Ming-Huang Li

Inst. of NanoEngineering and MicroSystems National Tsing Hua University 101, Sec. 2, Kuang-Fu Rd, Taiwan 30013, R.O.C. s100035807@m100.nthu.edu.tw (Lab): +886-3-571-5131 ext.80631 (Fax): +886-3-574-5454

2009 Fall

EDUCATION

National Tsing Hua University (NTHU), Hsinchu, Taiwan

Ph.D. in NanoEngineering and MicroSystems (NEMS), Sep. 2011 – Present

- Specification on CMOS-integrated micromechanical resonators and oscillators
- Thesis: <u>Standard CMOS BEOL-Embedded Micromechanical Oscillators</u>

M.S. in NanoEngineering and MicroSystems (NEMS), Sep. 2009 - Jun. 2011

- Specification on micromechanical resonators and CMOS-MEMS integration
- Thesis: Design of Low Motional Impedance CMOS-MEMS Micromechanical Resonator Arrays

National Chung Cheng University (CCU), Chiayi, Taiwan

- **B.S. in Mechanical Engineering (ME)**, Sep. 2005 Jun. 2009
- Minor in **Electrical Engineering** (EE)
- Graduation with distinction in Mechanical Engineering department (ranked 1st in the department)
- Specification on solid mechanics (ME) and analog circuit design (EE)

PROFESSIONAL INTERESTS

	Nano/Microelectromechanical systems	-	Micromechanical resonators and oscillators
--	-------------------------------------	---	--

- Semiconductor/MEMS fabrication technologies
- Automatic control systems

- Analog and mixed-signal circuits
- Sensors and sensor interface circuits

ACADEMIC EXPERIENCE

Graduate Research Assistant	Fall 2009 – Present	National Tsing Hua University, HsinChu, Taiwan

Advisor: Prof. Sheng-Shian Li

Phase noise (PN) optimization of nonlinear CMOS-MEMS oscillators

- > Demonstrated close-to-carrier PN reduction (up to 30 dB improvement) using bias-dependent nonlinearity.
- Reported a record-low FOM of -176.9dB at 10-Hz offset for BEOL-embedded, monolithic CMOS-MEMS oscillators.

Ultra-low-power ovenized CMOS-MEMS oscillator circuits

- > Designed a sub-mW micro-oven in standard CMOS for the first time, integrated with CMOS-MEMS resonator.
- > Demonstrated a low-power monolithic flexural-mode CMOS-MEMS oscillator with a FOM of -172.4dB at 1-kHz offset.
- > Designed a passively temperature-compensated CMOS-MEMS resonator with $TC_f < 5.1$ ppm/°C.

Process variation and temperature stability of CMOS-MEMS resonators

- > Designed a dual-mode CMOS-MEMS ring resonator to study the temperature-frequency dependency in different modes.
- > Reported the process variation in terms of resonance frequency, insertion loss and quality factors.

Design of mechanically-coupled CMOS-MEMS free-free beam resonator arrays

- Used mechanically-coupling approach to achieve higher power handling capability.
- > Used composite material layers (in standard CMOS) for thermal stability improvement.
- > Investigated the nonlinearity limit of the CMOS-MEMS resonator array.

Feaching Assistant		Fall 2009 – Spring 2013	National Tsing Hua Univ	versity, HsinChu, Taiwan	
-	Undergraduate Research Project M	Ientor in Dept. of Power Mechanical	Engineering (PME)	2012 - 2013	
-	Undergraduate-level Course: PME	E 3202 – Electronics II		2010 – 2015 Fall	
-	Graduate-level Course: PME 5271	-Fundamentals of Analog Circuit D	esign	2010 Spring	

■ Graduate-level Course: NEMS5000 – Seminar

HONORS AND AWARDS

-	CTCI Science and Technology Research Scholarship, CTCI Foundation	Dec. 2014
-	Honorable Mention, the 18 th Micro and Nano System Technology Conference	Aug. 2014
-	2014 CIC Outstanding Chip Design Award: Best Design	Aug. 2014
-	2 nd Place, NTHU iNEMS Student Paper Competition (Oral Presentation)	May. 2014
-	2013 CIC Outstanding Chip Design Award: Honorable Mention	Aug. 2013
-	3 rd Place, NTHU iNEMS Student Paper Competition (Oral Presentation)	Jun. 2012
-	President's Fellowship, National Tsing Hua University	Nov. 2011
-	2011 CIC Outstanding Chip Design Award: Best Design	Aug. 2011
-	Member of Phi Tau Phi Honor Society	Jun. 2011
-	Best Student Paper Award, 2011 IEEE IFCS-EFTF Joint Conference	May. 2011
-	2 nd Place, NTHU iNEMS Student Paper Competition (Oral Presentation)	May. 2010
-	Outstanding Engineering Student Scholarship, Chinese Institute of Engineers	Jun. 2009
•	President's Award of National Chung Cheng University (CCU), Six times	Feb. 2006 – Jun. 2009

PUBLICATIONS

Journal Articles:

