SUMMER SCHOOL ON COMPUTATIONAL MATERIALS SCIENCE

Computational Approaches for Simulation of Electron Devices and MEMS

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Beckman Institute,

University of Illinois at Urbana-Champaign

System-Level Modeling and Design of MEMS: Reading List

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Books

[1] Stephen D. Senturia, *Microsystem Design*, Kluwer Academic Publishers, 2000.
[2] Nadim Maluf, *An Introduction to Microelectromechanical Systems Engineering*, Artech House Mems Library, 1999.
[3] Gregory T. A. Kovacs, *Micromachined Transducers Sourcebook*, McGraw-Hill Higher Education, 1998.
[4] Marc J. Madou, *Fundamentals of Microfabrication,* CRC Press, 1997.
[5] W. Trimmer, *Micromechanics and MEMS: Classic and Seminal Papers to 1990*, IEEE Press, 1997.

Journals

[1] *Sensors Journal*, IEEE, 2000-.
[2] *Journal of Microelectromechanical Systems*, IEEE 1992-.
[3] *Sensors & Actuators: A. Physica*l, Elsevier Science, Lausanne, Switzerland, 1980-.
[4] *Journal of Micromechanics and Microengineering*, Institute of Physics Publishing, Techno House, Bristol, UK, 1991-.
[5] *Sensors and Materials*, MYU, Tokyo, Japan, 1989-.

Conferences

[1] *Int'l Conference on Solid-State Sensors and Actuators (Transducers)*, June, odd years, 1981-.
[2] *Solid-State Sensor and Actuator Workshop*, (Hilton Head Is., SC), June, even years, 1984-.
[3] IEEE *Int'l Conference on Microelectromechanical Systems*, January/February, yearly, 1987-.
[4] IEEE *Int'l Conf. on Modeling and Simulation of Microsystems*, April, yearly, 1998-.
[5] SPIE *Design, Test, Integration and Packaging of MEMS and MOEMS*, April, yearly, 1998-.
[6] also, BMAS, IMECE, MRS, IEDM, ISSCC, ...

Internet

[1] CMU MEMS Web Page, *http://www.ece.cmu.edu/~mems*

[2] MEMS Clearing House, *http://www.memsnet.org/,* originally started by ISI (at USC), now maintained by MEMS Exchange, includes an email discussion group (see their web page for more details)

[3] DARPA/MTO MEMS program, *http://www.darpa.mil/MTO/MEMS*

Basic Introductory Articles on MEMS

[1] R. T. Howe, R. S Muller, K. J Gabriel, W. S. N. Trimmer, "Silicon micromechanics: sensors and actuators on a chip," *IEEE Spectrum*, vol. 27, no. 7, pp. 29-31, 34-35, July 1990.

[2] S. T. Picraux and P. J. McWhorter, "The broad sweep of integrated microsystems," *IEEE Spectrum*, vol 35, no. 12, pp. 24-33, Dec. 1998.

[3] Entire *Proceedings of the IEEE*, vol. 86, no. 8, August 1998.

[4] S. Cass, "Large Jobs for Little Devices," *IEEE Spectrum*, vol. 38, no. 1, pp. 72-72, Jan., 2001.

MEMS Design Methodologies

[1] S. D. Senturia, "Microfabricated structures for the measurement of mechanical properties and adhesion of thin films," *Proc. 4th Int'l. Conf. Solid-State Sensors and Actuators (Transducers '87)*, Tokyo, 2-5 June, 1987, pp. 11-16.

[2] E.K. Antonsson, "Structured Design Methods for MEMS," *NSF Sponsored Workshop on Structured Design Methods for MEMS,* November 12-15, 1995.

[3] N. R. L. Lo, E. C. Berg, S. R. Quakkelaar, J. N. Simon, M. Tachiki, H.-J. Lee, and K. S. J. Pister, "parameterized Layout Synthesis, Extraction, and SPICE Simulation for MEMS," *Proc. 1996 IEEE International Symposium on Circuits and Systems*, pp 481-484, Atlanta, GA, May 12-15, 1996.

[4] T. Mukherjee and G.K. Fedder, "Structured Design Of Microelectromechanical Systems," *Proceedings of the 34th Design Automation Conference (DAC '97)*, Anaheim, CA, June 9-13, 1997, pp. 680-685.

[5] R. D. Blanton, G. K. Fedder and T. Mukherjee, "Hierarchical Design and Test of MEMS," *MST News*, vol. 1, 1998.

[6] T. Mukherjee and G.K. Fedder, "Design Methodology for Mixed Domain Systems on a chip," *Proc. IEEE Computer Society Workshop on VLSI 98*, Orlando FL, April 1998, pp 96-101.

[7] S. D. Senturia, "CAD Challenges for Microsensors, Microactuators and Microsystems," *IEEE Proceedings*, Aug, 1998, pp. 1611-1626.

[8] S. D. Senturia, "Simulation and design of microsystems: a 10-year perspective," *Sensors and Actuators A*, 70 (1998), pp. 1-7.

