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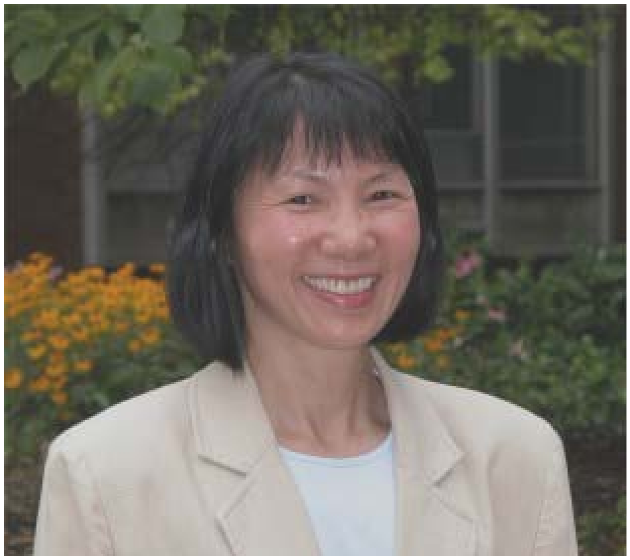

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EDUCATION:

1984	Ph.D in Physics, Ohio State University, Columbus, Ohio, 43210 Thesis Advisor: Prof. D. Stroud Thesis Title: Theory of Superconducting Arrays in a Magnetic Field
1976	B.S. in Physics, Tsing-Hua University, Hsin-Chu, Taiwan, ROC

EMPLOYMENT:

2006-present	Associate Professor, School of Biomedical Engineering, Science & Health Systems, Drexel University, Philadelphia, Pennsylvania
1993-2006	Research Associate Professor, Department of Materials Science and Engineering, Drexel University, Philadelphia, Pennsylvania.
1993-99	Research Scientist, Princeton Materials Institute, Princeton University, Princeton, New Jersey.
1985-92	Research Scientist, Department of Materials Science & Engineering, University of Washington, Seattle, Washington
1984-85	Postdoctoral Research Associate, Materials Research Laboratory and Department of Physics, Ohio State University, Columbus, Ohio
1982-84	Graduate Research Associate, Materials Research Laboratory and Department of Physics, Ohio State University, Columbus, Ohio
1979-82	Graduate Teaching Associate, Department of Physics, Ohio State University

1978-79 Research assistant, Ion-Implantation Laboratory, Tsing-Hua University, Hsin-Chu, Taiwan
1976-78 Physics Teacher, Hong-Zen Girls' Middle School, Chia-Yi, Taiwan.

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1. (Co-PI) Rheology of Silver Nanopowder Suspensions, PI: Wei-Heng Shih, funded by Ben Franklin Institute, **$50,000**, 12/1/2006-5/31/2007.
2. (Co-PI) Piezoelectric Biosensor for Anthrax Detection, PI: B. Onaral, funded by **DOT**, **$750,000**, 4/1/2006-3/31/2007.
3. (PI) Nanotechnology Institute Core Project: Array Piezoelectric Microcantilever Biosensors, funded by Ben Franklin Nanotechnology Institute, Philadelphia, **$100,000**. 1/1/2005-12/31/2005.
4. (Co-PI) Nanotechnology Institute Seed Project: Environmentally Friendly and Biocompitable QD, PI: Wei-Heng Shih, funded by Ben Franklin Nanotechnology Institute, Philadelphia, **$30,000**. 1/1/2005-12/31-2005.
5. (Co-PI) Piezoelectric Biosensor for Anthrax Detection, PI: B. Onaral, funded by **DOT**, **$1,000,000**, 3/1/2005-2/28/2006.
6. (Co-PI) Portable Array Piezoelectric Microcantilever Sensors for Chemical Terrorism Agent Detection, PI: W.-H. Shih, funded by **NSF**, **$200,000**, 9/1/2004-8/31/2006.
7. (Co-PI) Piezoelectric Biosensor for Anthrax Detection, PI: B. Onaral, funded by **DOT**, **$500,000**, 8/1/2004-2/28/2005.
8. (Co-PI) Molecular and Structural Mechanisms, Detection and Antagonism of Anthrax Toxins, PI: I Chaiken, funded by **Commonwealth of Pennsylvania, $75,000**, 6/1/2004-11/30/2004.
9. (PI) Quantitative Array Piezoelectric Microcantilever Sensors, funded by NIH, **$1,056,000**, 10/1/02-9/30/05.
10. (PI) Ultrasensitive Pathogen Quantification in Drinking Water Using Highly Piezoelectric PMN-PT Microcantilevers, funded by **EPA**, **$400,000**, 1/1/2002-12//31/2005.
11. (PI) Biomolecular and Cell Detection Using Piezoelectric Cantilevers, funded by Ben Franklin Nanotechnology Institute, Philadelphia, PA, **$147,500**, 8/02-7/04.
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13. (PI) Ultrasensitive High-Temperature Selective Gas Detection Using Piezoelectric Microcantilevers, funded by **DOE**, **$50,000**, 10/02-9/03.
14. (PI) Femtogram Biomolecular Recognition Using Piezoelectric Cantilevers funded by NSF, **$100,000**, 9/01/2001-8/31/2002.
15. (Co-PI) Study on the Gelation, Consolidation, and Rheology of Sol-Gel Coated Ceramic Suspensions, funded by **NSF**, **$259,463**, 1997-2001.

