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Novel Actuator Applications for New High Drive Piezoceramic Materials

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PiezoTechnologies

Indianapolis, IN

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Introduction

- Background: 2002 thru Today
- Actuator
  - Market
  - Requirements
  - Design
  - Results
  - Conclusions
- Future Work

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Background

- Work on New Materials first reported @ 32nd UIA Symposia, 2002 by Liufu et al
- Brosch et al reported latest work @ ISTU, Oct. 2005 on 128 element HIFU P.A.
- Chopra, et al Sunnybrook and Women's College,2005, Transurethral Prostate Therapy

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Liufu 2002

- Conclusions
- A new material is being developed that improves on current Navy I equivalent materials.
- The new material has equal or better performance in the tested high power transducers.
- Higher d_{33} value should allow for higher displacement at high power.
- This ceramic may be applicable for high power composites and therapeutic array work, as well as industrial high power applications.

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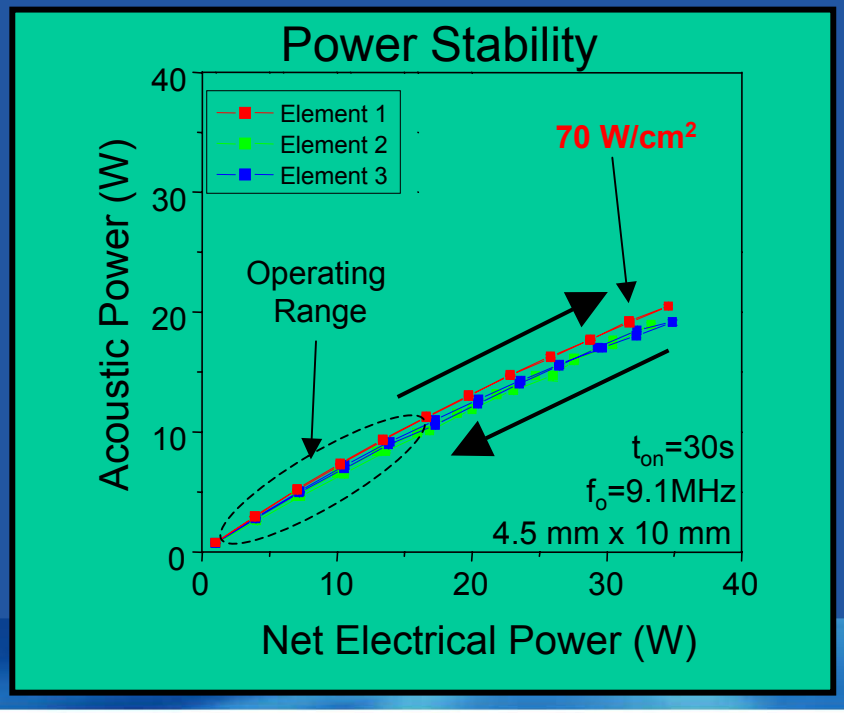
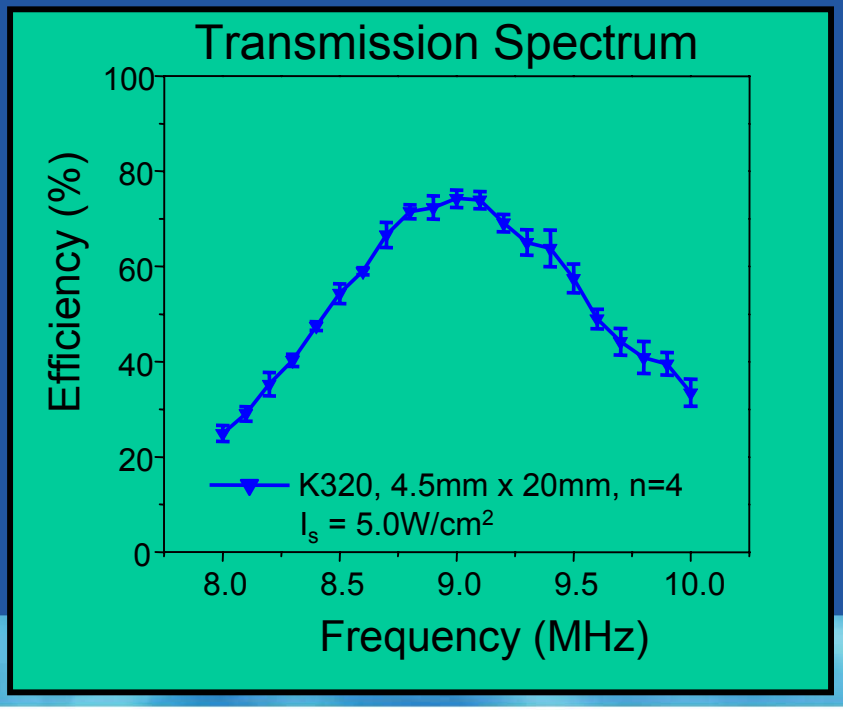
Brosch 2005

