LA-UR- 11-04047

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Title:	Novel uses and environments for biologically inspired fibrillar adhesives
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Intended for:	American Glovebox Society Conference San Francisco, CA July 18, 2011

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Abstract for: Novel uses and environments for biologically inspired fibrillar adhesives

Irradiation of polymer based gecko-like synthetic adhesives (GSAs) using an accelerated beam of Helium ++ions has been performed. This irradiation simulates large alpha radiation doses that the GSAs may experience if deployed on a robotic platform in some radiological environments. After irradiation, the adhesive samples were tested for adhesion on a three-axis adhesion testing stage and were examined via scanning electron microscope. The GSA samples showed significant changes in surface morphology at high radiation doses. Additionally, radiation doses larger then 750kGy resulted in a significant deterioration of the adhesive performance. Eventually, the adhesive samples lost all ability to generate frictional adhesion. Such results allow us to make quantitative statements about the applicability of GSAs for robotic applications in nuclear environments.

Novel uses and environments for biologically inspired fibrillar adhesives

Paul Day
LANL / Stanford University
July 18, 2011

Overview

- Brief history of biomimetic fibrillar adhesives
- Hostile environments: high alpha radiation exposure
- Hostile environments: high gammaradiation exposure
- Radiation conclusions
- Future Work

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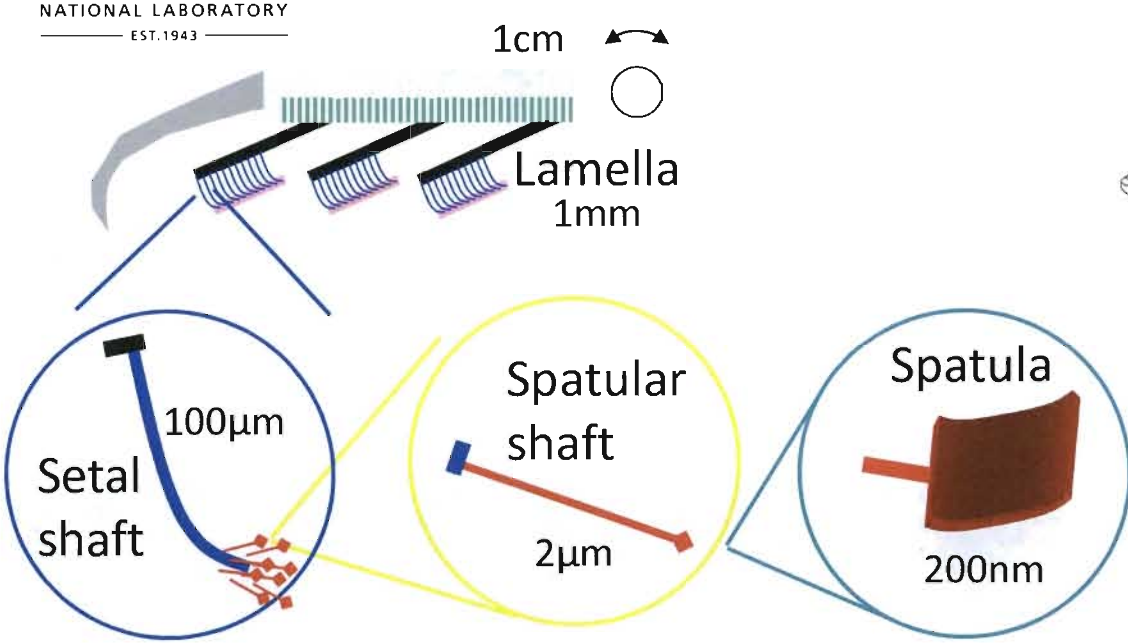
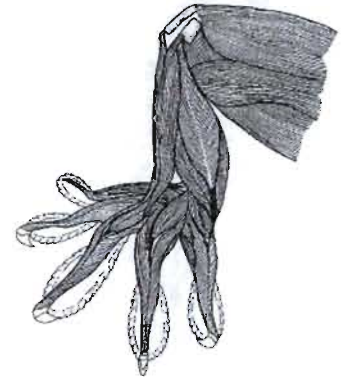
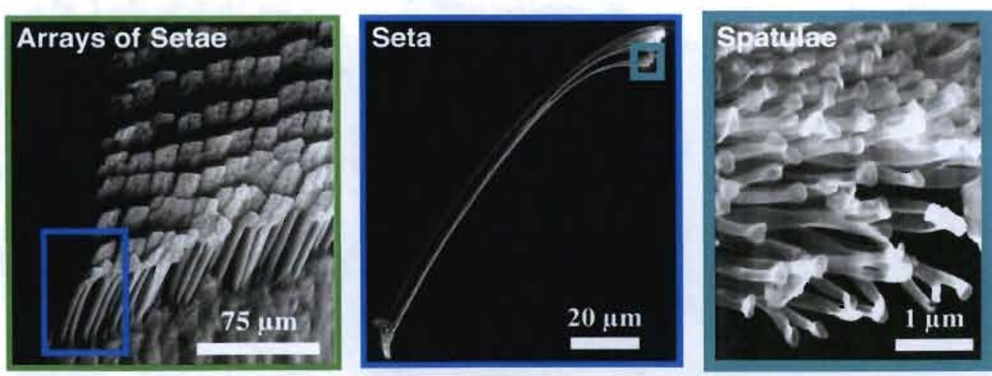
Gecko Adhesive System





