Shih-Chi Chen

Curriculum Vitae

Work
Wellman Center for Photomedicine
Massachusetts General Hospital, CPZN 8238
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91 Westland Avenue
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Research Interests

- Micro- and nanosystem design and manufacturing; actuators and sensors
- Precision machine design, compliant mechanisms, and flexures
- Optics for biomedical and *in vivo* applications

Teaching Interests

- Mechanical design, precision design, thermal and fluid systems
- Microsystems, microfabrication, and relative experimental techniques
- Biomedical optics, optical metrology, and systems and design

Education

Massachusetts Institute of Technology — **Cambridge, MA**
Ph.D. in Mechanical Engineering — *Sept. 2007*
Dissertation title: "Design of a high-speed-force-stroke thermomechanical micro-actuator via geometric contouring and mechanical frequency multiplication"
GPA: 4.8/5.0

S.M. in Mechanical Engineering — *Sept. 2003*
Thesis: "A six-degree-of-freedom compliant micro-manipulator for silicon optical bench"
GPA: 4.8/5.0

National Tsing Hua University — **Hsin-Chu, Taiwan**
B.S. in Power Mechanical Engineering — *June 1999*
Rank 1st out of 100 undergraduates, GPA: 3.98/4.0

Academic Appointments

Research Fellow, Dermatology, Harvard Medical School, Boston, MA — *Sept. 2007-present*
Research Fellow, Massachusetts Institute of Technology, Cambridge, MA — *Sept. 2007-present*

Affiliated Institution Appointments

Research Fellow, Wellman Center for Photomedicine, Massachusetts General Hospital, Boston, MA — *Sept. 2007-present*

Awards & Honors

Massachusetts General Hospital–MIT Career Development Postdoctoral Fellowship in Translational Research — *Mar. 2007*

R&D 100 Award for One of 100 Best New Technical Products of the Year—HexFlex™ Nanomanipulator, shared with Dr. Martin Culpepper — *Oct. 2003*

MIT Martin Fellowship and Martin Fellow, Martin Family Society of Fellows for Sustainability — *Sept. 2003*

Lee Fellowship, Department of Mechanical Engineering, MIT — *Sept. 2001*

Recipient seven times of an Academic Achievement Award (top 2% of class) from National Tsing Hua University (NTHU) — *1996-99*

Outstanding Engineering Student Prize, Chinese Institute of Engineers — *Feb. 1999*

The Chinese Society of Mechanical Engineers Scholarship	*Feb. 1999*
Mr. Tzu-His Lin Scholarship, Ministry of Education	*Feb. 1999*
The United World Chinese Commercial Bank Scholarship	*Feb. 1999*
Research Creativity Award, National Science Council of Taiwan	*Feb. 1998*
NTHU Tai Ta Electronics Scholarship	*Feb. 1998*
The Yu Kuo-Hua Culture and Education Foundation Scholarship	*Sept. 1998*
NTHU Yung Tuan Scholarship	*Feb. 1997*
The Yen Scholarship, Yen Ching-Ling Industrial Developing Foundation	*Sept. 1997*
NTHU Tai Ta Electronics Scholarship	*Feb. 1996*
NTHU Mr. Ta-Chung Liu Memorial Scholarship	*Sept. 1996*
NTHU Mr. Feng-chang Lu Memorial Scholarship	*Feb. 1995*

Research Funding

MGH-MIT Career Development Postdoctoral Fellowship in Translational Research
Budget: $200,000
Period: 09/2007 – 09/2009

Research Experience

Massachusetts Institute of Technology, Mechanical Eng. Dept. Adviser: Prof. Martin L. Culpepper
Research Fellow *Oct. 2007–present*
Graduate Research Assistant *June 2002–Sept. '07*

- High-speed 3-D microscanner for two-photon endomicroscope: Invented the techniques of geometric contouring and mechanical frequency multiplication that led to simultaneous improvements of the force, speed, and stroke of a thermomechanical actuator (TMA) by factors of 4, 2.5, and 10, respectively, and a reduction in driving power of up to 40%. The TMA actuation technology was used to design a high-speed microfabricated optical scanner for an endomicroscope to enable minimally invasive optical biopsy. Characterized the optical scanner and obtained 3-D images of fluorescent beads via the scanner. The optical scanner, with a 7-mm envelope, was capable of 3.5 kHz × 100 Hz × 30Hz scanning throughout a 125×200×200 μm^3 volume, in contrast to the existing microscale TMA technology for this application that could scan only 12.5% of the required volume (100×100×100 μm^3) at 10% of the frequency required. The two-photon endomicroscope offers opportunities to significantly impact the diagnosis, staging, and treatment of various prevalent cancers such as early epithelial (including colorectal, esophageal, and cervical) cancers, for which tissue imaging to a depth of a few hundred microns may suffice. In collaboration with Dr. Peter So and Dr. Susumu Tonegawa (1987 Nobel Laureate), current effort is focused on modifying the scanner into a head–mounted endomicroscope for imaging real-time neuron activity in mice under various conditions. *June 2005–present*