- K320 is superior to standard high power PZT's for HIFU in terms of efficiency and power handling capability.
- K320 is easily fabricated into complicated geometries and integrated into HIFU arrays.
- The material is functional in a HIFU array in an in vitro setting

Application: Transurethral Prostate Thermal Therapy

- Multi-element transducers: small size (5mmx10mm), high power (P_a~10W)
- Limited space for cooling
- Continuous application of power (up to 20min)
- Characterized prototype devices (K320) with radiation force measurements





Rajiv Chopra, Michael Bronskill, et al.

Sunnybrook & Women's College Health Sciences Centre, Toronto, Canada

SUNNYBROOK & WOMEN'S
Sunnybrook and Women's College Health Sciences Centre

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Miniature Piezo Fan

Market Drivers

- Increased Power Requirements
- Smaller Packages: Handhelds, Portables
- Greater Heat Dissipation Needs
- Very Low Power Consumption
- Very High Annual Volumes: >10^9/ yr
- Target Spot Cooling Applications

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General Requirements

- Low Voltage Source: 3 to 12 Vdc typ.
- Low Power Consumption: <100 mW
- Survive Reflow Process: <= 300 C, 90 Sec
- Very Small Footprint: < 38 mm L
  x 12 mm W x 2 mm H
- Temperature: - 60 to +100 C

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Miniature Piezo Fan Cooling Technologies

- PiezoFans: Single layer, Series/Parallel Bimorphs
- Heat sinks / Thermal Conductive Greases
- Heat Pumps/ Radiators
- Thermoelectric Coolers
- Axial Fans
- Evaporative Spray

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Some Equations

- Series BM, D = 1.5* d31*V*(L^2/t^2)
- Parallel BM, D = 3 * d31*V*(L^2/t^2)
- Cm = (4/Y11)* (L^3/(W*t^3))
- Fb = D/Cm
- M = (d31*E)/Y11 , E = V/mm

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Some More Equations

- Vtip = F x D
- A = D x W
- CFM = Vtip x A /450

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	Qm (planar)	Kp	K31	D31 (pC/N)	ε	Dissipation factor	Y11 10^10 N/M^2	E (kVrms /mm)	Tc (˚C)	M
K278 (Type III)	1000	0.51	0.30	-95	1000	0.004	9.9	1	300	9.6
K270 (Type I)	800	0.58	0.33	-120	1300	0.008	8.5	.4	325	5.6
*K350 (type II)	75	0.60	0.35	-170	1450	0.015	6.9	.088	350	2.2
*K320	>1500	0.58	0.27	-140	1500	0.003	9.4	1.3	335	19.4
K700 (type VII)	80	0.71	0.40	-290	4000	0.020	7.0	.08	225	6.6