PATENTS:

1. J. Vartuli, D. L. Milius, Xiaoping Li, W.-H. Shih, **W. Y. Shih**, R. K. Prud'homme, and I. A. Aksay, "Multilayer Cermic Piezoelectric Laminates with Zinc Oxide Conductors," United States Patent No. 6,329,741 issued Dec. 11, 2001.

PATENT APPLICATIONS:

2. **W. Y. Shih**, W.-H. Shih, and Z. Shen, “Piezoelectric Cantilever Sensor,” Patent Application No. PCT/US2004/036705, October 27, 2004.
3. W.-H. Shih, **W. Y. Shih**, and H. Gu, “Method of Making Mixed Metal Oxide Ceramics,” US Patent Application No. 10/981,985, Nov. 6, 2004.
4. W.-H. Shih, H. Li, M. Schillo, and **W. Y. Shih**, “Synthesis of Water Soluble Nanocrystalline Quantum Dots and Uses Thereof,” US Patent application No. 60/573,804, May 24, 2005.
5. **W. Y. Shih**, W.-H. Shih, A. Markidou, S. T. Szewczyk, H. Yegingil, “All-electrical Piezoelectric Finger Sensor (PEFS) for Soft Material Stiffness Measurement,” Patent Application No. 11/136,173, May, 2005.
6. Wei-Heng Shih, Hongyu Luo, Christian Martorano, and **Wan Y. Shih**, “Freestanding Films with Giant Electric-Field-Enhanced Piezoelectric Coefficients,” US patent application No. 11/392,116, filed March 29, 2006, Publication no. Us 2006 022 3691.
7. **Wan. Y. Shih**, Wei-Heng Shih, and Joseph Capobianco, “Electrical Insulation of Devices with Thin Layers” filed in July 7, 2006. US Provision patent application No. 60/806,765.
8. **Wan Y. Shih**, Wei-Heng Shih, Zuyan Shen, Qing. Zhu, Joeseph Capobianco, and John-Paul-McGovern, “Piezoelectric Microcantilever Sensors for Biosensing,” filed on November 6, 2006, US provisional patent application No. 60/867,538.
9. **Wan Y. Shih**, Wei-Heng Shih, and Zuyan Shen, “Piezoelectric Microcantilevers and Uses in Atomic Force Microscopy,” filed November 6, 2006, US provisional patent application No. 60/867,539.
10. **Wan Y. Shih**, Wei-Heng Shih, Zuyan Shen, Huidong Li, and Xiaotong Gao, “Sol-Gel Precursors and Methods for Making Lead-Based Perovskite Films,” filed November 20, 2006, US provisional patent application No. 60/864,470.
11. Wei-Heng Shih, **Wan Y. Shih**, and Hakki Yegingil, “Energy Harvesting Device,” filed in January 29, 2007. US Provision patent application No. 60/887,051.
12. **Wan Y. Shih** and Wei-Heng Shih, “A Hand-Held Phase-Shift Detector for Sensor Applications,” filed February 1, 2007, US provisional patent application 60/887,686.
13. Wei-Heng Shih, **Wan Y. Shih**, and Hui Li, “Nontoxic Quantum Dots,” filed November, 2006.
14. **Wan Y. Shih** and Wei-Heng Shih, “Use of Fluorescent Microspheres for Sensitivity Enhancement and Selectivity Verification in Resonance Frequency-Based Biosensors,” filed April, 2007.
15. **Wan Y. Shih**, Wei-Heng Shih, and John-Paul McGovern, “Flow Enhanced Specificity in Biosensing,” filed April, 2007.

