

The Development of Contractile Electroactive Polymer (EAP) Based Materials and Actuators that Act as Artificial Muscle

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Carl Tilman,³ David Schramm,¹ Kelsey Pargon,² and Carl J. Erickson,^{1,2}

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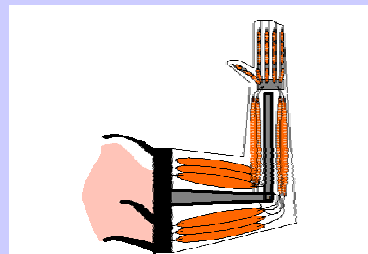
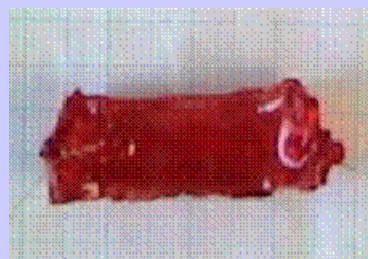
²US DOE's Princeton Plasma Physics Laboratory at Princeton University

³Princeton Environmental Analytical Radiological Laboratory at PPPL

Northeast Federal Laboratory Consortium – September 2009



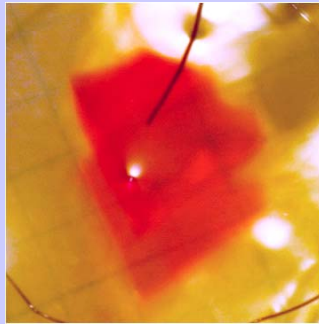
Ras Labs ~ Chemistry, Biology,
Biochemistry, & Engineering



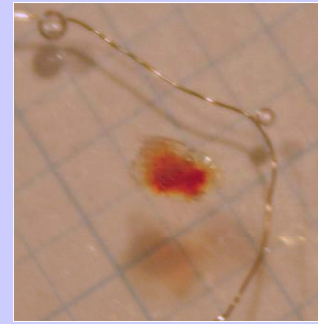
PPPL

Princeton Plasma
Physics Laboratory

Electroactive Materials Produced by Ras Labs



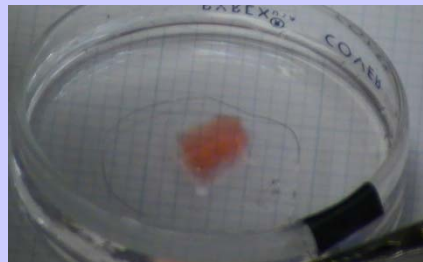
A. Weight ($t = 0$) = 0.11 g



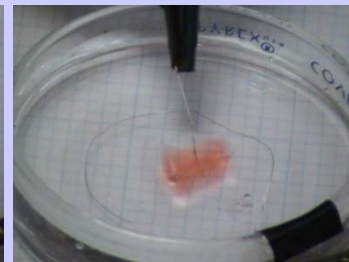
B. Weight ($t = 1$ minute, 50 V) = 0.01 g

Note: Red dye added to (uncoated) EAP to improve visualization.

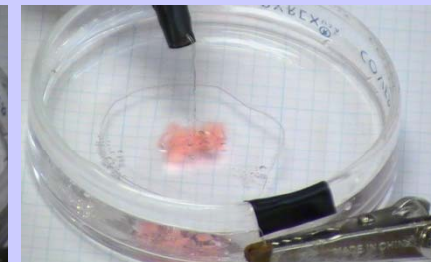
Embedded
videoclip of
contractile EAP



0.40 g (before V)