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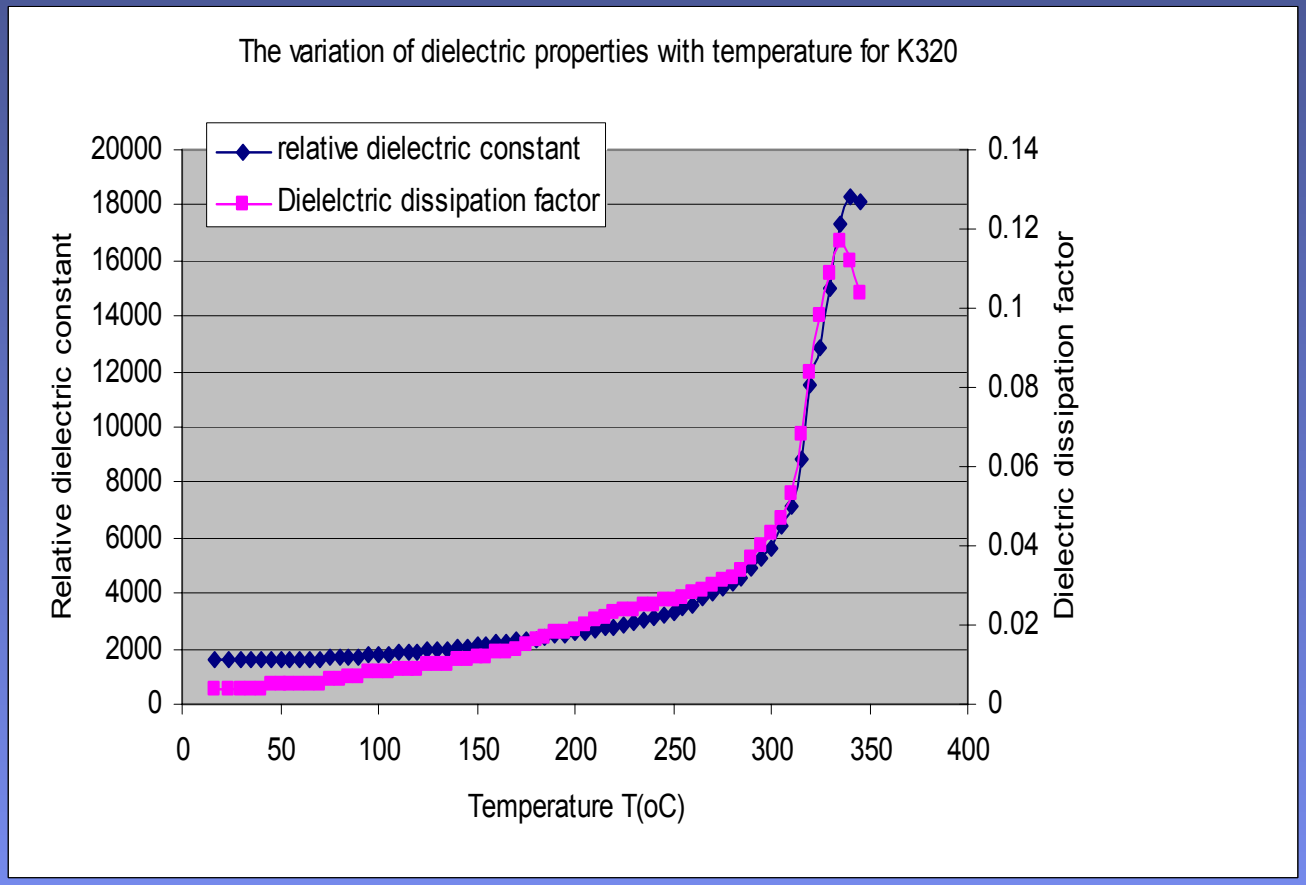