- Micro-HexFlex™ and HyperBit™ Technology: Created the first six-axis microscale nanopositioner: the μHexFlex™, a six-axis micromechanism with repeatable nanometer-level resolution. The μHexFlex™, with its 2.5-mm device envelope, sandwiches a layer of silicon dioxide between two silicon layers. The integrated TMAs can exert both in-plane and out-of-plane forces on the central stage and flexure bearings. Controlled commands, with the application of Input Shaping® and HyperBit™ control technology, allowed the device to exhibit displacements across six axes with a 1-Å resolution over a 10×10×10 μm^3 work volume. For the first time, a microdevice successfully generated repeatable 5-nm resolution motions in all six axes. *Sept. 2002–05*

- Carbon Nanotube (CNT)-Based Compliant Mechanism: Developed microfabrication techniques and recipes to manufacture and manipulate single-wall CNT, exploiting CNT's extraordinary mechanical properties for use in compliant flexures or mechanical linkages. *June 2005-06*

- Mechagami (Sheet-Metal Origami): Produced low-cost, high-precision, 3-D compliant mechanism via forming processes. Developed parametric models for a first-pass design that had 98% accuracy compared to FEA data (Lead student) *June 2003-04*

- Digital Nanoactuation Technology (DNAT™): Invented the DNAT technology that uses multiple pairs of binary actuators to generate hundreds to thousands of tunable discrete states for high-precision 2-D positioning. Achieved submicron precision without a feedback and control system. (Lead student) *June 2002-03*

- Flexure Stage for a High-Performance Microscope: In collaboration with University of Illinois, co-designed and built an ultra-precision flexure stage to guide a lens assembly for high-precision *z*-axis motion (100μm), producing less than 5 nm parasitic motion in the other axes. *June 2002-03*

Harvard Medical School, Wellman Center for Photomedicine. Adviser: Prof. Charles P. Lin
Research Fellow *Oct. 2007–present*

- Tunable high-speed scanning MEMS mirror for laser treatment: Invented the tunable resonant mirror technology and modeled/designed a microscale high-speed resonance mirror for laser treatment applications, *e.g.*, treatment of diseased rabbit retinas. The mirror's resonant frequency is designed to be tunable between 3 kHz and 6kHz, to precisely control dosage from a femto-second pulsed laser. *July 2008–present*

- High-resolution compact endomicroscope based on interspatial fiber-bundle scanning: In the process of creating an endoscopic system for non-invasive, intravital imaging via creation of (1) the electronics and optics for an interspatial fiber-bundle scanning system and (2) a microscanner to scan the fiber bundle during imaging. The endomicroscope is envisioned to enable rapid, minimally invasive imaging of internal organs with sub-cellular resolution. This technology—intravital microscopy—is emerging as a powerful tool for real-time study of cell trafficking, *e.g.* cancer cells, because it is capable of spatial and temporal resolutions not possible with other modalities, *e.g.* X-ray, CT, and MRI. *June 2008–present*

Advising and Teaching Experience

MIT Department of Mechanical Engineering
Invited Lecturer & Teaching Assistant (D = Doctoral; U = Undergraduate)

- Elements of Mechanical Design (U level) *Spring 2007, '08, '09*
  - Gave guest lectures on microdevice modeling, actuation, and metrology systems.

- Precision Machine Design (D level) *Fall 2007*
  - Gave guest lectures on design of precision biomedical devices.

- Multi-scale System Design (D level) *Fall 2006*
  - Gave guest lectures on manufacturing, actuation, and optical metrology for microsystems.

- How and Why Machines Work (U level) *Spring 2003, '04, '06*
  - Developed MEMS Accelerometer project (2004): Designed the microfabrication processes and built the electronics and testing station for MEMS accelerometers. Introduced students to the basics of accelerometer and flexure design and helped them generate design concepts and lithographic masks. Tested and characterized the fabricated accelerometers on the testing station. Emphasis was placed on basic MEMS knowledge and precision flexure design.