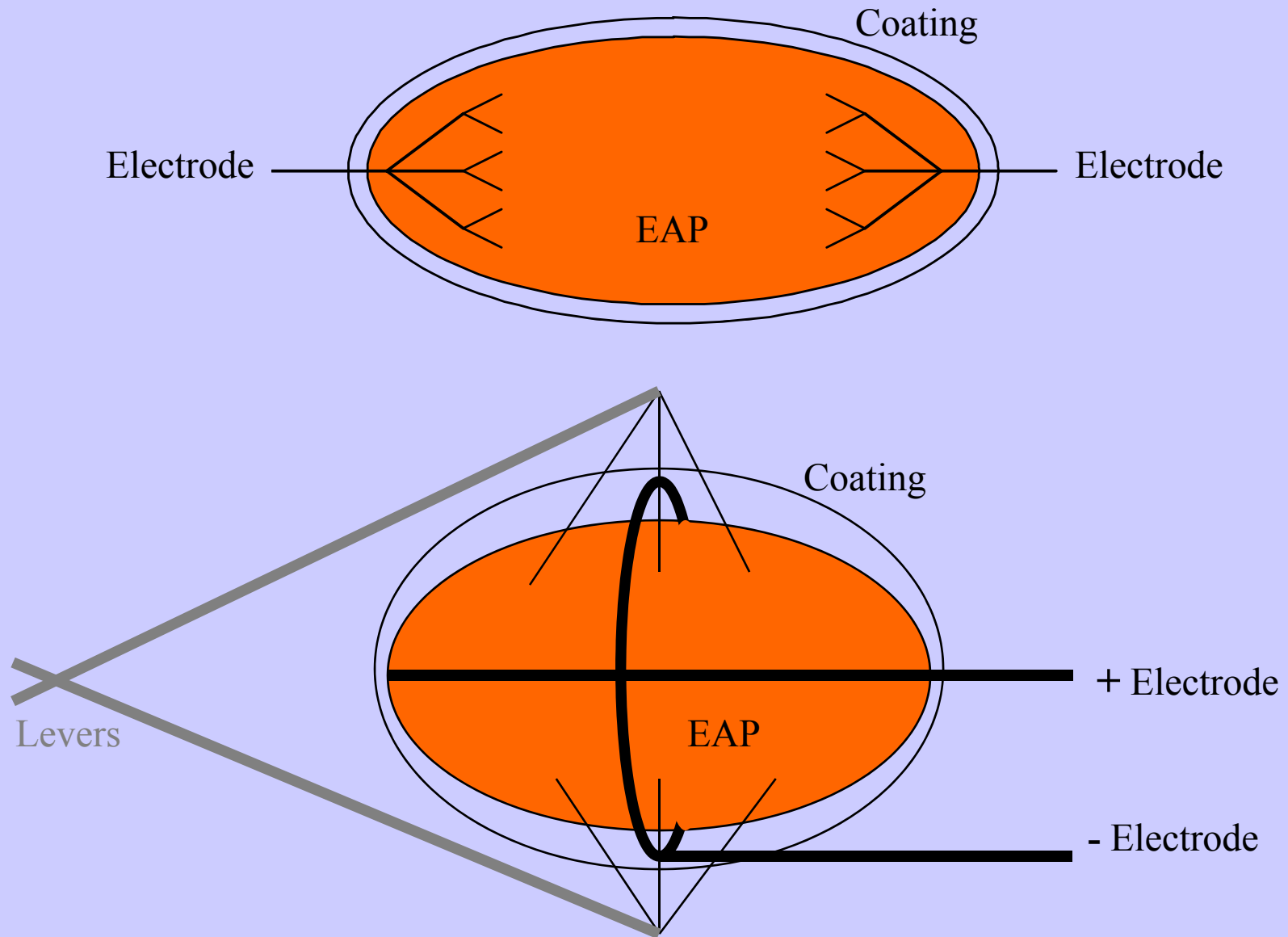


0.36 g after + 13 V



0.40 g after - 13 V