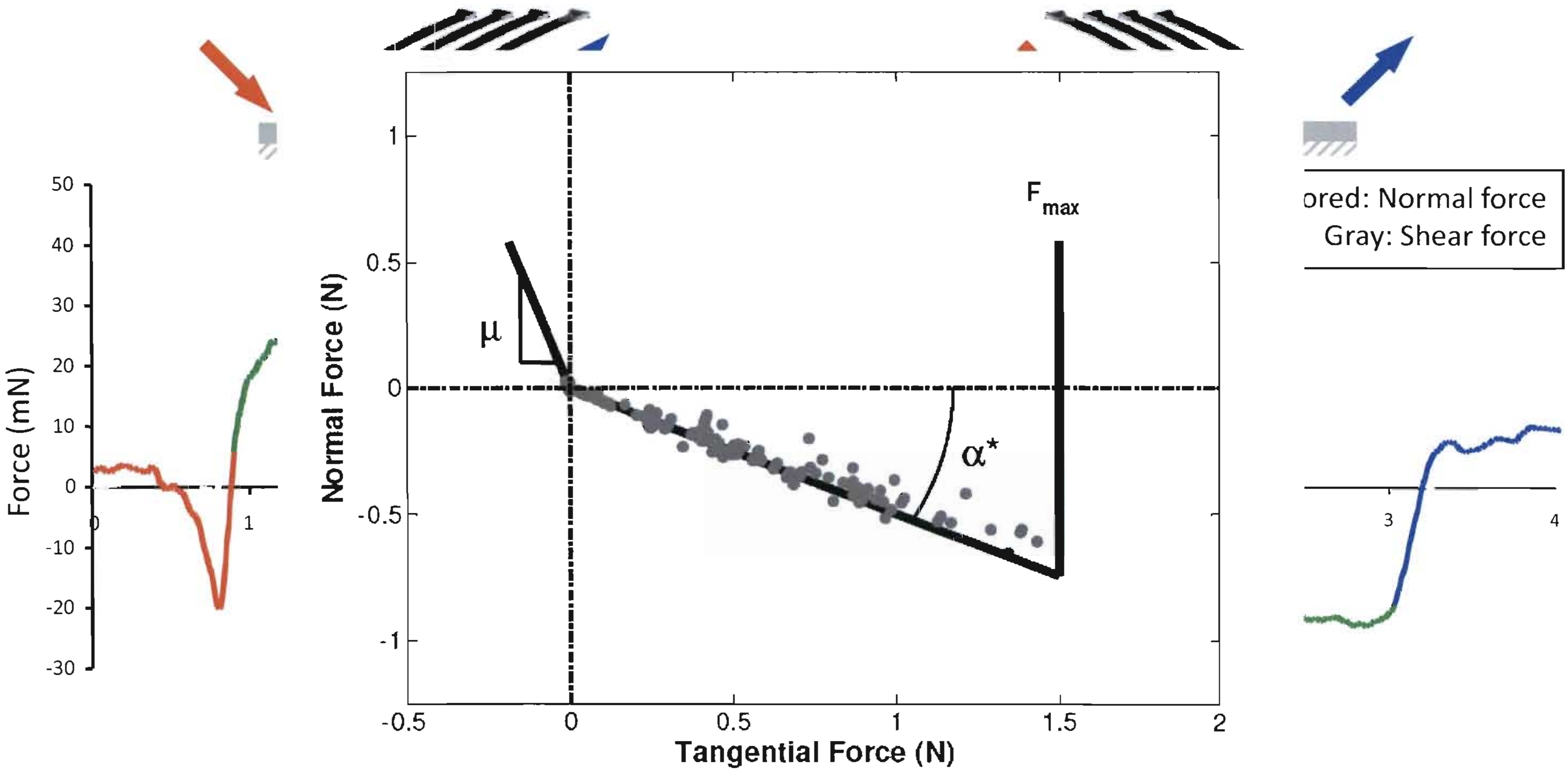


- Directional/Controllable
- Minimal Preload to Engage
- Dry Adhesion
- Robust
- Hierarchical Structure