PUBLICATIONS:

1. **W. Y. Shih** and D. Stroud, "Molecular-Field Approximation for Josephson-Coupled Superconducting Arrays in a Magnetic Field," *Phys. Rev. B* **28**, 6575 (1983).

2. **W. Y. Shih**, C. Ebner and D. Stroud, "Frustration and Disorder in Granular Superconductors," *Phys. Rev. B* **30**, 134 (1984).
3. **W. Y. Shih** and D. Stroud, "Superconducting Arrays in a Magnetic Field: Effects of Lattice Structure and a Possible Double Transition," *Phys. Rev. B* **30**, 6774 (1984).
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5. **W. Y. Shih** and D. Stroud, "Effects of Lattice Structure on 2d Superconducting Arrays in a Magnetic Field," *Phys. Rev. B* **32**, 158 (1985).
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11. I. A. Aksay, **W. Y. Shih**, and M. Sarikaya, "Colloidal Processing of Ceramics with Ultrafine Particles," in *Ultrastructure Processing of Advanced Ceramics*, ed. by J. D. Mackenzie and D. R. Ulrich (John Wiley & Sons, New York, 1988), p. 393.
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45. C.-Y. Yang, **W. Y. Shih**, and W.-H. Shih, “Gelation, Consolidation, and Rheological Properties of Boehmite-Coated Silicon Carbide Suspensions,” *J. Am. Ceram. Soc*., **83**[8], 1879-84 (2000).
46. **W. Y. Shih**, X. Li, H. Gu, W.-H. Shih, and I. A. Aksay, "Simultaneous Liquid Viscosity and Density Determination Using Piezoelectric Unimorph Cantilevers," *J. Appl. Phys*., **89**, 1497 (2001).
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83. J.-P. McGovern, **W. Y. Shih**, and W.-H. Shih, “In-Situ Detection of Bacillus Anthracis Spores Using Fully Submersible, Self-Exciting, Self-Sensing PMN-PT/Sn Piezoelectric Microcantilevers,” *The Analyst*, 132, 777-783 (2007).
84. W.-S. Su, **W. Y. Shih**, H. Luo, Y.-F. Chen, and W.-H. Shih, “Non-180° Domain Switching in PMN-PT Polycrystalline Sheets at Single Grain Level,” *Appl. Phys. Lett*., **91**, 112903 (2007)
85. Z. Shen, **W. Y. Shih**, and W.-H. Shih, “Flexural Vibrations and Resonance of Piezoelectric Cantilevers with a Nonpiezoelectric Extension,” *IEEE Trans. on Ultra. Ferro. Freq. Cont.*, in print (2007).
86. H. Luo, **W. Y. Shih**, and W.-H. Shih, “Double Precursor Solution Coating approach for Low-Temperature Sintering of $[Pb(Mg_{1/3}Nb_{2/3})O_3]_{0.63}[PbTiO_3]_{0.37}$ Solids,” *J. Am. Ceram. Soc.*, (2007), DOI: 10.1111/j.1551-2916.2007.02072.x.
87. H. Yegingil, **W. Y. Shih**, and W.H. Shih, “Probing Bottom-Supported Inclusions in Model Tissues Using Piezoelectric Cantilevers,” *Rev. Sci. Instr*., (2007), DOI: 10.1063/1.2793502.
88. H. Li, **W. Y. Shih**, and W.-H. Shih, “Stable aqueous ZnS quantum dots using (3-mercaptopropyl)trimethoxysilane as capping molecule,” Nanotechnology, (2007), in print.