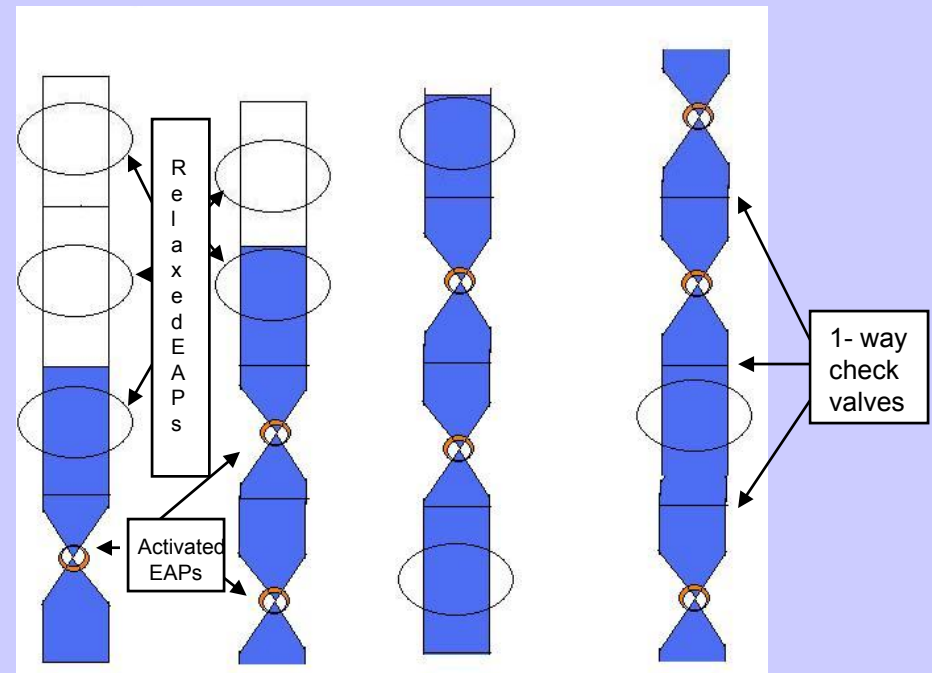
Depictions of encapsulated EAP materials with embedded electrodes