- Co-developed Nano-Etch-A-Sketch project (2003): Guided students to design, build, and test a two-axis precision stage actuated and controlled by handmade solenoids and electronics. Emphases on precision flexure design, control electronics, and metrology.
- Gave guest lectures on MEMS-related topics.
- Led weekly laboratory sessions in which students took apart various machines, including automobile transmissions, engines, toys, and floppy disc drives.

- Signal Processing—Continuous and Discrete (D level) *Spring 2002*
  - Created solution sets and tutored students during weekly office hours.

Research Advising Experience

- Mentored and advised three MIT Mechanical Engineering bachelor's thesis projects.

Engineering Consulting Experience

- Consultant for TissueVision, Inc. Developing an automated multi-axis mechanical positioning system and a novel vibration microtome for precision tissue handling and slicing as well as whole organ imaging. *June 2008–present*

Skills **Microfabrication**: MIT Microsystems Technology Laboratory, qualified advanced user: familiar with general silicon processes and general gold processes.
Computer: Matlab, Mathcad, Mathmatica, FORTRAN, C, Solidworks, COSMOS Works, ADINA, FEMLAB, AutoCad.

Languages Chinese (Mandarin), English

Publications

Journal Publications

S. Chen and M. L. Culpepper, "Design of Contoured Thermomechanical Actuators for Enhanced Dynamic Performance—a Pulsing Technique for Non-uniform Heat Generation Thermal System," submitted to *Journal of Microelectromechanical Systems*, July. 2008.

S. Chen and M. L. Culpepper, "Design of Contoured Microscale Thermomechanical Actuators," *Journal of Microelectromechanical Systems*, 2006, Vol. 15, Issue 5, pp. 1226–34.

S. Chen and M. L. Culpepper, "Design of a Six-axis Microscale Nano-positioner – μHexflex," *Journal of Precision Eng.* 2006, Vol. 30, Issue 3, pp. 314–24.

Journal Publications in Preparation

S. Chen, H. Choi, M. L. Culpepper, and P. T. So, "Design and Characterization of a Multiphoton Endomicroscope," in preparation, to be submitted to *Optics Letters.* in 2009.

S. Chen and M. L. Culpepper, "Design of a Thermomechanical Actuator Based High-Speed Fiber Resonator via Mechanical Frequency Multiplication," in preparation, to be submitted to *Journal of Microelectromechanical Systems* in 2009.

S. Chen and M. L. Culpepper, "Design and Optimization of Precision Active Silicon Optical Bench via Cascaded Chevron Flexures and Actuators," in preparation, to be submitted to *Precision Eng.* in 2009.

S. Chen, M. L. Culpepper, S. Jordan, J. Danieli, and J. Wenger, "Application of Input Shaping® and HyperBit Control™ to Improve the Dynamic Performance of a Six-axis Micro-scale Nanopositioner", in preparation, to be submitted to *Precision Eng.* in 2009.

Proceedings of Peer-reviewed Conferences

S. Chen and M. L. Culpepper, "The Design and Optimization of Cascaded Chevron Flexures and Actuators for Precision Motion Guidance," *Proceedings of the Annual Meeting of the ASPE*, Portland, OR, Oct. 2008, pp. 480–83.

H. Choi, S. Chen, P. T. So, and M. L. Culpepper, "Characterization of a Multiphoton Endomicroscope," OSA Biomedical Optics Topical Meeting and Tabletop Exhibit, FL, March 16–19, 2008.

S. Chen, H. Choi, M. L. Culpepper, and P. T. So, "The Design and Dynamic Characterization of a Precision Three-axis Microscale Fast Scanning Stage for Two-photon Endomicroscopy," *Proceedings of the Annual Meeting of the ASPE*, Dallas, TX, Oct. 2007, pp. 111–14.

S. Chen, M. L. Culpepper, and S. Jordan, "Six-axis Compliant Mechanisms for Manipulation of Micro-scale Fiber Optics Components," *Proceedings of the 2007 Photonics West* (MOEMS-MEMS), SPIE, San Jose, CA, Jan. 2007.

S. Jordan, M. L. Culpepper, and S. Chen, "Positioning Resolution Enhancement of MEMS and Piezo Nanopositioners," *Proceedings of the 4th International Symposium on Nanomanufacturing*, Cambridge, MA, Nov. 1–4, pp. 166–70.

S. Chen, M. L. Culpepper, and S. Jordan, "Application of Input Shaping® and HyperBit Control™ to Improve the Dynamic Performance of a Six-axis MEMS Nanopositioner," *Proceedings of the Annual Meeting of the ASPE*, Monterey, CA, Oct. 2006, pp. 287–90.