SUBMITTED PAPERS:

1. Z. Shen, H. Li, W. Y. Shih, and W.-H. Shih, “Synthesis, Properties, and Micro-patterning of Sol-Gel $Pb(Zr_{0.53}Ti_{0.47})O_3$ Thin Films, submitted to *Thin Solid Films*.
2. H. Li, W. Y. Shih, and W.-H. Shih, “Colloidal Coating Approach for Sodium Potassium Niobate Solids,” submitted to *J. Am. Ceram. Soc.*
3. J. Capobianco, W. Y. Shih, W.-H. Shih, Q.-A. Yuan, and G. P. Adams, “Label-free, All-electrical, In-Situ Human Epidermal Growth Receptor-2 Detection,” submitted to Biosensors and Bioelectronics.
4. Q. Zhu, W. Y. Shih, and W.-H. Shih, “Scaling Behavior of Lateral Strain-Induced Resonance Frequency Shift of Piezoelectric Microcantilever Sensors,” submitted *J. Appl. Phys.*
5. H. Gu, W. Y. Shih, and W.-H. Shih, “Effect of Excess PbO on the Sintering and

Dielectric properties of $(PbMg_{1/3}Nb_{2/3}O_3)_{0.9}(PbTiO_3)_{0.1}$ Prepared by a One-Step, Low-Temperature, Reactive Sintering Process," submitted to *Int. J. Appl. Ceram. Tech*.

6. J.-P. McGovern, W.Y. Shih, R. Rest, M. Purohit, Y. Pandia, "Label-Free Flow-Enhanced Specific Detection of Bacillus anthracis Detection Using a Piezoelectric Microcantilever Sensor," Submitted to *The Analysit*.

INVITED SEMINARS/PRESENTATIONS:

1. US EPA Region 3 Workshop on: Cryptosporidium Research Associated with Monitoring and Analytical Efforts in the Mid-Atlantic, 9/13/2007, "Array Piezoelectric Microcantilever Sensors (PEMS) for Rapid, Label-Free, Real-Time Cryptosporidium parvum (CP) Oocysts Detection in Water,"
2. EPA, Fort Meade, 7/25/2007, "Array Piezoelectric Microcantilevers for Rapid, High-through-put, Label-free, Protein Detection in Serum."
3. LiveSensors, 4/19/2007, "Array Piezoelectric Microcantilevers for Rapid, High-though-put, Label-free, Protein Detecton in Serum"
4. Fox Chase Cancer Center, 4/10/2007, "Array Piezoelectric Microcantilevers for Rapid, High-though-put, Label-free, Protein Detecton in Serum."
5. Proctor and Gamble, 2/23/2007, "Piezoelectric Microcantilever Sensors and Piezoelectric Fingers"
6. National Tsinghua University, 3/6/07, "Piezoelectric Microcantilever Sensors and Fluorescent Nanoparticles: Materials, Fabrication, and Applications"
7. ITRI, 2/26/07, "Piezoelectric Microcantilever Sensors and Fluorescent Nanoparticles"
8. Tunghai University, 12/22/06, "Piezoelectric Microcantilever Sensors and Fluorescent Nanoparticles"
9. Third International Conference on Technological Advances of Thin Films and Surface Coatings, Singapore, 12/12/06, "Synthesis of PZT Thin Films and Microfabrication of Piezoelectric Microcantilever Sensors".
10. 39th International Microelectronic and Packaging Society Conference, in San Diego, CA, October 11, 2006, "Self-Exciting, Self-Sensing PZT/SiO_2 Piezoelectric Microcantilever Mass Sensors with Femtogram/Hz Sensitivity."
11. Workshop on Bioimaging and Engineered Biosystems, Lehigh University, September 28, 2006, "Piezoelectric microcantilever sensors, piezoelectric fingers and quantum dots."
12. La Jolla Institute for Molecular Medicine, January 13, 2006, "Piezoelectric Cantilever Sensors for Biomedical Applications."
13. Millipore, January 10, 2006, "Piezoelectric Cantilever Sensors for Biomedical Applications."
14. Nanotechnology and the Environment: Applications and Implications Progress Review Workshop III, in Arlington VA, October 27, 2005 "Ultrasensitive Pathogen Quantification in Drinking Water Using High Piezoelectric PMN-PT Microcantilevers."
15. National Taiwan University, Taiwan, 8/29/05, "Piezoelectric Cantilever Sensors for Emerging Biotechnology."
16. Stryker, August 11, 2005, "Piezoelectric Microcantilever sensors for Biomedical Applications."
17. Stryker, August 11, 2005, "Piezoelectric Fingers for Tissue Stiffness Imaging and