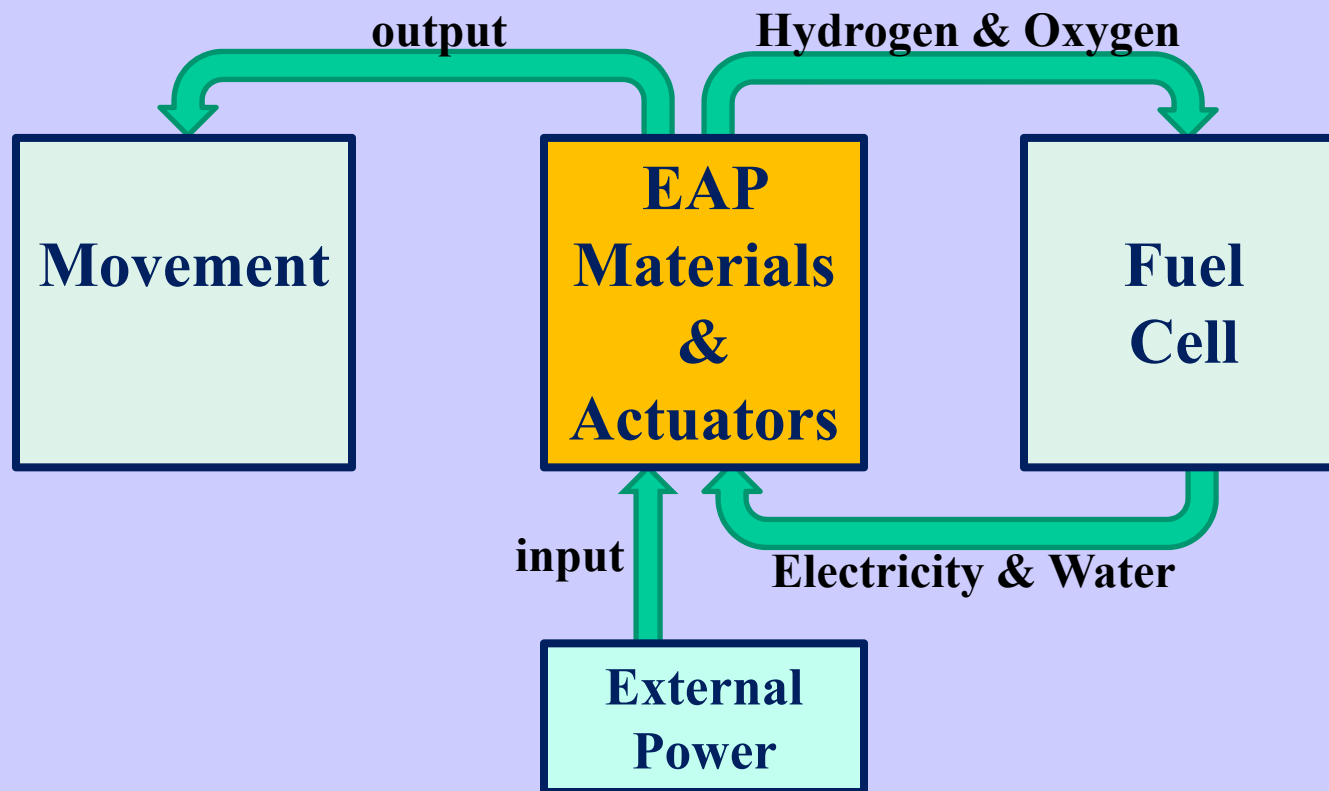
Bilayer for Negative Electrode

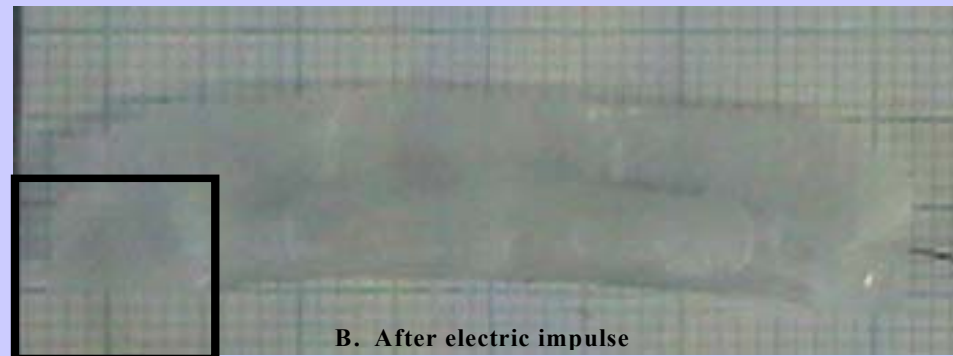
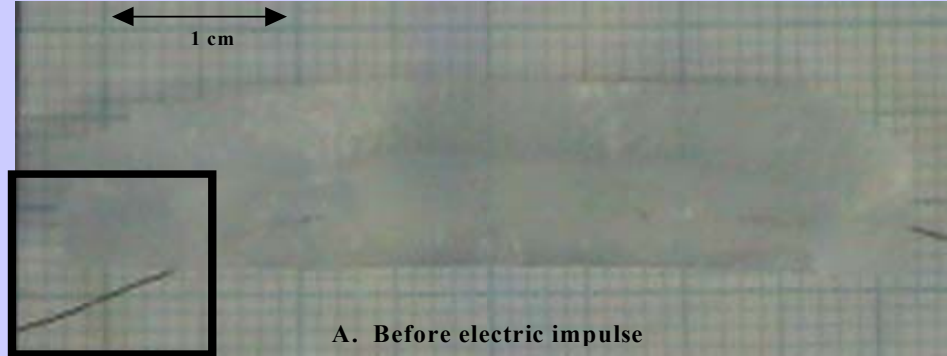
Kelsey and I are working on this figure –
having some computer incompatibility
issues.