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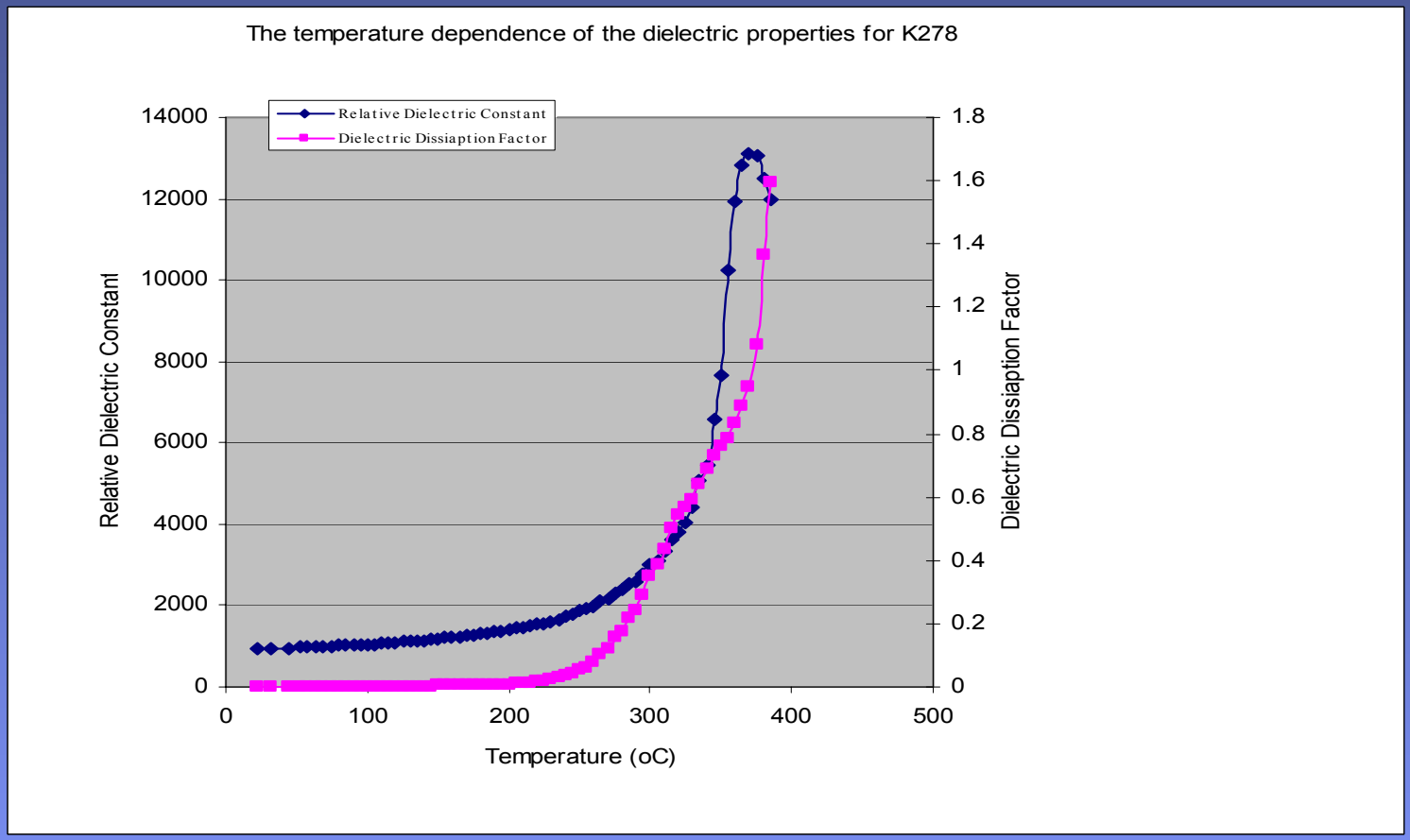