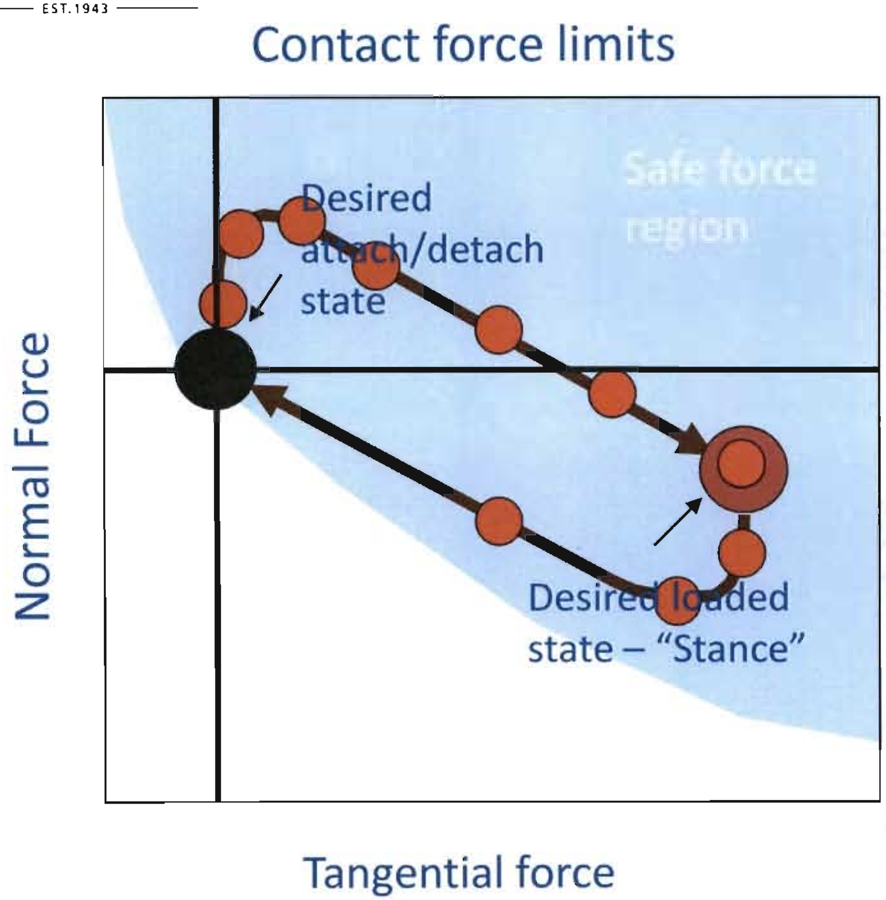
Anisotropic Gecko Adhesion

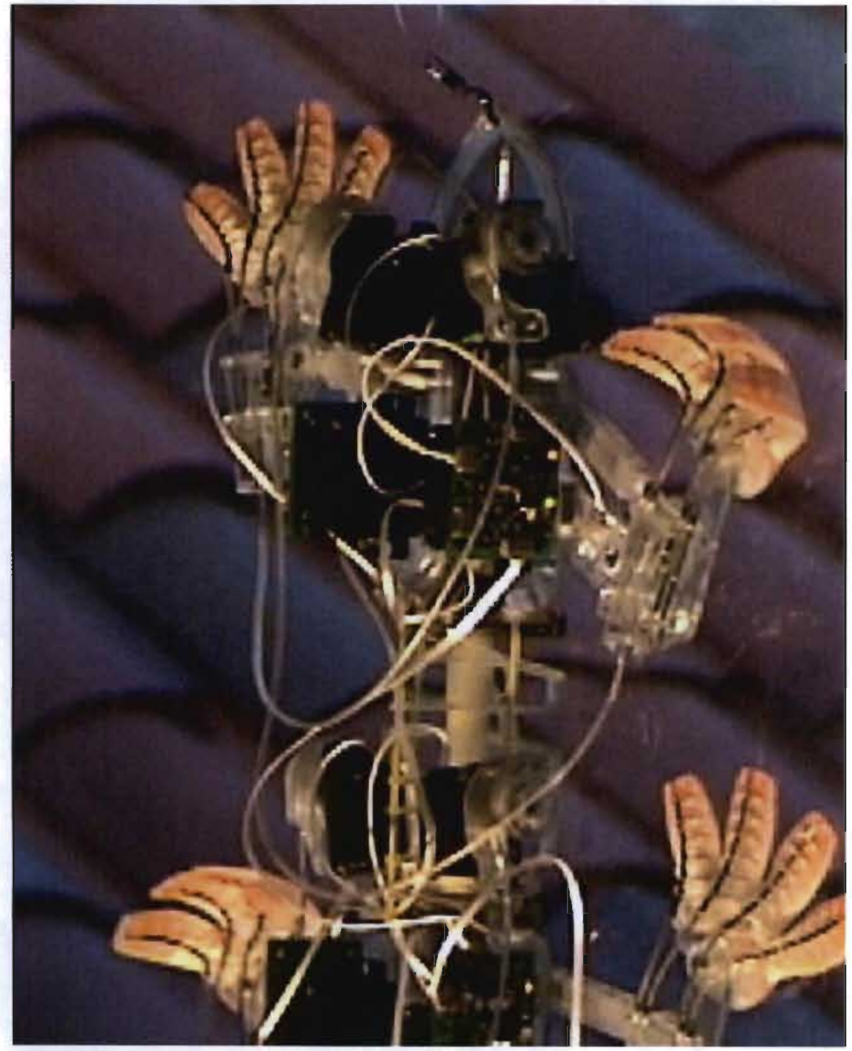
Gecko setae dragging with curvature

Dragging against curvature

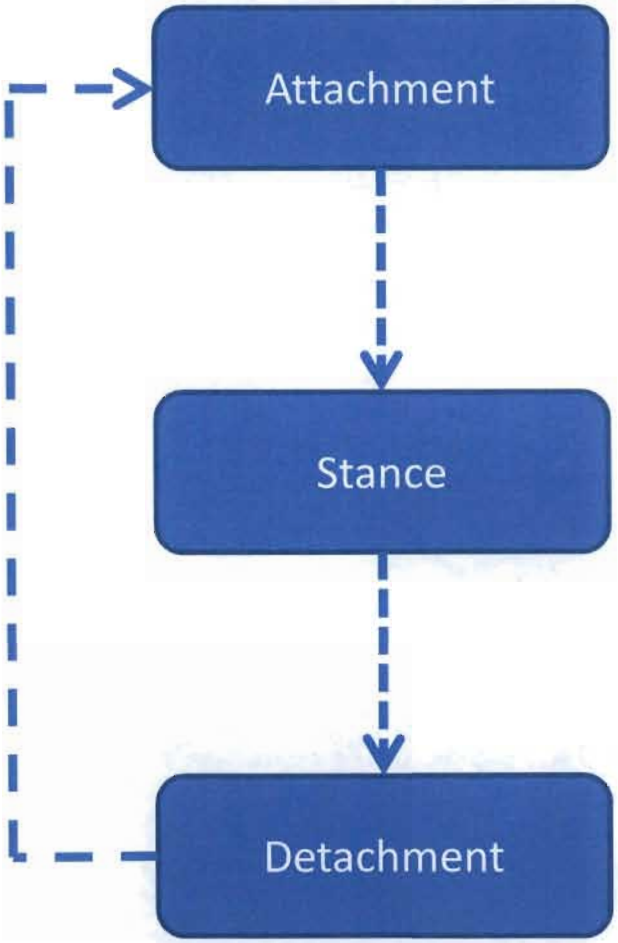


A closer look at climbing

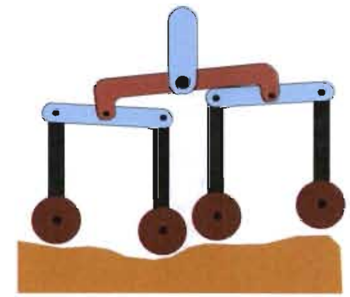




Principles for Efficient Climbing

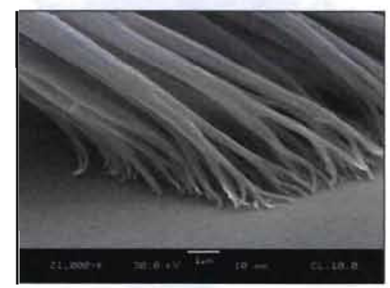


1. Hierarchical compliance



2. Directional adhesives

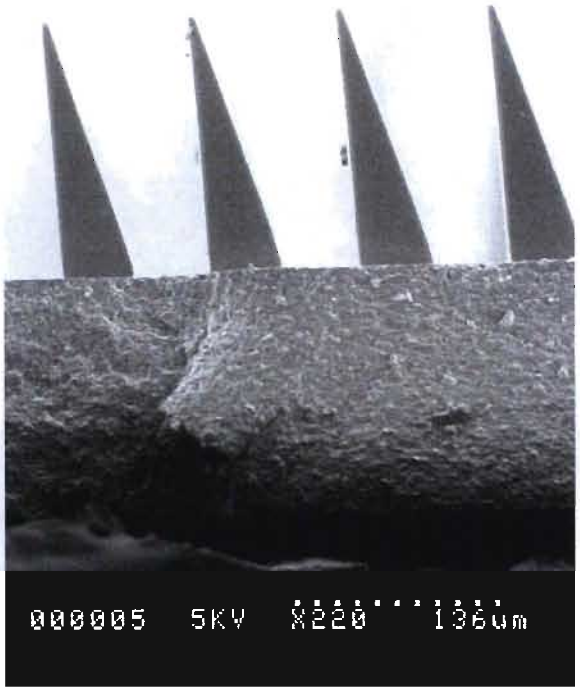
3. Even load distribution

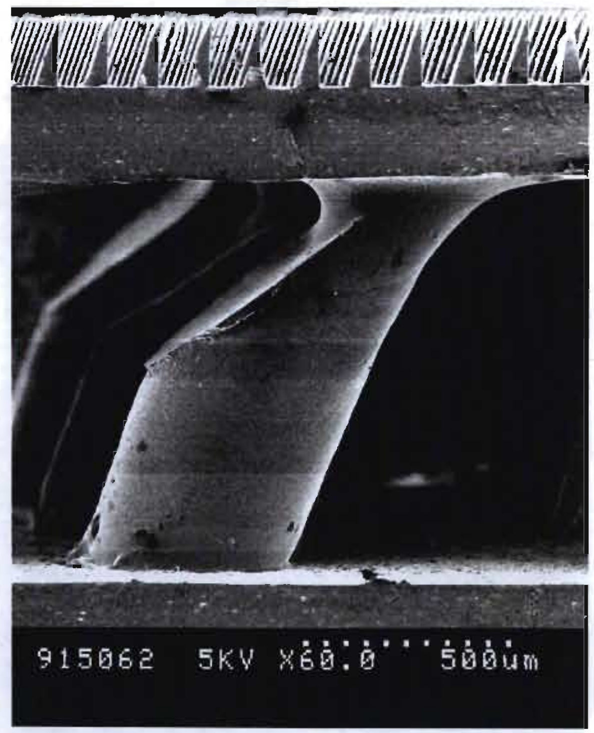


4. Reusability

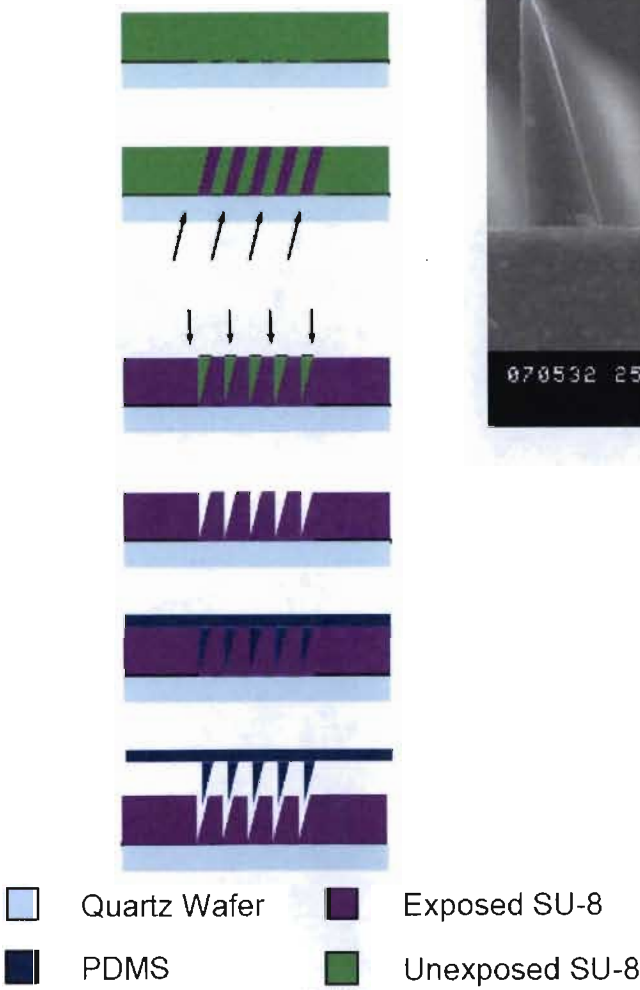
Approximating the gecko

- Directional/Controllable
- Minimal Preload to Engage
- Dry Adhesion
- Robust
- Hierarchical Structure