Peristaltic Pump Design

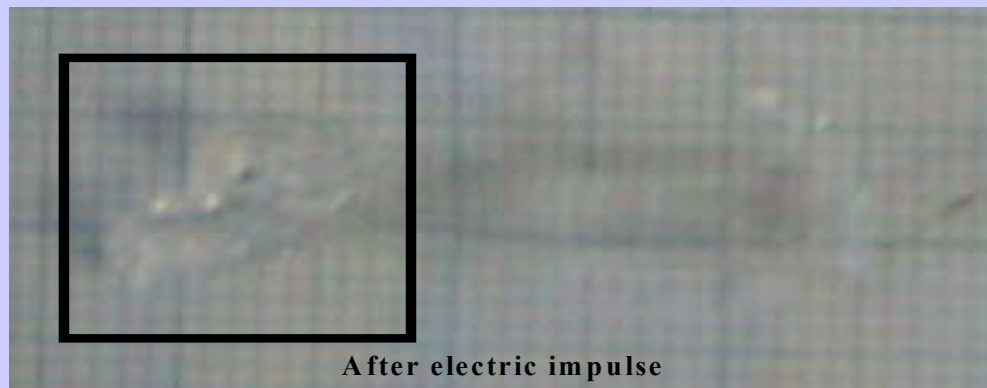


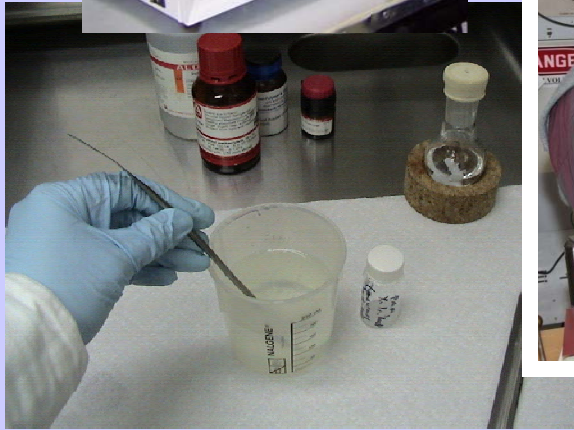
Extremely Energy Efficient Movement





Damage to electroactive material in boxed area.





Ras Labs and Princeton University Plasma Physics Laboratory formed CRADA

Combines

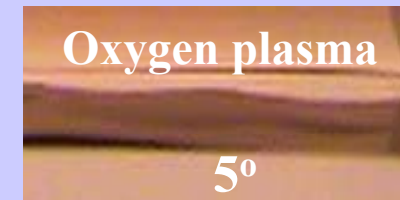
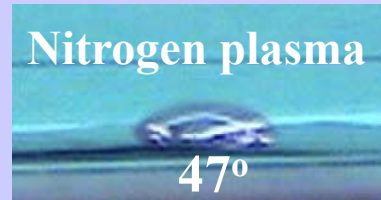
synthetic expertise of Ras Labs