Energy Harvesting."

18. GlaxoSmithKline, April 15, 2004, "Aqueous Quantum Dots and Piezoelectric Microcantilevers for Biomedical Applications."
19. U.S. EPA 2004 Nanotechnology Science To Achieve Results (STAR) Workshop-Nanotechnology and the Environment II, August 18-20, 2004 "Ultrasensitive Pathogen Quantification in Drinking Water Using High Piezoelectric PMN-PT Microcantilevers."
20. Kulicke and Soffa, October 8, 2004, "Piezoelectric Cantilever Biosensors."
21. A. J. Drexel Institute of Basic and Applied Protein Science 2nd Annual Retreat, June 15, 2004, In-Situ Quantification of Cells and Proteins Using Array Piezoelectric Microcantilevers: Potential for Real-Time Immunoassay.
22. Benjamin Franklin Institute, March 5, 2004, Piezoelectric Microcantilever Biosensors.
23. Exxon-Mobil, April 28, 2004, *Piezoelectric Cantilever Biosensors*.
24. Invited talk, 227th American Chemical Society National Meeting, Anaheim, CA, March 31, 2004, Nanotechnology and the Environment Session, *Miniaturized highly piezoelectric cantilevers for rapid direct pathogen detection.*
25. Invited talk, 225th American Chemical Society National Meeting, New Orleans, LA, March 27, 2003, Nanotechnology and the Environment Session, *Miniaturized highly piezoelectric unimorph cantilevers for rapid in situ pathogen quantification*.
26. Department of Materials Science and Engineering, Clemson University, Clemson, SC, February 25, 2003, *PiezoElectric Microcantilevers (PEMS) for Sensing Applications.*
27. Materials Research and Education Center, Auburn University, Auburn, AL, December 11, 2002, *PiezoElectric Microcantilevers (PEMS) for Sensing Applications*.
28. American Vacuum Society topical conference on understanding and operating in threat environments, Monterey, CA, May 2, 2002, *Miniaturized Piezoelectric Microcantilevers for Chem/Bio Detection*.
29. Scientists Help America Conference, Washington DC, March 11, 2002, *Miniaturized Piezoelectric Microcantilevers for Chem/Bio Detection*.
30. School of Environmental Science, Engineering, and Policy, Drexel University, Philadelphia, PA, March 8, 2002, *Piezoelectric Cantilever Sensors for Environmental Application*.
31. Department of Materials Science and Engineering, Lehigh University, Bethlehem, PA, December 3, 2001, d_{31}*-gradient Piezoelectric Transducers for Sensing Applications*.
32. Department of Ceramic Engineering, University of Missouri Rolla, October 29, 2001, d_{31}*-gradient Piezoelectric Transducers for Sensing Applications*.
33. Industrial Technology Research Institute, Hsin-Chu, Taiwan, July 1992, *Colloidal Aggregation and Ceramic Processing*.
34. Academia Sinica, Taipei, Taiwan, December 1989, *Aggregation in Colloidal Suspensions with finite Interparticle Attraction Energies.*
35. Department of Materials Science and Engineering, University of Washington, Seattle, WA, April, 1989. *Polymer Adsorption on Colloidal Surface*.
36. 3M Corporations, St. Paul, NM, October 1988, *Aggregation of Colloidal Particles With Finite Interparticle Attraction Energies.*

CONFERENCE PRESENTATIONS:

Co-author of 139 conference presentations.