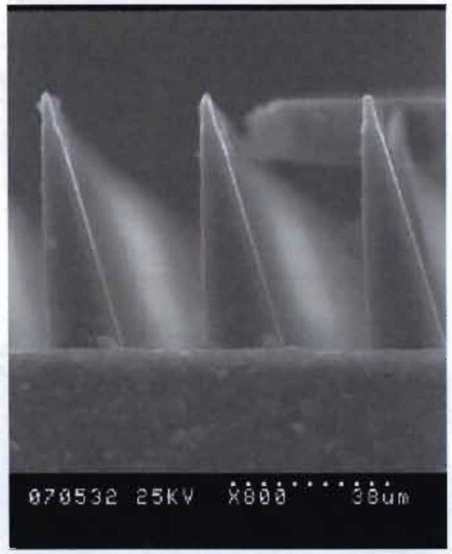




Wedge Design

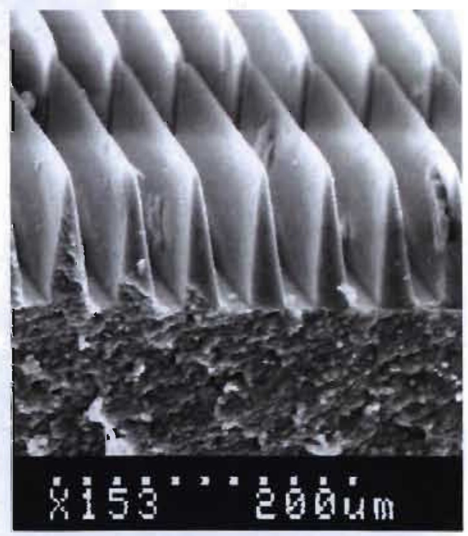


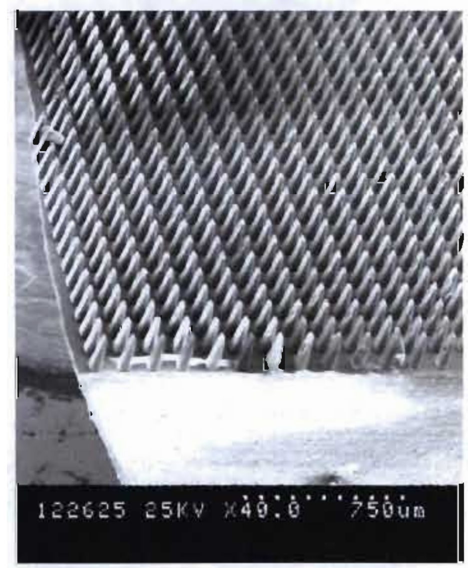
Parness, 2009



Key Design Parameters

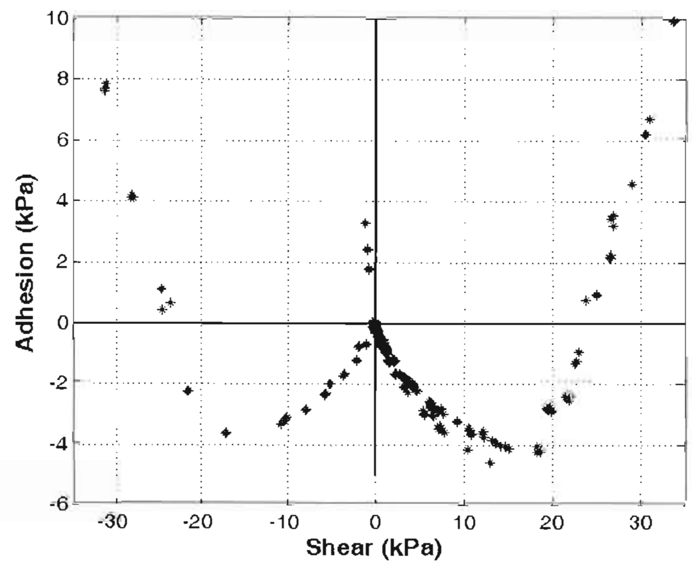
- ϕ: angle of fiber
- θ: interior fiber angle
- h: fiber height
- s: fiber spacing
- E: material Young's Modulus

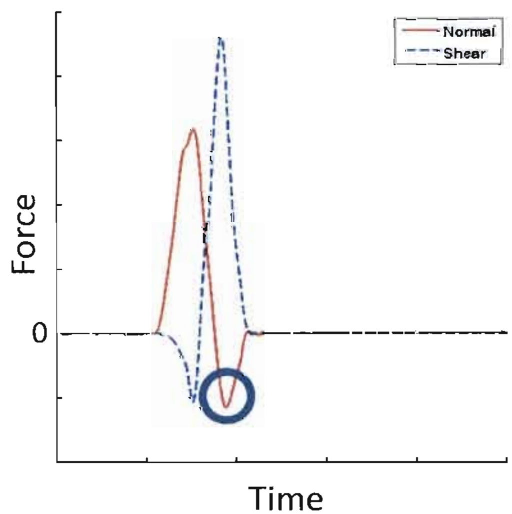




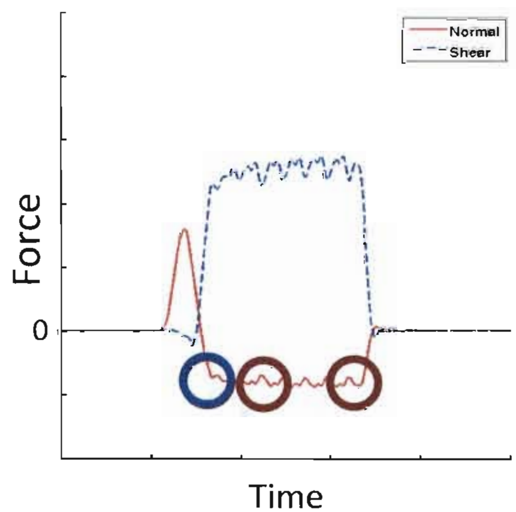
Directional Limit Surface

- Limit surface points defined by individual failures
- 2 modes of contact failure
  - Single event failure
  - Sliding failure