[9] G. K. Fedder, "Structured design for Integrated MEMS," *Proc. of 12th IEEE Int'l. Conf. on Micro Electro Mechanical Systems (MEMS '99)*, Orlando, FL, January 17-21, 1999, pp. 1-8, (invited).

[10] T. Mukherjee and G. K. Fedder, "Hierarchical Mixed-Domain Circuit Simulation, Synthesis and Extraction Methodology for MEMS," *Journal of VLSI Signal Processing - Systems for Signal Image and Video Technology*, July 1999, pp. 233-249.

[11] T. Mukherjee, G. K. Fedder and R. D. Blanton, "Hierarchical Design and Test of Integrated Microsystems," *IEEE Design and Test*, vol. 16, no. 4, Oct-Dec 1999, pp. 18-27.

[12] N. Swart, "A Design Flow for Micromachined Electromechanical Systems," *IEEE Design and Test*, vol. 16, no. 4, Oct-Dec 1999, pp. 39-47.

[13] G. K. Fedder and T. Mukherjee, "Path Towards Future CAD Environments for MEMS," *Proc. IEEE/ACM Int'l. Conf. on CAD-99*, San Jose, CA, November 8-12, 1999 (invited embedded tutorial).

[14] G. K. Fedder, "Top-Down Design of MEMS," *Proc. 2000 Int'l. Conf. on Modeling and Simulation of Microsystems (MSM 2000)*, San Diego CA, March 27-29, 2000, pp. 7-10, (invited).

[15] T. Mukherjee, "CAD for Integrated MEMS Design," *Proc. Design, Test Integration, and Packaging of MEMS/MOEMS (DTIP 2000)*, Paris, France, May 9-11, 2000, pp. 3-14, (invited).

[16] T. Mukherjee, G. K. Fedder and J. White, "Emerging Simulation Approaches for Micromachined Devices," *IEEE Transactions on CAD, "Special Issue: EDA at the Turn of the Century"*, vol. 19, no. 12, Dec. 2000, pp.1572-1589.

[17] B. Baidya, K. He, and T. Mukherjee, "Layout Verification and Correction of CMOS-MEMS Layouts," in *Technical Proceeedings of 2001 International Conference on Modeling and Simulation of Microsystems (MSM '01)*, Hilton Head Island, SC, March 19-21 2001.

MEMS Circuit Simulation

[1] H. A. C. Tilmans, "Equivalent circuit representation of electromechanical transducers: I. Lumped-parameter systems," *J. Micromech. Microeng.*, vol. 6, no. 1, pp. 157-176, 1996.

[2] J.E. Vandameer, M.S. Kranz and G.K. Fedder, "Nodal Simulation of Suspended MEMS with Multiple Degrees of Freedom," *1997 Int'l. Mechanical Engineering Congress and Exposition: The Winter Annual Meeting of ASME in the 8th Symposium on Microelectromechanical Systems,* Dallas, TX, Nov. 16-21, 1997.

[3] J.E. Vandemeer, M.S. Kranz, G.K. Fedder, "Hierarchical Representation and Simulation of Micromachined Inertial Sensors," *Proc. 1998 Int'l. Conf. on Modeling and Simulation of Microsystems (MSM 1998)*, Santa Clara, CA, April 6-8, 1998, pp. 540-545.

[4] G. K. Fedder and Q. Jing, "NODAS 1.3 - Nodal Design Of Actuators And Sensors," *Proc. of IEEE/VIUF Int. Workshop on Behavioral Modeling and Simulation*, Orlando, FL, October 27-28, 1998.

[5] G. K Fedder and Q. Jing, "A Hierarchical Circuit-level Design Methodology for Microelectromechanical Systems," *IEEE Trans. on Circuits and Systems-II*, vol. 46, no. 10, Oct. 1999, pp. 1309-1315.

[6] G. Lorenz and R. Neul, "Network Modeling of Micromachined Sensor Systems," *Proc. 1998 Int'l. Conf. on Modeling and Simulation of Microsystems (MSM 1998)*, Santa Clara, CA, April 6-8, 1998, pp. 233-238.

[7] J. Clark, N. Zhou, S. Brown and K.S.J. Pister, "Nodal Analysis for MEMS Simulation and Design," *Proc. 1st Int'l. Conf. on Modeling and Simulation of Microsystems (MSM 1998)*, Santa Clara, CA, April 6-8, 1998, pp. 308-313.

[8] J. Clark, N. Zhou, and K.S.J. Pister, "Fast, Accurate MEMS Simulation with SUGAR 0.4," *Proc. 1998 Solid State Sensors and Actuators Workshop*, Hilton Head, GA, June 7-11, 1998, pp. 191-196.

[9] D. Teegarden, G. Lorenz and R. Neul, "How to model and simulate microgyroscope systems," *IEEE Spectrum*, Vol 35, No. 7, 1998, pp. 66.

[10] M. S.-C. Lu, and G. K. Fedder, "Parameterized Electrostatic Gap Models for Structured Design of Microelectromechanical Systems," *Proc. 2nd Int'l. Conf. on Modeling and Simulation of Microsystems (MSM '99)*, San Juan Puerto Rico, April 19-21 1999, pp. 280-283.