plasma expertise of PPPL

EAP Materials & Actuators

EAP and embedded electrode(s) to move as unit

Water Drop Contact Angle Test

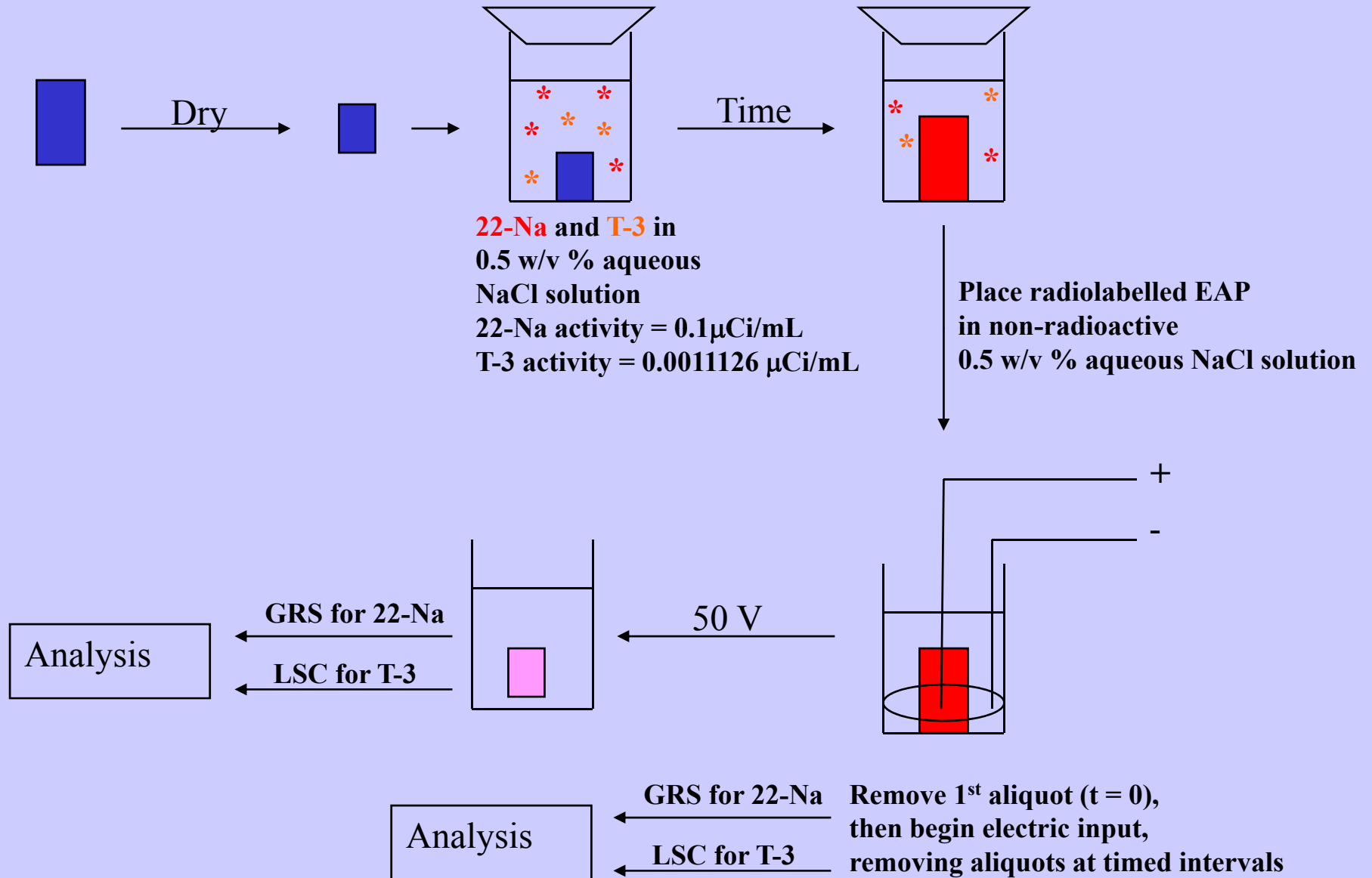


Stress Test to Break of Plasma Treated Titanium Electrodes in EAP Actuators

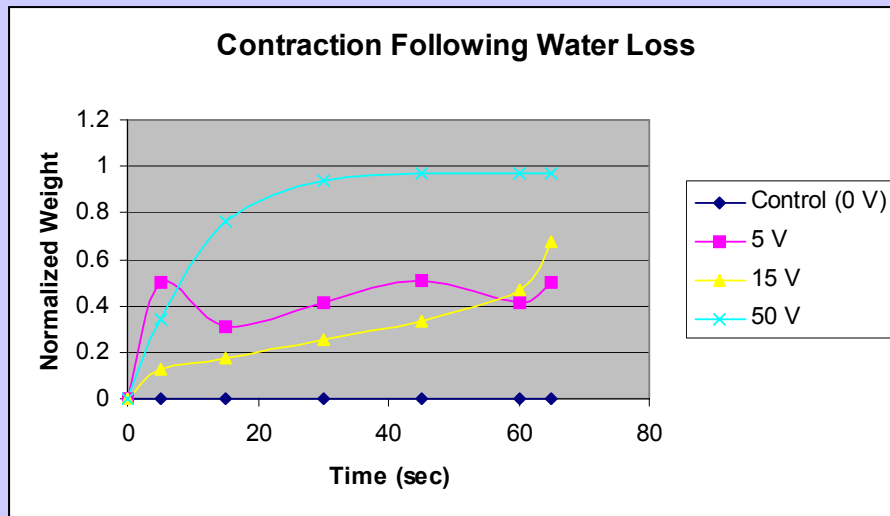
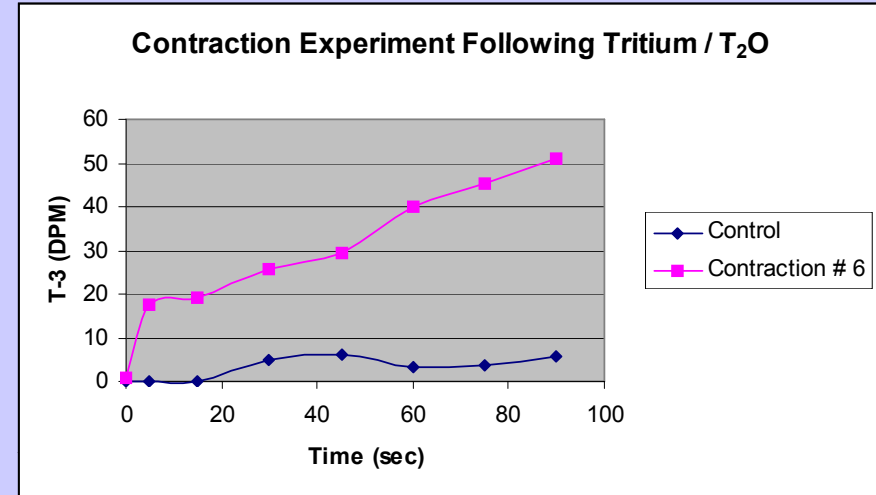