Single Event Failure



Sliding Failure

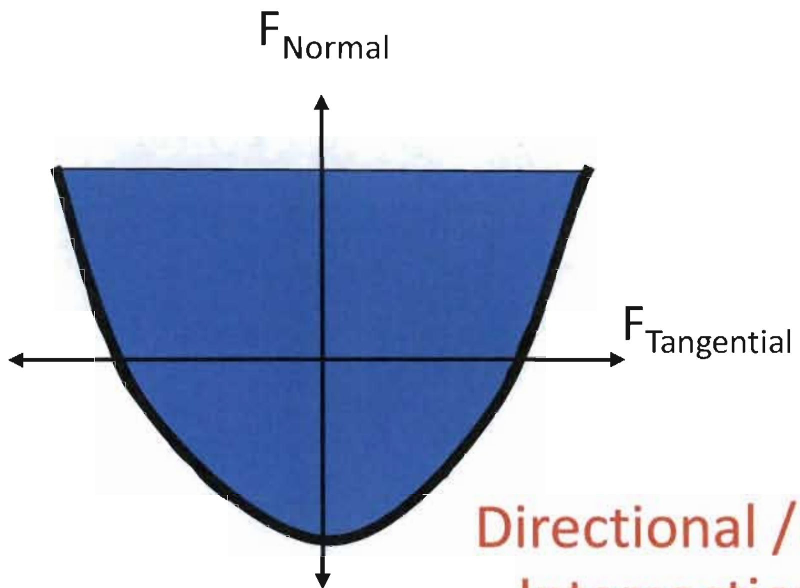
Max Power Method*

$$F(t_{fail}) \bullet v(t_{fail}) \leq F(t) \bullet v(t), \forall t$$

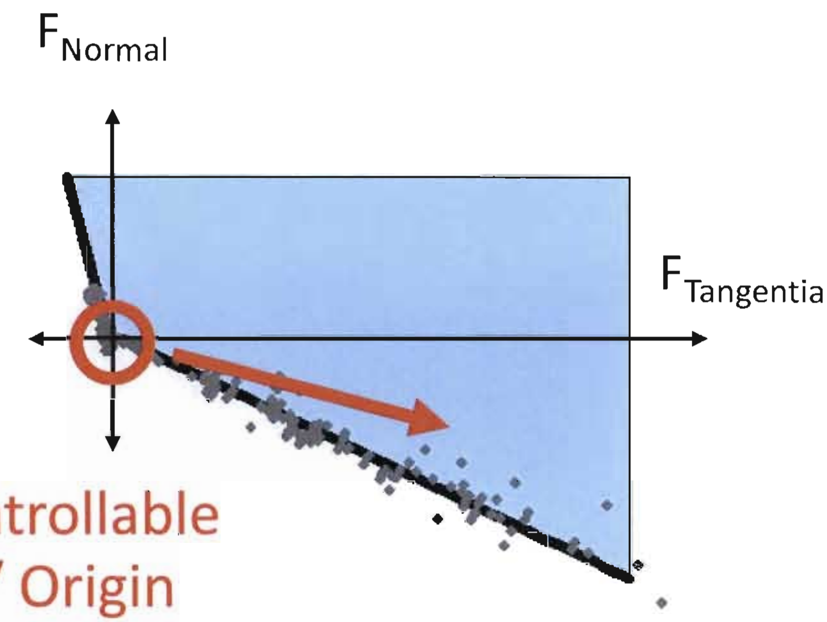
* S. Goyal, A. Ruina, and J. Papadopoulos

Modeling Adhesion

Johnson-Kendall-Roberts



Gecko
"Frictional Adhesion"



Directional / Controllable
Intersection w/ Origin

Autumn, et al.; Journal of Experimental Biology; Volume 209, 2006

Overview

- Brief history of biomimetic fibrillar adhesives
- **Hostile environments: high alpha radiation exposure**
- Hostile environments: high gamma radiation exposure
- Radiation Conclusions
- Future Work

Hostile Environments: Motivation

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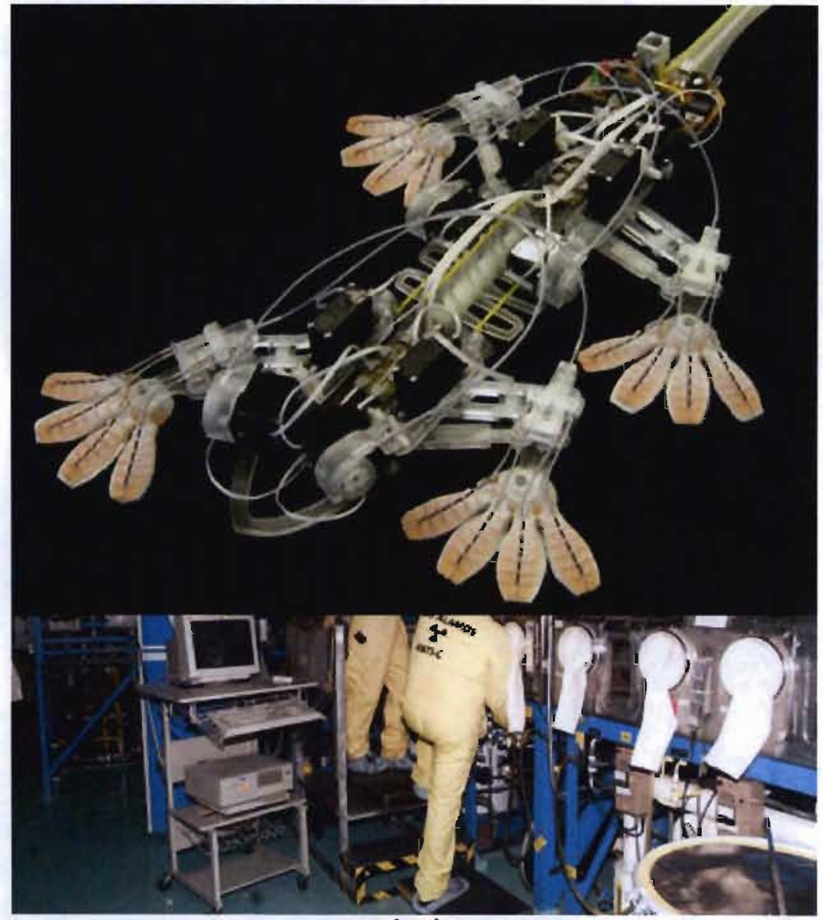
- Interested in deploying platforms using adhesives in nuclear gloveboxes
  - Grip improvement in gloves
  - Grip improvement in robotics manipulators
- Would be exposed to high alpha and gamma fields due to glovebox contents
- Radiation aging of polymers is well known
  - Effect on fibrillar adhesives is not



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Hostile Environments: Previous Work

- Chapiro (1962), Murphy (2005), Zhang (2004) discuss alpha effects on mechanical properties of polymers
- Chapiro (1962), Palsule (2008), Maxwell (2003), Hill (2001) discuss gamma irradiation effects
- Difficult to extract adhesive performance information from mechanical property changes

Hostile Environments: Experimentation

- 1 cm^2 samples
- Accelerated He^{2+} ions at 2.5 MeV simulated alpha radiation
  - Doses from 25kGy to 2.5MGy
- Identical pre and post-irradiation adhesion testing
- Contact angle measurements taken
- Samples examined via SEM