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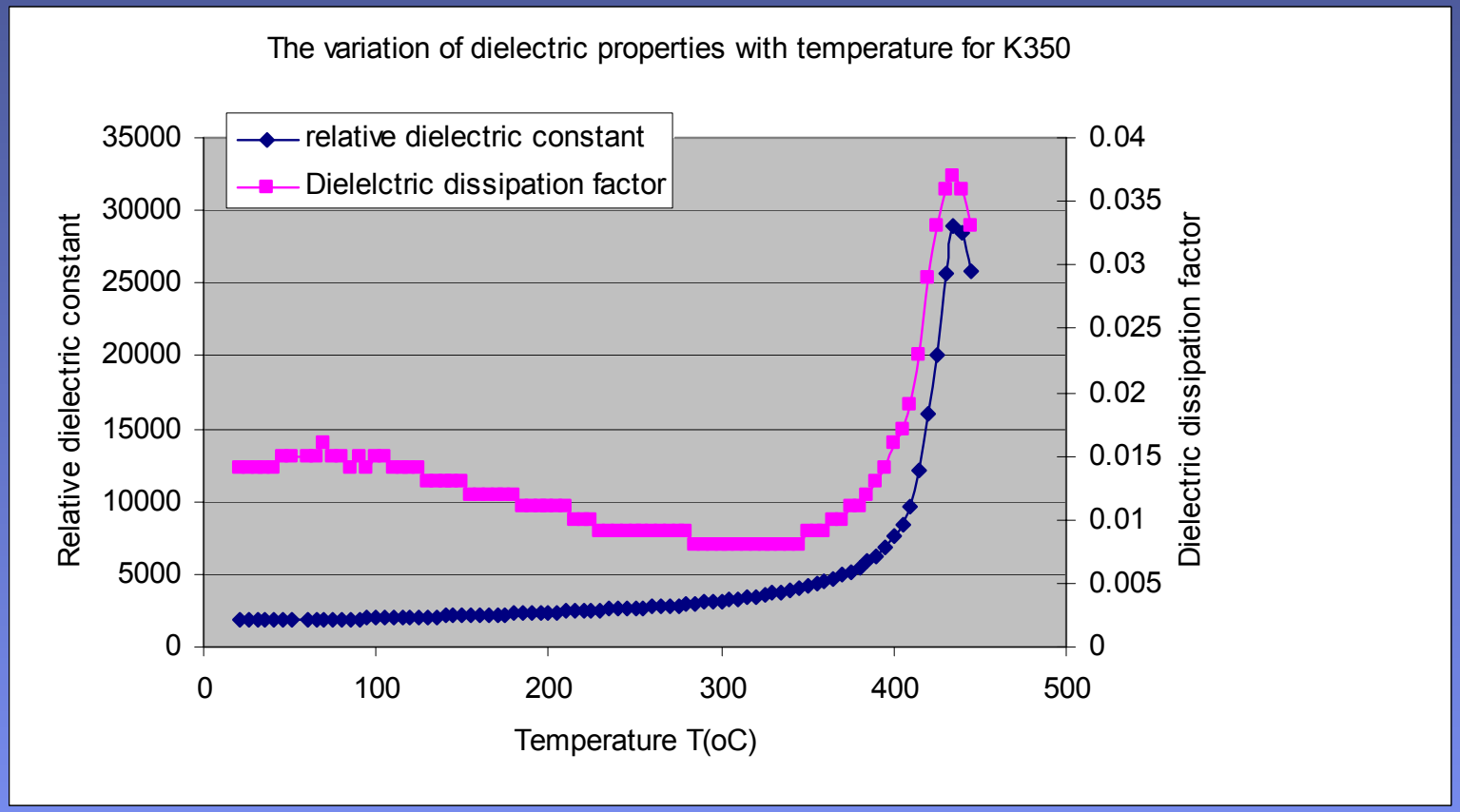

