photo Credit: ESO/L.Calçada

This work was partially supported by NASA Grant NNX14AH57G.

CONCLUSIONS & FUTURE WORK

- Desired thickness at minimal roughness was successfully obtained
- Currently in production of +150 bilayer sample for proof-of-concept gamma ray channeling test
- Further work includes scale up parameters and further investigating whether defects may propagate to successive layers
- Upon successful channeling, faster production rate via Magnetron Sputter (Au/Pd) and Pulsed Laser Deposition (PMMA) will be explored

RESULTS: FRACTURE METHODS

- Focused Ion Beam (FIB) image show successful mutlilayer structure (14-bilayers)
- Cryogenic fracturing (LN_2, -196^{o}C) shows smoother cross areas, less debris, and better integrity than fracturing at room temperature
- Polishing ion gun does not improve cross area smoothness nor remove debris
- Minimizing time between fracturing and testing reduces accumulation of debris