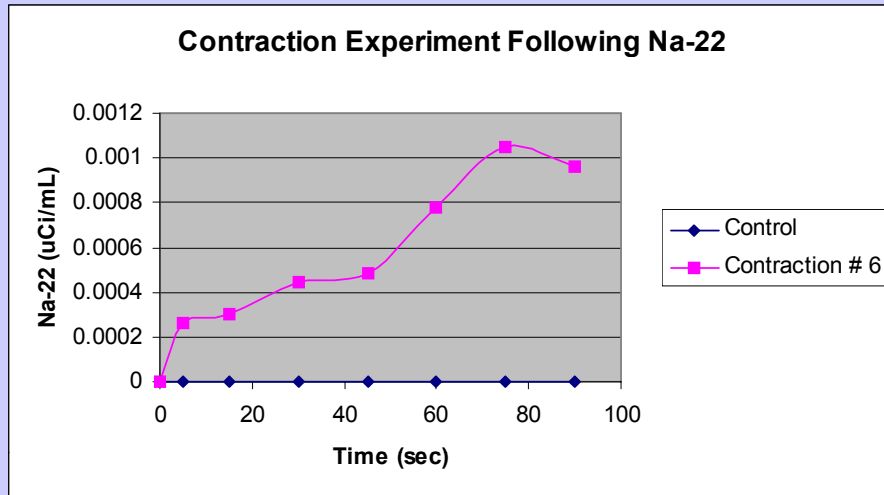
Sample	Weight to break (g)	Distance (cm)	Stress (N/m ² = kg/ms ²)	<Stress> (N/m ²)
Control 1†	183	1	18.3	
Control 2	5,600	1.3	431	431
N plasma 1	6,800	1.5	453	476
N Plasma 2	7,500	1.5	500	
O plasma 1	6,300	1	630	746
O plasma 2	6,900	0.8	862	

† Control 1 not used in average data set.