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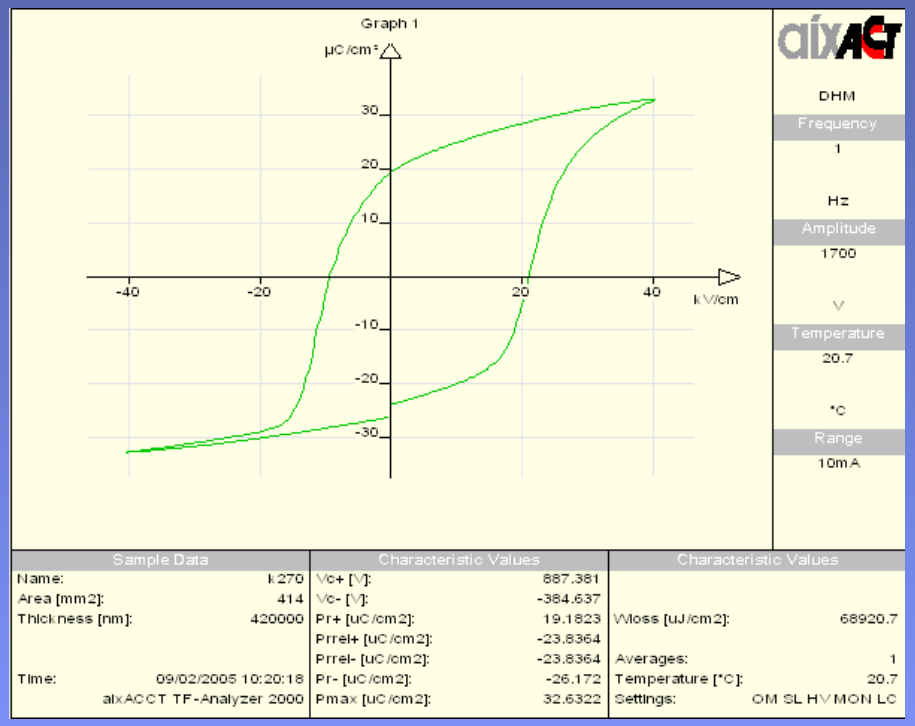
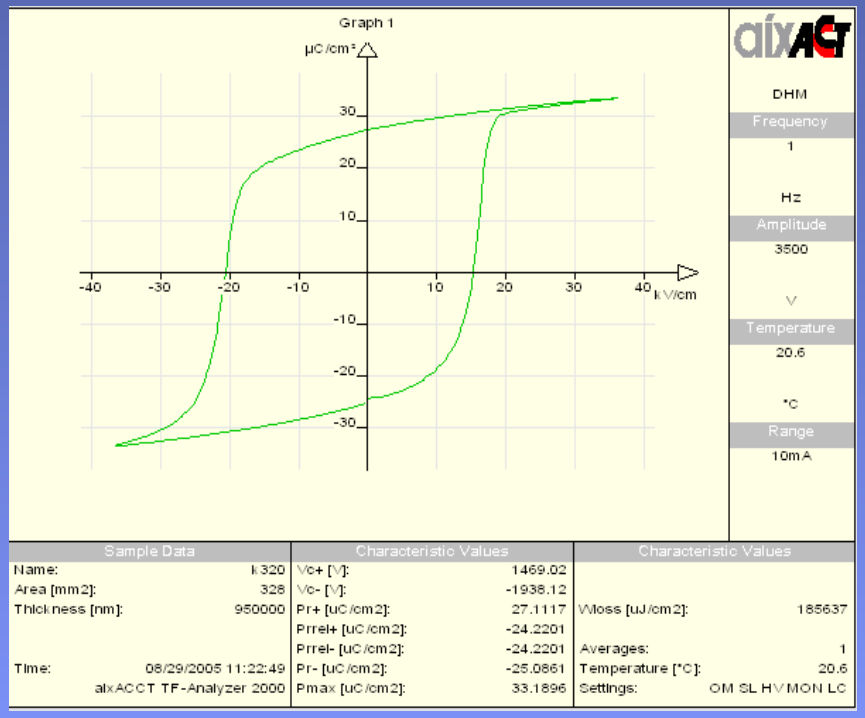
Hysteresis Loops at 1Hz show the difference in coercive fields. K320 is closer to ideal. Coercive field for PZT-4 is approximately 1.5kV/mm, K-320 is 1.8kV/mm



Sample Data		Characteristic Values		Characteristic Values	
Name:	k270	Vc+ [V]:	887.381		
Area [mm2]:	414	Vc- [V]:	-384.637		
Thickness [nm]:	420000	Pr+ [uC/cm2]:	19.1823	Wloss [uJ/cm2]:	68920.7
		Prrel+ [uC/cm2]:	-23.8364		
		Prrel- [uC/cm2]:	-23.8364	Averages:	1
Time:	09/02/2005 10:20:18	Pr- [uC/cm2]:	-26.172	Temperature [°C]:	20.7
	aixACCT TF-Analyzer 2000	Pmax [uC/cm2]:	32.6322	Settings:	OM SL HV MON LC