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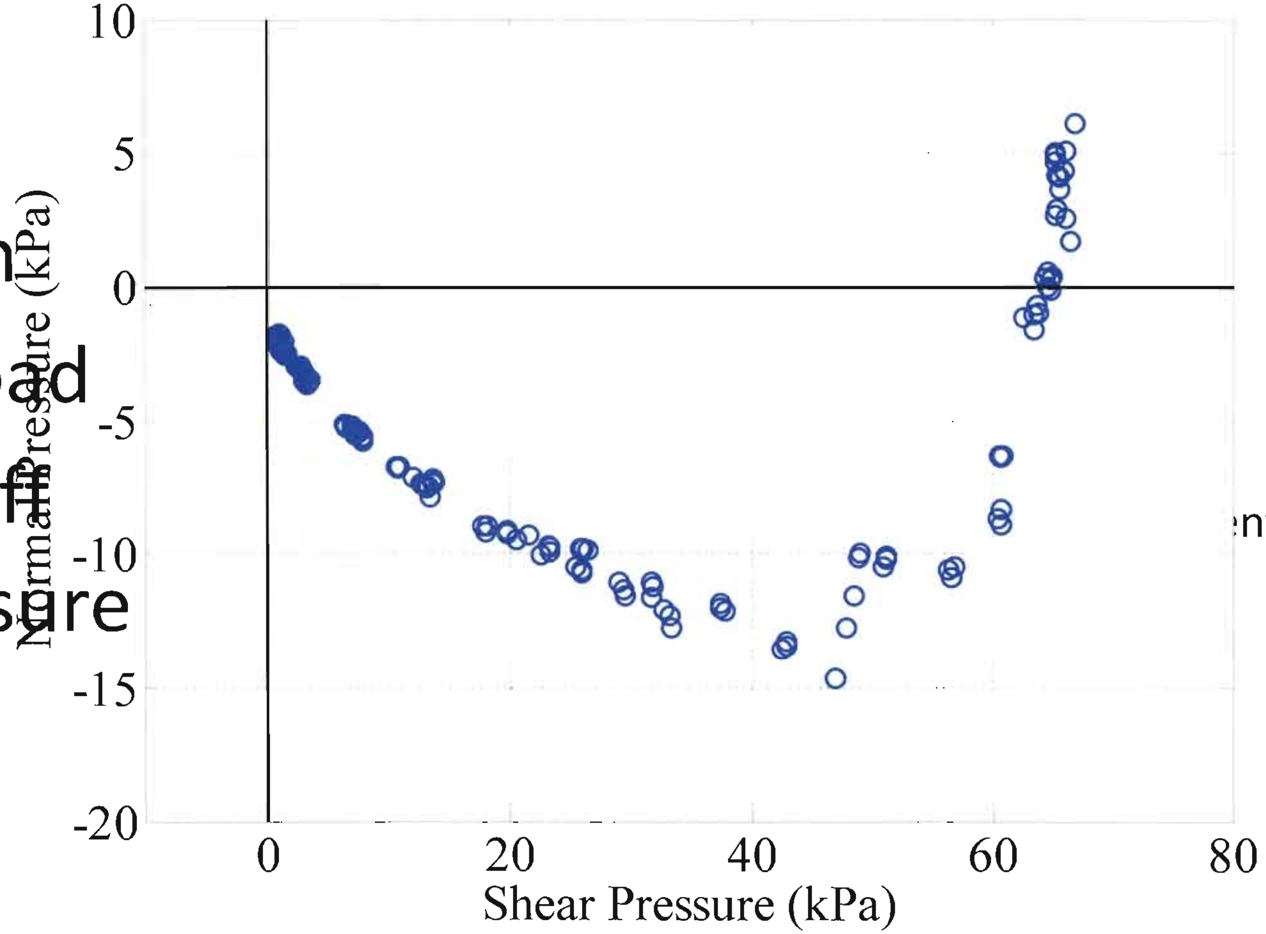
Adhesion Testing

- Clean
- Preload
- Pulloff
- Measure



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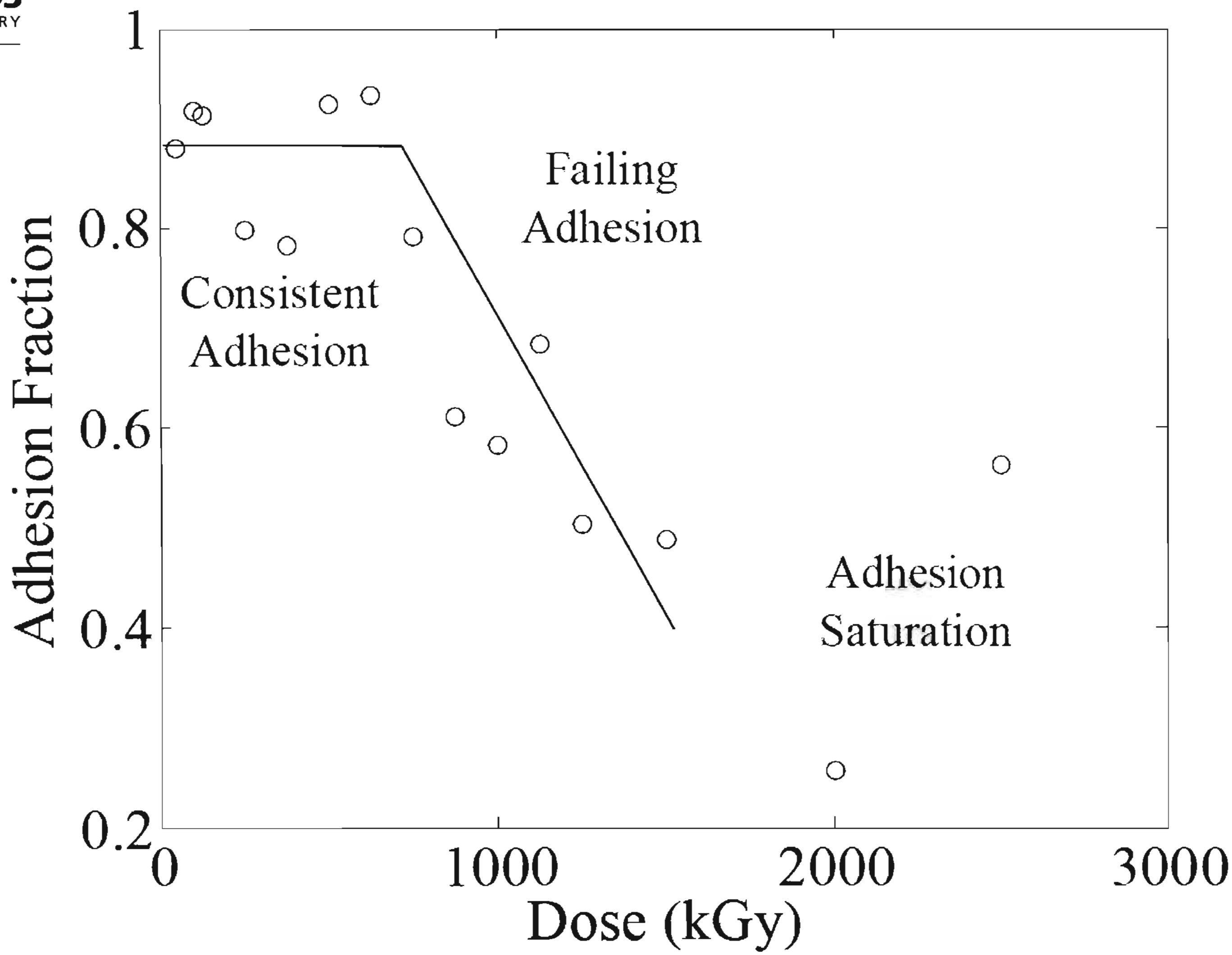
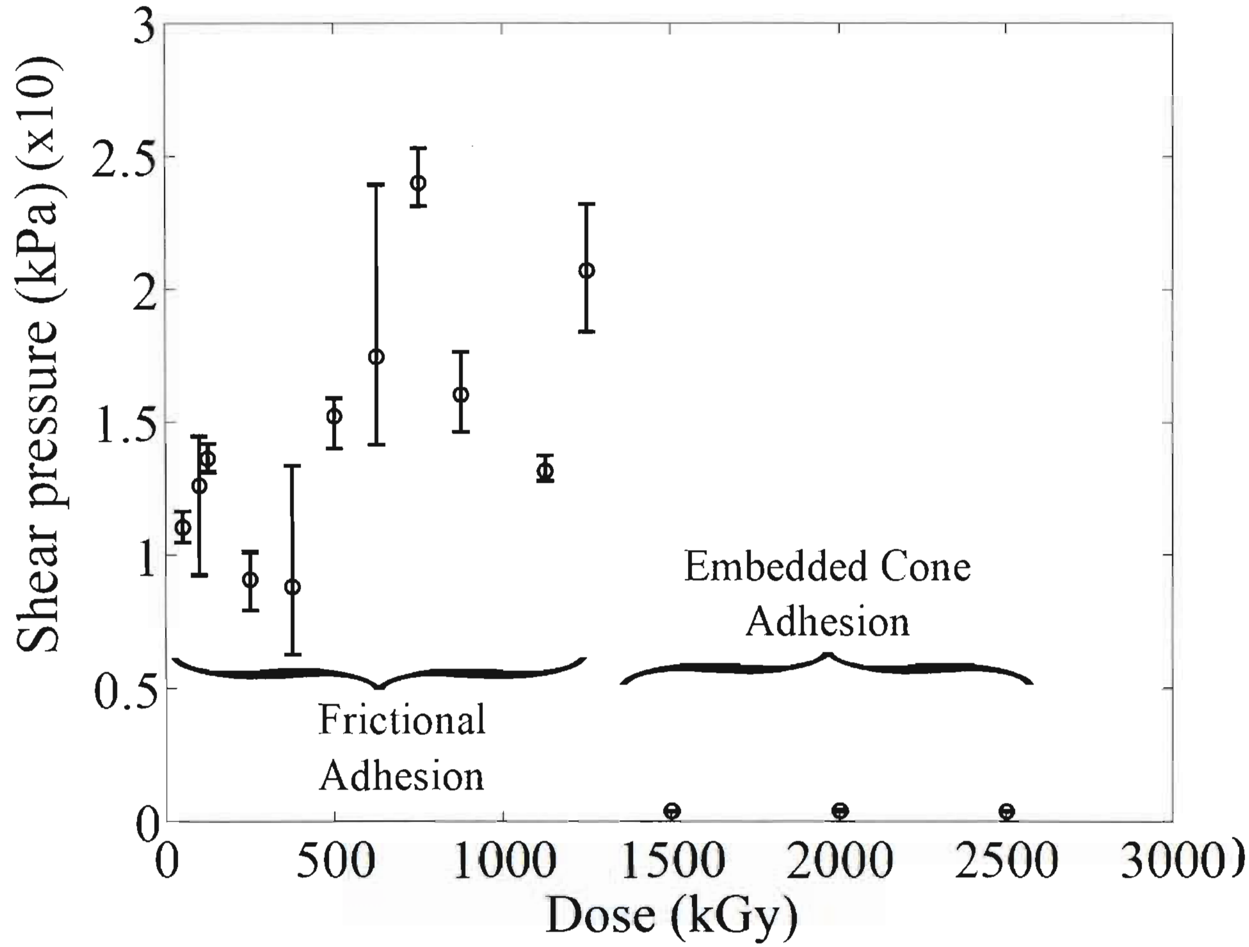
Aplha Radiation: Adhesion Results