STUDENTS SUPERVISED:

6 Ph.D.'s and 4 MS granted, 6 senior design projects, 7 current Ph.D students

STUDENT	DEGREE	YEAR	PROJECT	CO-ADVISOR	CURRENT JOB
Xiaoping Li	Ph.D	Graduated 1999	Piezoelectrics	W.-H. Shih	American Superconductor
Chia-Yi Yang	Ph.D	Graduated 2001	Colloids	W.-H. Shih	Amgen
Huiming Gu	Ph.D	Graduated Fall,2003	Piezoelectrics, Colloids	W.-H. Shih	Cadient
Qiang Zhao	Ph.D	Graduated Spring,2004	Colloids	W.-H. Shih	Saint-Gobain
Hongyu Lou	Ph.D	Graduate Spring 2005	Piezoelectric thick films, Colloids	W.-H. Shih	Halliburton
Zuyan Shen	Ph.D	Graduate Fall 2006	Piezoelectric Microcantilever Fabrication		Fuji Films
Hakki Yegingil	PhD		Piezoelectric cantilever/tissue imaging		
Hui Li	PhD		Quantum Dots		
Qing Zhu	PhD		Piezoelectric Cantilever Fabrication		
John-Paul McGovern	PhD		Piezoelectric cantilevers/biosensor		
Huidong Li	PhD		Piezoelectric thin films	W.-H. Shih	
Joseph Capobianco	PhD		Piezoelectric Sensors	W.-H. Shih	
Xiaotong Gao	PhD		Piezoelectric disk Fabrications		
Anna Markidou	MS	Graduated Summer 2003	Piezoelectric cantilever/tissue characterization		Teaching and pursuing PhD at University of Cyprus
Suk Hun Choi	MS	Graduated Summer 2002	Piezoelectric thin films	Y. Lee	Samsung Electronics, Korea
Rocky Chiu	MS	Graduated Spring 2005	Piezoelectric thin films	W.-H. Shih	Alinc Taiwan, Taiwan

Jose Bermudas	MS	Graduated Summer 2005	Ceramic Nanoparticles and Nanocoating	W.-H. Shih	DU-CO Ceramics

POSTDOCTORAL SCHOLARS SPONSORED:

1 postdoc, Dr. Jeong Woo Yi

COLLABORATORS OVER THE PAST FIVE YEARS:

Prof. Ihlan. A. Aksay, Chemical Engineering Dept., Princeton University
Prof. Wei-Heng Shih, Materials Engineering Dept., Drexel University
Prof. B. Keimer, Physics Dept., Princeton University
Prof. Raj. Mutharasan, Chemical Engineering Dept., Drexel University
Prof. Young. Lee, Chemical Engineering Dept., Drexel University
Prof. Robert. K. Prud'homme, Chemical engineering Dept., Princeton University
Prof. Jeff. Carbeck, Chemical Engineering Dept., Princeton University
Prof. Kambiz Pourrezaei, School of Biomedical Engineering, Science and Health Systems, Drexel University
Prof. Richard Rest, Department of Microbiology and Immunology, Drexel University College of Medicine
Prof. R. Lec, School of Biomedical Engineering, Science and Health Systems, Drexel University
Prof. Irwin Chaiken, Biochemistry Dept., Drexel University College of Medicine
Dr. Lydia Komarnicky, Chair, Dept. of Radiation Oncology, Drexel University College of Medicine
Dr. Ari Brooks, Department of Surgery, Drexel University College of Medicine
Prof. Banu Onaral, Director, School of Biomedical Engineering, Science, and Health Systems, Drexel University
Prof. Patrick J. Loll, Biochemistry Dept., Drexel University College of Medicine
Dr. Noreen M. Robertson, Biochemistry Dept., Drexel University College of Medicine
Prof. Aleister J. Saunders, Dept. of Bioscience, Drexel University
Dr. Jun Park, Edgewood Chemical and Biological Center, US Army SBCCOM: Soldier and Biological Chemical Command
Dr. Dalia. G. Yablon, ExxonMibil Research and Engineering Company
Dr. Alan Schilowitz, ExxonMibil Research and Engineering Company
Prof. Elisabeth Papazoglou, School of Biomedical Engineering, Science, and Health Systems, Drexel University
Prof. Peter Baas, Department of Neurobiology & Anatomy, Drexel University College of Medicine
Prof. Gianluca Gallo, Department of Neurobiology & Anatomy, Drexel University College of Medicine
Prof. Peter D. Katsikis, Department of Microbiology and Immunology, Drexel University College of Medicine
Prof. Guoliang Yang, Department of Physics, Drexel University
Prof. J. Desai, Department of Mechanical Engineering and Mechanics, Drexel University