Sample Data		Characteristic Values		Characteristic Values	
Name:	k320	Vc+ [V]:	1469.02		
Area [mm2]:	328	Vc- [V]:	-1938.12		
Thickness [nm]:	950000	Pr+ [uC/cm2]:	27.1117	Wloss [uJ/cm2]:	185637
		Prrel+ [uC/cm2]:	-24.2201		
		Prrel- [uC/cm2]:	-24.2201	Averages:	1
Time:	08/29/2005 11:22:49	Pr- [uC/cm2]:	-25.0861	Temperature [°C]:	20.6
	aixACCT TF-Analyzer 2000	Pmax [uC/cm2]:	33.1896	Settings:	OM SL HV MON LC

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Miniature Piezo Fan

- Fan Design Requirements
- 1.27 cm (.50 in)L x .32 cm (.13 in)W x Max blade deflection (D)
- Frequency : < = 1 KHz
- Survive Reflow Temperatures, >260 C, 90 S
- Power Consumption: mW's
- High Humidity: > 90 %
- Operating Life: > = 10,000 hrs over 3 to 20 year periods

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Miniature Piezo Fan Results

Type	Length	Tp	Tb	Width	Blade Mat'l	Piezo Mat'l	Vrms	Imp, Kohm	P, mW
1. Ser	12.7	.15	.05	1.0	Poly	K-320	120	>100	144
2. Ser	12.7	.15	.12	1.0	Poly	K-320	120	>100	144
3. Ser	25.4	.48	.05	6.3	Poly	K-700	120	147	98
4. Par	25.4	.30	.04	4.0	Metal	K-700	50	75	33

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Miniature Piezo Fan Results

Type	F, Hz	D , mm	Vtip, mm/s	CFM	%, D/L
1.	340	5	1700	.02	39.4
2.	833	5	4160	.05	39.4
3.	202	8	1616	.18	31.5
4.	165	6.5	1070	.093	25.6

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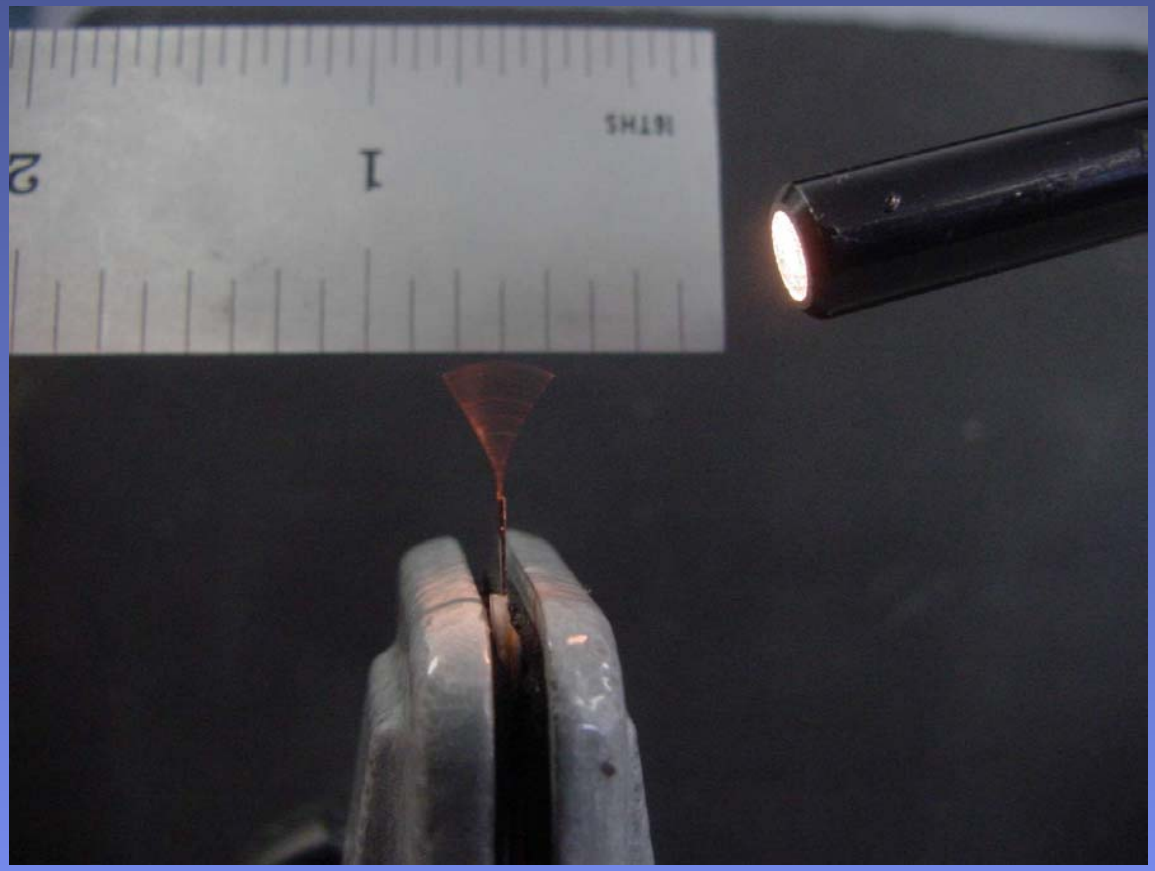