S. Chen, H. Choi, D. Kim, L. Munro, M. L. Culpepper, and P. T. So, "Design of a High-speed, Micro-scale Fast Scanning Stage for Two-photon Endomicroscopy," *Proceedings of the Annual Meeting of the ASPE*, Monterey, CA, Oct. 2006, pp. 279–82.

S. Chen, M. L. Culpepper, J. Bardt, and J. Ziegert, "Formation of Micro-scale Precision Flexures via Molding of Metallic Glass," *Proceedings of the Annual Meeting of the ASPE*, Monterey, CA, Oct. 2006, pp. 283–86.

H. Choi, S. Chen, D. Kim, P. T. So, and M. L. Culpepper, "Design of a Non-linear Endomicroscope Biopsy Probe," OSA Biomedical Optics Topical Meeting and Tabletop Exhibit, FL, March 19–23, 2006.

S. Chen and M. L. Culpepper, "Design and Optimization of Thermomechanical Actuator via Contour Shaping," *Proceedings of the ASME International Mechanical Engineering Congress & Exposition*, MEMS, Orlando, FL, Nov. 2005, pp. 201–08.

S. Chen, D. Golda, A. Herrmann, and A. Slocum, "Design of an Ultra Precision Diaphragm Flexure Stage for Out-of-plane Motion Guidance," *Proceedings of the ASME International Design Engineering Technical Conference*, DETC 2004 – 57401, Salt Lake City, UT, Sept. 28–Oct. 2, 2004, pp. 1015–21.

S. Chen and M. L. Culpepper, "Compliant Mechanisms for Micro-scale Spatial Manipulators: Applications in Nanomanipulation," *Proceedings of the Annual Meeting of the ASPE*, Orlando, FL, Oct. 2004, pp. 293–96.

M. L. Culpepper, S. Chen, and M. V. Kartik, "Precision Engineering Education at MIT via Hands-on Design Projects: The MIT Nano-Etch-A-Sketch Course Project," *Proceedings of the Annual Meeting of the ASPE*, Orlando, FL, Oct. 2004, pp. 337–40.

S. Chen and M. L. Culpepper, "A Six Degree-of-Freedom Tri-layer Chevron Beam Thermal Actuator," *Proceedings of the Annual Meeting of the ASPE*, Orlando, FL, Oct. 2004, pp. 329-32.

M. L. Culpepper, S. Chen, and S. Korb, "Design and Manufacture of Monolithic, 3D Compliant Mechanisms for Nanomanipulation Equipment," *Proceedings of the Annual Meeting of the ASPE*, Orlando, FL, Oct. 2004, pp. 333–36.

M. L. Culpepper and S. Chen, "Design of Precision Manipulators using Binary Actuation and Differential Compliant Mechanisms," *Proceedings of the Annual Meeting of the ASPE*, Portland, OR, Oct. 26–31, 2003, pp. 293–96.

Patents and Patent Applications

S. Chen and M. L. Culpepper, Massachusetts Institute of Technology, "Multiple Degree-of-Freedom Micro Electro-mechanical System Positioner and Actuator," U.S. Patent 7,451,596, November 18, 2008.

S. Chen and M. L. Culpepper, Massachusetts Institute of Technology, "Microfabricated Mechanical Frequency Multiplier," U.S. Patent Application, filed September 2007.

S. Chen and M. L. Culpepper, Massachusetts Institute of Technology, "High Speed Pulsing Technique for Non-uniform Heat Generation Thermal System," U.S. Patent Application, filed September 2007.

S. Chen and M. L. Culpepper, Massachusetts Institute of Technology, "Discrete Surface Tension Actuation Technology (DSTAT™)," MIT Technology Disclosure, filed October 2002.

Professional Activities

Professional Memberships

American Society of Mechanical Engineers (2003–present)

American Society for Precision Engineering (2003–present)

Society for Experimental Mechanics (2007–present)

Sigma Xi, the Scientific Research Society (2007–present)

Sessions Chaired in Conferences

Chair, Session on Major Issues in Nanomanufacturing, 4th International Symposium on Nanomanufacturing (ISNM 2006), Cambridge, MA, November 1–4, 2006.

Conference Reviewer

International Design Engineering Technical Conferences, ASME, August 2008 & 2009.

Presentations

Invited Talks

S. Chen, "Creating the Next-Generation Small-scale Machines for Precision Engineering, Microscopy and Biomedical Applications," invited presentation at Wellman Center for Photomedicine, Massachusetts General Hospital, Harvard Medical School, March 17, 2009.

S. Chen, "Creating the Next-Generation Small-scale Machines for Precision Engineering, Microscopy and Biomedical Applications," invited presentation at Department of Mechanical Engineering, National Tsing Hua University (Taiwan), February 26, 2009.