Dr. Xiao-Qing Yang, National Synchrotron Light Source, Brookhaven National Laboratory
Dr. George Paoli, Eastern Region Research Center, ARS, USDA
Dr. Greg Adams, Fox Chase Cancer Center
Prof. Mario A. Bourdon, Director, La Jolla Institute of Molecular Medicine
Prof. Andrew Baird, La Jolla Institute of Molecular Medicine

RESEARCH

1. Highly piezoelectric mcirocantilever (PEMS) for biological and chemical sensing

Piezoelectric microcantilevers (PEMS) consisted of a highly piezoelectric layer bonded to a nonpiezoelectric layer are tiny mechanical resonators whose resonance can be excited and detected by simple electrical means. Receptors specific to the target antigens can be immobilized on the PEMS surface. Binding of the target antigen to the PEMS surface increases the PEMS mass and decreases the PEMS resonance frequency. Detection of the target antigen is achieved by monitoring the PEMS resonance frequency shift. Because PEMS uses electrical signal for actuation and detection, they can be easily set up for simultaneous array sensing of multiple antigens. Furthermore, the sensor and all necessary electronics can be easily portable in such broad ranging applications as bioreactor monitoring and environmental sensing. There are two PEMS systems currently under development in our laboratory: lead magnesium niobate-lead titanate solid solution (PMN-PT) freestanding-film-based PEMS and lead zirconate titanate (PZT) sol-gel-thin- film based PEMS. Currently we are working closely with Banu Onaral, Kambiz Pourrezaei, and R. Lec of BioMed on an anthrax detector for public safety.

1.1. PMN-PT/tin PEMS-- PMN-PT freestanding films were developed in our laboratory which exhibited a giant electric field enhanced piezoelectric coefficient larger than that of specially-cut single crystals. Two US patent applications have been filed related to this development. Using PMN-PT freestanding films less than 8 μm in thickness, PEMS smaller than 300 μm in length were fabricated by simple wire-saw cutting, offering low-cost and yet highly sensitive PEMS for various biological and chemical detection. Coupled to antibodies, current PMN-PT/tin PEMS 300 μm in length with 10^{-14} g/Hz sensitivity were demonstrated in *in-water*, *in-situ*, *real-time* quantification of *E. coli*, *Salmonella t.*, *Bacillus anthraces*, and *Bacillus globigii* with better than 30 total cells sensitivity in less than 1 ml of liquid and less than 10 min of time. They were also demonstrated in *real-time*, *in-liquid* detection of proteins, e.g., PSA and Her2 with 1 ng/ml sensitivity in less than 1 ml of liquid and less than 10 min. Selective receptors were also developed for nerve gas simulant, and vapor of explosives.

1.2. PZT/SiO_2 PEMS---Using sol-gel deposition and silicon-based microfabrication techniques, we have also succeeded in fabricating highly piezoelectric PZT/SiO_2 PEMS less than 60 μm in length with Q values ranging 120-320 and with 10^{-16} g/Hz sensitivity. Next in the pipeline are PZT/SiO_2 PEMS less than *20 μm in length with 10^{-18} g/Hz,* which will afford *single protein and single DNA sensitivity* in real time in situ detection. Such unprecedented sensitivity will open up many opportunities for proteomics and other applications.

1.3. Direct in-air detection of air-borne pathogens and influenza—There are no known techniques at the moment that can detect air-borne pathogens directly from aerosols due to insufficient sensitivities. Because of the unprecedented high sensitivities of the PEMS under development, in addition to in-liquid detection, we are currently exploring in-air detection of air-borne cells and viruses such as influenza and M. tuberculosis directly from aerosols. The ability to detect air-borne pathogens directly in air will permit rapid mitigation of the spread of the diseases.