Radionuclide Experiment



Contraction Experiment



Sample	Na-22	T-3	T-3 Normalized (DPM)
Control	0	53.60	100
Bending EAP	0	47.60	72
Contraction EAP # 6	0	20.85	34

Conclusions and Goals

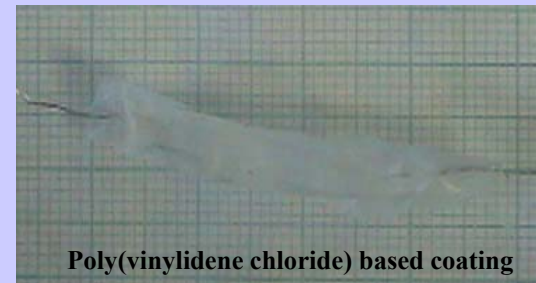
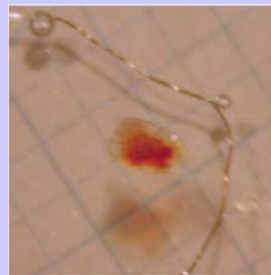
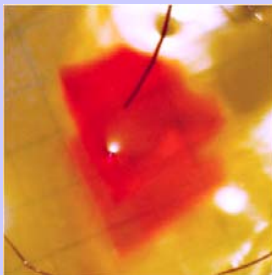
- **Materials were synthesized to produce EAP smart materials with good strength, durability, and electroactivity (with electric input). Some of these EAP material expand, some bend, and some contract. Reversing the polarity produces contraction-expansion cycles. Data driven contractile theory being determined.**
- **Thin elastomeric coatings or coverings, which also serve as a moisture barrier, act as “skin,” preventing evaporation and leakage of the electrolyte solution(s) and allowing these actuators to be fully operational anywhere. Electrolytic effects being investigated as part of a bilayer coating.**

Goal: Byproduct gases used to drive a fuel cell. Electricity generated used to drive next EAP in series of device. Conceivably could produce extremely energy efficient devices.

- **Research and development to significantly improve the polymer-electrode interface was accomplished. Further improvements using a variety of mechanisms are ongoing.**

Goal: For both the electroactive smart material and the embedded electrodes to move as a unit, analogous to our muscles and nerves moving together.

The embedded electrode serves a dual purpose: conducting the electric stimulus, analogous to a nerve; and connecting the electroactive material to jointed levers, analogous to a tendon connecting muscle to bone.



Poly(vinylidene chloride) based coating

Patents pending

Acknowledgements

Prof. Steven L. Bernasek, Esta Abelev

Princeton University Department of Chemistry

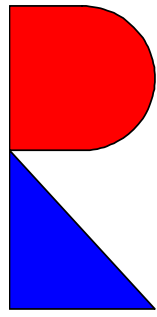
Prof. Nan Yao, Jane Woodruff

Princeton University Imaging and Analysis Center (IAC)

Prof. Robert J. Cava, Anthony Williams

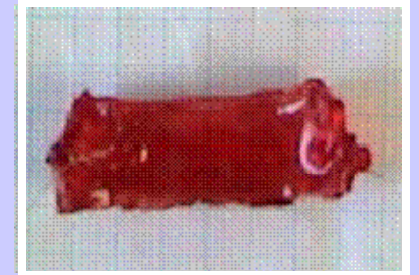
Princeton University Department of Chemistry

Q & A



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TRI/Princeton



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