S. Chen, "Creating the Next-Generation Small-scale Machines for Precision Engineering, Microscopy and Biomedical Applications," invited presentation at Department of Mechanical Engineering, Carnegie Mellon University, February 09, 2009.

S. Chen, "MEMS Technology for Biomedical Applications," invited presentation at Center for Systems Biology, Massachusetts General Hospital, Harvard Medical School, December 17, 2007.

S. Chen, "Design of a High Performance Thermomechanical Actuator for High-Speed Endoscopic Scanning System," invited presentation at Wellman Center for Photomedicine, Massachusetts General Hospital, Harvard Medical School, August 31, 2007.

S. Chen, H. Choi, M. L. Culpepper, and P. T. So, "The Design and Dynamic Characterization of a Precision Three-axis Microscale Fast Scanning Stage for Two-photon Endomicroscopy," invited oral presentation at the Annual Meeting of the American Society for Precision Engineering, Oct. 15–20, 2007, Dallas, TX, USA.

S. Chen, D. Golda, A. Herrmann, and A. Slocum, "Design of an Ultra Precision Diaphragm Flexure Stage for Out-of-plane Motion Guidance," oral presentation at the ASME International Design Engineering Technical Conference, Sept. 28–Oct. 2, 2004, Salt Lake City, UT, USA.

Poster Presentations *(Underlined name indicates Presenter)*

S. Chen, "The Design and Optimization of Cascaded Chevron Flexures and Actuators for Precision Motion Guidance," poster presentation at the Annual Meeting of the American Society for Precision Engineering, October 19–24, 2008, Portland, OR, USA.

H. Choi and S. Chen, "Characterization of a Multiphoton Endomicroscope," poster presentation at the Gordon Research Conference on Lasers in Medicine and Biology, July 20–25, 2008, at Holderness, NH, USA.

S. Chen, M. L. Culpepper, and S. Jordan, "Application of Input Shaping® and HyperBit Control™ to Improve the Dynamic Performance of a Six-axis MEMS Nanopositioner," poster presentation at the Annual Meeting of the American Society for Precision Engineering, October 15–20, 2006, Monterey, CA, USA.

S. Chen, H. Choi, D. Kim, L. Munro, M. L. Culpepper, and P. T. So, "Design of a High-speed, Micro-scale Fast Scanning Stage for Two-photon Endomicroscopy," poster presentation at the Annual Meeting of the American Society for Precision Engineering, October 15–20, 2006, Monterey, CA, USA.

S. Chen, M. L. Culpepper, J. Bardt, and J. Ziegert, "Formation of Micro-scale Precision Flexures via Molding of Metallic Glass," poster presentation at the Annual Meeting of the American Society for Precision Engineering, October 15–20, 2006, Monterey, CA, USA.

S. Chen, H. Choi, D. Kim, L. Munro, M. L. Culpepper, and P. T. So, "High-speed micro-scanners for in vivo, biomedical imaging," poster presentation at the MEMS@MIT Fall 2006 meeting, October 10, 2006.

S. Chen and M. L. Culpepper, "Six-axis Compliant Micro-Manipulator for Small-scale Fiber Optics Components," poster presentation at the Photonics & Roadmapping Spring Conference of the MIT Microphotonics Center, May 3, 2004.

S. Chen and M. L. Culpepper, "Compliant Mechanisms for Micro-scale Spatial Manipulators: Micro-Hexflex," poster presentation at the MIT Microsystems Technology Laboratories Annual Review, Waterville Valley, NH, January 28–29, 2004.

Citizenship Taiwan R.O.C. (**U.S. Permanent Resident**)

Extracurricular Activities

- President, MIT Chinese Choral Society (2005–07). Organized events and promoted Chinese culture and choral music/folk songs to MIT faculties, students, and greater Boston audience.
- Principal saxophone soloist, Chinese Air Force Military Band (1999–2001, during full-time military service)
- Coordinator and tenor saxophone player, Taipei Saxophone Ensemble (1995–99)
- Member (player), Chinese Youth Wind Band (1997–99)
- Representative of seniors and thus Organizer of the graduation ceremony and graduation booklet at National Tsing Hua University (1998–99)

- Member, National Tsing Hua University Wind Orchestra (1995-1999)
- Director, Taiwan Saxophone Summer Camp at National Tsing Hua University (July 1998)
- Exchange student to Tsinghua University, Beijing, China (January 1998)
- Department representative, Undergraduate Academic Affairs Committee at National Tsing Hua University (1995–98)

References (Listed in rank order based on familiarity with my work)

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