[11] J. V. Clark, N. Zhou, and K.S.J. Pister, "Modified Nodal Analysis for MEMS with Multi-Energy Domains", *Proc. 3rd Int'l. Conf. on Modeling and Simulation of Microsystems (MSM*

2000), San Diego, CA, March 27-29, 2000, pp. 723-726.

[12] Q. Jing, T. Mukherjee and G. K. Fedder, "A Design Methodology for Micromechanical Bandpass Filters," *Proc. IEEE Behavioral Modeling And Simulation Workshop*, Oct. 6, 1999.

[13] Q. Jing, H. Luo, T. Mukherjee, L. R. Carley, and G. K. Fedder, "CMOS Micromechanical Bandpass Filter Design Using a Hierarchical MEMS Circuit Library," *Proc. of 12th IEEE Int'l. Conf. on Micro Electro Mechanical Systems (MEMS '00)*, Miyazaki, Japan, pp. 187-192, January 23-27, 2000.

[14] H. Xie, L. Erdmann, Q. Jing, and G. K. Fedder, "Simulation and Characterization of a CMOS Z-axis Microactuator with Electrostatic Comb Drives," *Proc. 3rd Int'l. Conf. on Modeling and Simulation of Microsystems (MSM 2000)*, San Diego, CA, March 27-29, 2000, pp. 181-184.

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[17] S. Iyer, Q. Jing, G. K. Fedder and T. Mukherjee, "Convergence and Speed Issues in HDL-A Model Formulation for MEMS," *in Technical Proceedings of 2001 International Conference on Modeling and Simulation of Microsystems (MSM '01)*, Hilton Head Island, SC, March 19-21 2001.

[18] S. Iyer, H. Lakdawala, G. K. Fedder and T. Mukherjee, "Macromodeling Temperature-Dependent Curl in CMOS Micromachined Beams", in *Modeling and Simulation of Microsystems (MSM 01)*, Hilton Head Island, South Carolina, March 19-21, 2001, pp. 88-91.

[19] R. Neul, "Modeling and Simulation for MEMS Design: Industrial Requirements," *in Technical Proceedings of 2002 International Conference on Modeling and Simulation of Microsystems (MSM '02)*, San Juan, Puerto Rico, April 22-25 2002, pp. 6-9, (invited).

[20] Q. Jing, T. Mukherjee and G. K. Fedder, "Large-Deflection Beam Model for Schematic-Based Behavioral Simulation in NODAS," *in Technical Proceedings of 2002 International Conference on Modeling and Simulation of Microsystems (MSM '02)*, San Juan, Puerto Rico, April 22-25 2002, pp. 136-139.

Optimal Design

[1] D. Haronain, "Maximizing microelectromechanical sensor and actuator sensitivity by optimizing geometry", *Sensors and Actuators A,* 50 (1995) , pp. 223-236.

[2] G.K. Ananthasuresh and S. Kota, "Designing Compliant Mechanisms," *Mechanical Engineering*, Vol. 117, No. 11, November 1995, pp. 93.

[3] D. L. DeVoe and A. P. Pisano, "Modeling and optimal design of piezoelectric cantilever microactuators," *J. Microlectromech. Syst.*, vol. 6, no. 3, pp. 266-270, 1997.

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[5] A. Saxena and G. K. Ananthasuresh, "An Optimality Criteria Approach for the Topology Synthesis of Compliant Mechanisms," *Proc. 1998 ASME Design Engineering Technical Conferences (DETC '98) - 25th Biennial Mechanisms Conference*, paper DETC98/MECH-5937, Atlanta, Sept. 1998.

[6] W. Ye, S. Mukherjee, and N.C. MacDonald, "Optimal Shape Design of an Electrostatic Comb

Drive in Microelectromechanical Systems", *J. Microelectromechanical Systems,* March 1998, vol. 7, pp. 16-26.

[7] S. Iyer, T. Mukherjee and G.K. Fedder, "Multi-Mode Sensitive Layout Synthesis of Microresonators," *1998 International Conference on Modeling and Simulation of Microsystems, Semiconductors, Sensors and Actuators (MSM 98)*, Santa Clara CA, April 6-8, 1998.

[8] T. Mukherjee, Y. Zhou and G. K. Fedder, "Automated Optimal Synthesis of Microaccelerometers," *Proc. IEEE Intl'l Conference on Microelectromechanical Systems*, Orlando FL, January 1999, pp. 326-331.

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[13]J. F. Alfaro and G. K. Fedder, "Actuation for Probe-based Mass Data Storage," *in Technical Proceedings of 2002 International Conference on Modeling and Simulation of Microsystems (MSM '02)*, San Juan, Puerto Rico, April 22-25 2002, pp. 202-205.

Extraction

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[2] B. Baidya and T. Mukherjee, "MEMS Component Extraction," *Proc. 1999 Int'l Conference on Modeling and Simulation of Microsystems, Semiconductors, Sensors and Actuators (MSM '99)*, San Juan PR, April 1999, pp. 143-146.

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