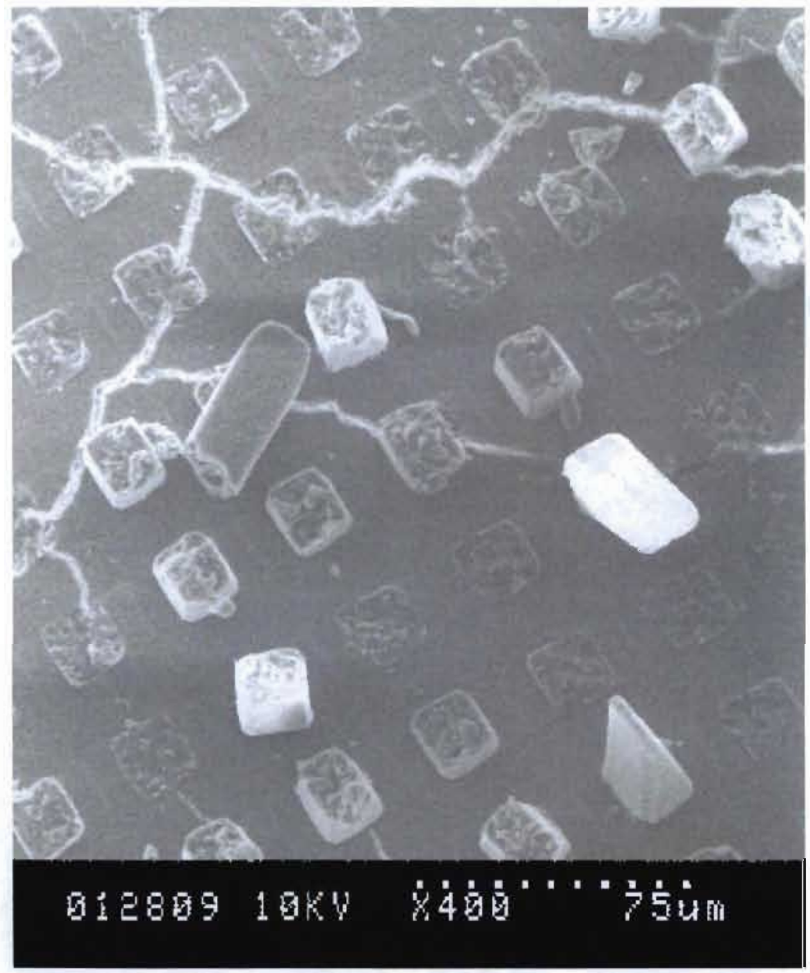


Hostile Environments: Shear results



Hostile Environments: Alpha results

- No visible damage up to 1.25MGy
- Mechanical hardening observed at high doses, 2.5MGy
- Widespread cracking and feature failure
- Contact angle increase suggests reduction in surface energy of bulk PDMS at high doses.