2. Piezoelectric Finger for tissue stiffness measurement/imaging

Piezoelectric fingers (PEF) are piezoelectric cantilever sensors offering all-electrical tissue-stiffness measurement (electronic palpation). The technique uses simple electrical means for both actuation and detection and can be easily portable. *Measurement of tissue elastic properties is achieved by simply placing a PEF on a tissue much like palpation.*

2.1. Breast Cancer Imaging and Differentiation---*Preliminary results in real breast tissues indicated that PEF of 8 mm in width was able to detect a small satellite cancer 3 mm in the smallest dimension that was not detected by mammography, ultrasound, and the physician's palpation preoperatively. Such sensitivity was also better than the current commercially available tactile breast cancer detector.* With suitable tip geometry, a PEF can measure tissue shear modulus under shear in addition to elastic modulus under compression. No existing techniques examine tissue stiffness both under compression and under shear. No existing techniques can differentiate malignant tumor from benign one. The ability of PEF sensors to detect tissue stiffness both under shear and under compression offers a unique opportunity to probe tumor interfacial properties for cancer malignancy screening non-invasively. *Preliminary breast tissue measurements indicated that the ratio of the shear modulus over Young's modulus was indeed higher over a malignant tumor than the surrounding tissues as well as benign tumors.* We have been working with Dr. Ari Brooks of DUCOM on this research.

2.2. Prostate cancer detection---Prostate cancer is also stiffer than its surrounding tissues. Currently, prostate cancer relies on digital examination for screening, which has a 50% false positive/negative rate. Potentially, PEF can be applied for prostate cancer detection. What we have learned in the breast cancer measurement will be very useful in applying PEF to prostates.

2.3. Skin elasticity characterization---Another area of interest is the measurement of skin elasticity. Currently, there is no instrument that can reliably measure the skin elasticity in-vivo. Because we can control the probe depth of a PEF, it has the potential to unambiguously determine the elasticity of the skin alone. An *in-situ* skin elasticity meter is of interest to the cosmetics industry. It is also of interest for artificial skin monitoring.

2.4. Miniaturized PEF for cellular and molecular elasticity measurements---The miniaturized PZT and PMN-PT PEMS that we have developed for sensor application can also be used for all-electrical cellular and molecular elasticity measurement. The miniaturized PEF will be better than atomic force microscopy (AFM) in that the PEF does not need the optical detection system that AFM needs and potentially can offer better resolutions than the AFM.

3. Piezoelectric Devices for Energy Harvesting

Piezoelectric devices are also excellent tools for converting mechanical vibrations to electricity. The primary goal of the study is to utilize the giant electric-field enhanced properties of piezoelectric freestanding films that we discovered recently to fabricate piezoelectric devices for energy harvesting. There are many portable low-energy consumption electronic devices such as cell phones and palm pilots that must be recharged on a daily basis. It is desirable if they can be recharged by harvesting vibration energies from the environment. Piezoelectric devices are ideal to convert ambient vibration energy (refrigerator, washer, dryer, etc.) into electricity. The same concept can also be applied to biomedical devices perhaps even for in-vivo applications to circumvent the need of replacing the batteries.

4. Nontoxic Quantum Dots for biomedical photovoltaic, photoluminescent, and electroluminescent applications

We have succeeded in developing an aqueous synthesis route to produce highly luminescent quantum dots (QDs) that are capped with carboxylated molecules in one single step. The QDs have a wide excitation bandwidth with good emission intensity. Current emission wavelength ranges from 420 nm to 600 nm by varying particle size and compositions. The photoluminescence properties are stable over days in various biological solutions including phosphorous buffer solution and cytosol. Because of the carboxyl groups on the particle surface, the QDs can be easily bioconjugated for targeted imaging in biomedical applications. The present focus is to make *ZnS-based nontoxic QDs for biomedical applications*. Currently we are working with Prof. Elisabeth Papazoglu on the cytotoxicity of our QDs.