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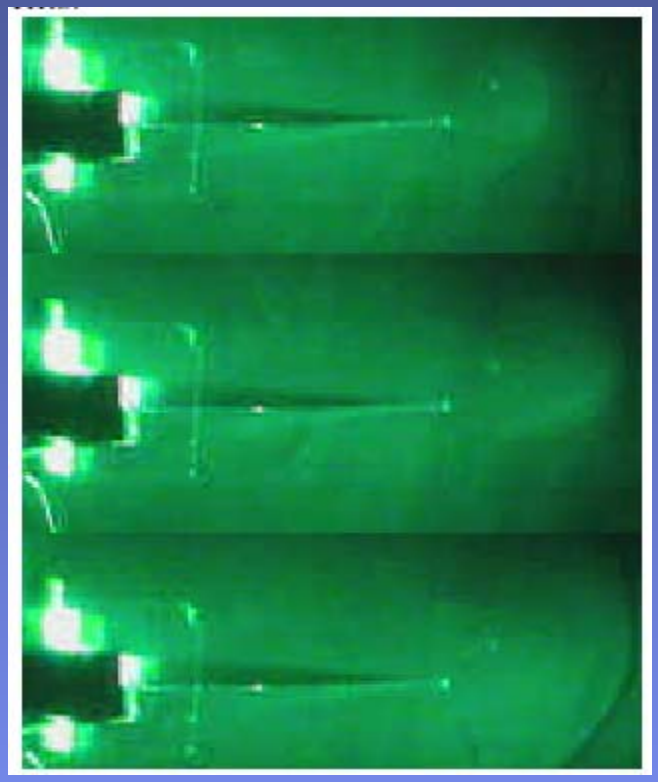
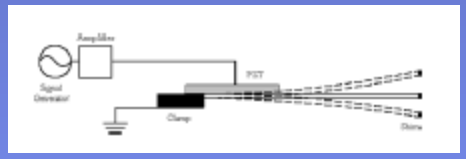
Photos courtesy CTRC, Purdue University



Edge-on view of piezoelectric fan

Fluid flow visualization from piezoelectric fan



Schematic of piezoelectric fan design

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Conclusions

- K320 is a viable alternative to soft piezo's for small actuator applications
- Can achieve high tip displacements and flow rates
- Can potentially reduce input power requirements to achieve this
- Can meet environmental requirements

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Future Work

- Design an even thinner bimorph to operate at lower voltage, yet maintain D, i.e. CFM
- Integrate with SMT connector and Drive Circuit For DC input
- Validate Operational Parameters and Survivability

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Additional Work

- High Output, 260 C Use Audio Tone Generator
- 1000 W Langevin Transducer, < 40 mm AED
- < 12 mm AED, High Displacement Langevin
- HIFU Arrays and Single Element Transducers
- Several Patents applied for covering some or all of the technology being developed
- Licensing or Acquisition of IP for certain markets available

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Acknowledgements

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