Overview

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- **Hostile environments: high gamma radiation exposure**
- Radiation Conclusions
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Hostile Environments: Gamma radiation

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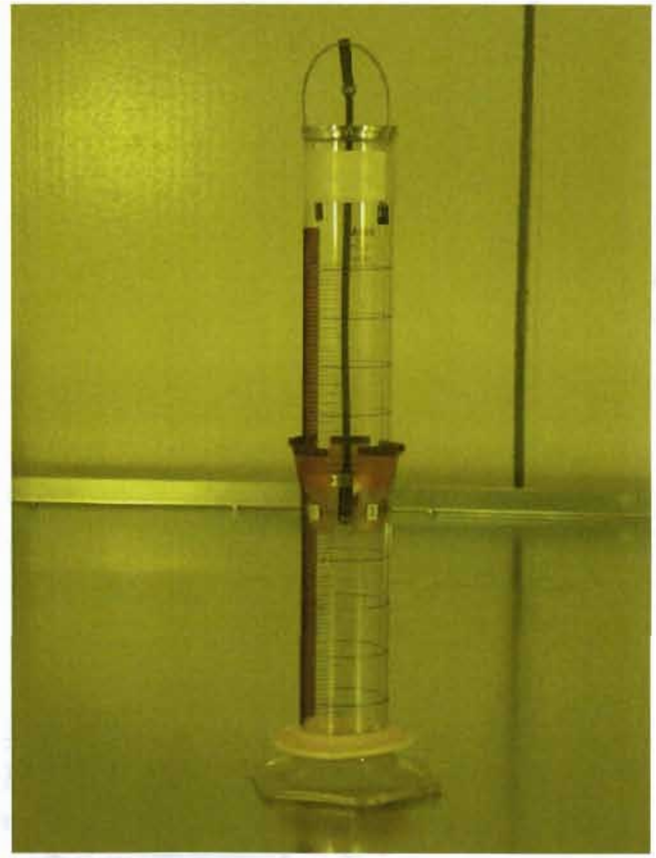
- Gamma irradiation conducted using a Co^{60} source at LANL
- Source fixed within glass graduated cylinder
- Samples affixed to the outside of the cylinder at fixed distance



Hostile Environments: Gamma radiation

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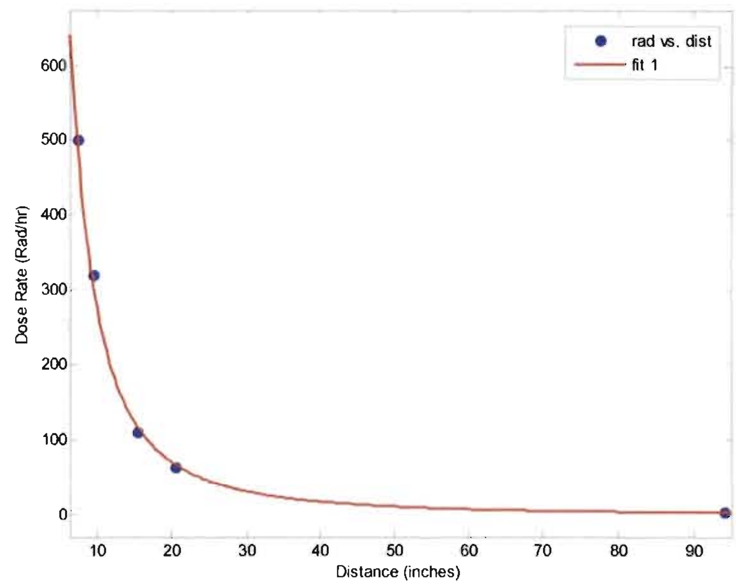
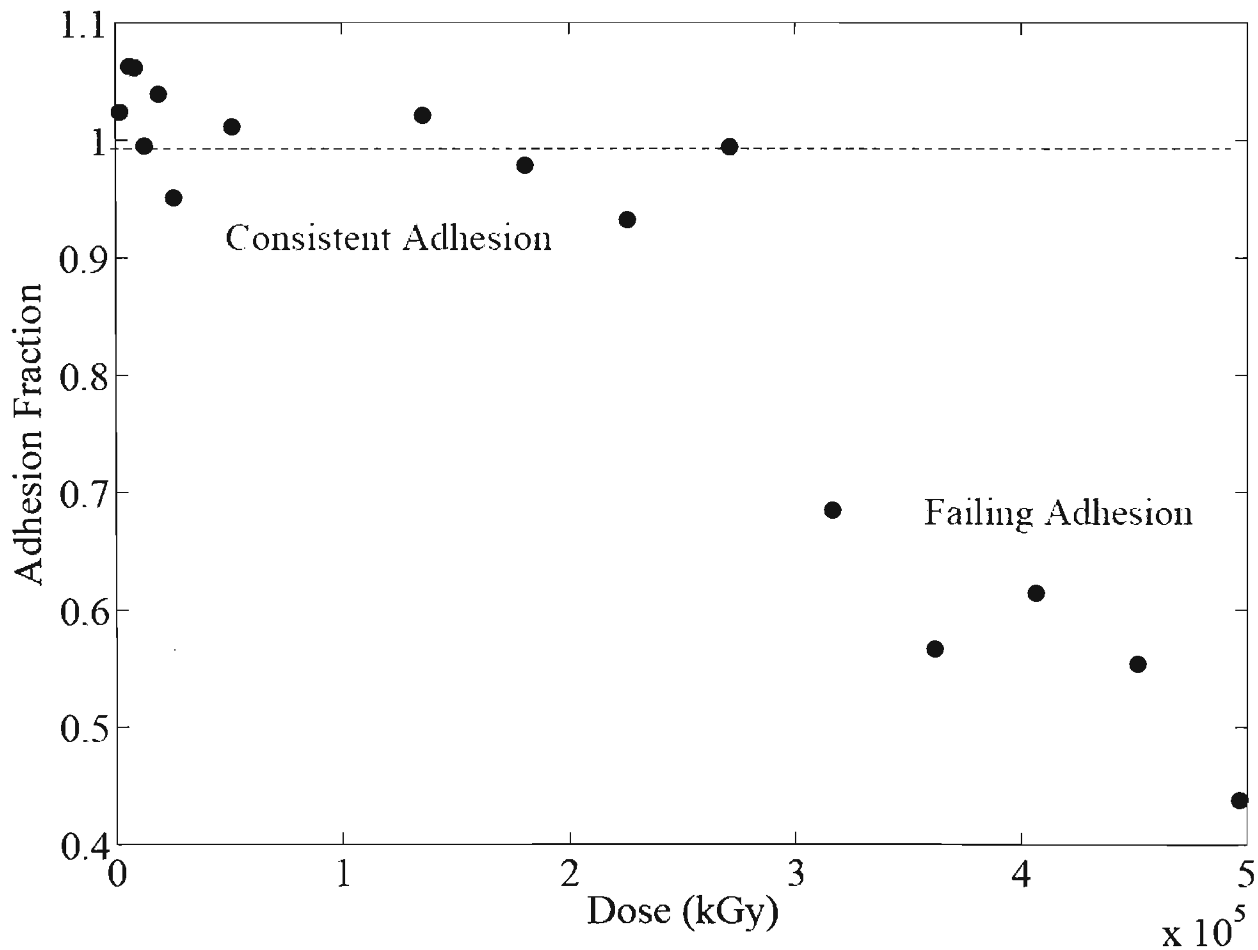
- Dose rate calculations
  - Dose too high at exposure distance
  - Dose rate measured at various distances via ???
  - Data points were used to fit an inverse square curve
- Exposure rate approximately 269Gy/hr
- Samples exposed to 25kGy - ~500kGy



Hostile Environments: Gamma results



Radiation Conclusions

- Adhesives are quite robust
- Capable of taking extremely high doses while maintaining adhesive functionality
  - Years in high alpha environment
  - Months in high gamma environment
- Should be suitable for applications in glovebox environments

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Future Work

- Trial applications in gloveboxes at LANL
- Continue to improve manufacturing methods for adhesives
- Improve performance on stainless steel surfaces
- Graduate!

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Thanks

- Rich Greco, LANL
- Ed Garcia, LANL
- Stacy McLaughlin, LANL
- Mark Cutkosky, Stanford
- Noe Esparza, Stanford

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Questions?

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