- M.-H. Li, C.-Y. Chen, C.-S. Li, C.-H. Chin, and S.-S. Li, "A monolithic CMOS-MEMS oscillator based on an ultra-low-power ovenized micromechanical resonator," J. Microelectromech. Syst., 2014. In Press
- [2] <u>M.-H. Li</u>, C.-Y. Chen, C.-S. Li, C.-H. Chin, and S.-S. Li, "Design and characterization of a dual-mode CMOS-MEMS resonator for TCF manipulation," *J. Microelectromech. Syst.*, 2014. *In Press*
- [3] C.-S. Li, <u>M.-H. Li</u>, C.-C. Chen, C.-H. Chin, and S.-S. Li, "A low voltage CMOS-MicroElectroMechanical Systems thermal-piezoresistive resonator with Q > 10,000," *IEEE Electron Device Lett.*, vol. 36, no. 2, pp. 192-194, Feb. 2015.
- [4] C.-S. Li, <u>M.-H. Li</u>, and S.-S. Li, "Differentially piezoresistive transduction of high-Q encapsulated SOI-MEMS resonators with sub-100nm gaps," *IEEE Trans. Ultrason. Ferroelect. Freq. Contr.*, vol. 62, no. 1, pp. 220-229, Jan. 2015.
- [5] C.-H. Chin, C.-S. Li, <u>M.-H. Li</u>, Y.-L. Wang, and S.-S. Li, "Fabrication and characterization of a charge-biased CMOS-MEMS resonant gate field effect transistor," *J. Micromech. Microeng.*, vol. 24, no. 9, pp. 095005, 2014. (2014 JMM highlighted paper)
- [6] C.-Y. Chen, <u>M.-H. Li</u>, C.-S. Li, and S.-S. Li, "Design and characterization of mechanically coupled CMOS-MEMS filters for channel-select applications," *Sens. Actuators A: Phys*, vol. 216, pp. 394-404, Sep. 2014.
- [7] C.-S. Li, <u>M.-H. Li</u>, C.-H. Chin, and S.-S. Li, "Differentially piezoresistive sensing for CMOS-MEMS resonators," J. *Microelectromech. Syst.*, vol. 22, no. 6, pp. 1361-1372, Dec. 2013.
- [8] Y.-C. Liu, M.-H. Tsai, W.-C. Chen, <u>M.-H. Li</u>, S.-S. Li, and W. Fang, "Temperature-compensated CMOS-MEMS oxide resonators," *J. Microelectromech. Syst.*, vol. 22, no. 5, pp. 1054-1065, Oct. 2013.
- [9] V. Pachkawade, <u>M.-H. Li</u>, C.-S. Li, and S.-S. Li, "A CMOS-MEMS resonator integrated system for oscillator application," *IEEE Sens. J.*, vol. 13, no. 8, pp. 2882-2889, Aug. 2013.
- [10] <u>M.-H. Li</u>, W.-C. Chen, and S.-S. Li, "Realizing deep-submicron gap spacing for CMOS-MEMS resonators," *IEEE Sens. J.*, vol. 12, no. 12, pp. 3399-3407, Dec. 2012.
- [11] Y.-C. Lee, <u>M.-H. Li</u>, W. Hsu, Y.-T. Cheng, and S.-S. Li, "Electroplated Ni-CNT Nanocomposite for Micromechanical Resonator Applications," *IEEE Electron Device Lett.*, vol. 33, no. 6, pp. 872-874, Jun. 2012.
- [12] W.-C. Chen, <u>M.-H. Li</u>, Y.-C. Liu, W. Fang, and S.-S. Li, "A fully-differential CMOS-MEMS DETF oxide resonator with Q > 4,800 and positive TCF," *IEEE Electron Device Lett.*, vol. 33, no. 5, pp. 721-723, May 2012.
- [13] <u>M.-H. Li</u>, W.-C. Chen, and S.-S. Li, "Mechanically-coupled CMOS-MEMS free-free beam resonator arrays with enhanced power handling capability," *IEEE Trans. Ultrason. Ferroelect. Freq. Contr.*, vol. 59, no. 3, pp. 346-357, Mar. 2012. (Featured as the front cover)

Conference Proceedings:

- C.-Y. Chen, C.-H. Chin, <u>M.-H. Li</u>, and S.-S. Li, "Statistical characterization of a CMOS-MEMS resonator for monolithic ovenized oscillator applications," in *Tech. Dig.*, 18th Int. Conf. on Solid-State Sensors & Actuators (*Transducers'15*), Alaska, USA, June 21-25, 2015 (Accepted).
- [2] C.-Y. Chen, <u>M.-H. Li</u>, C.-H. Wang, and S.-S. Li, "Transduction comparison of a resonant transducer realized in a commercially available CMOS-MEMS platform," in *Tech. Dig.*, 18th Int. Conf. on Solid-State Sensors & Actuators (*Transducers'15*), Alaska, USA, June 21-25, 2015 (Accepted).
- [3] J. Ren, C.-Y. Liu, <u>M.-H. Li</u>, C.-C. Chen, C.-Y. Chen, C.-S. Li, and S.-S. Li, "A mode-matching 130-kHz ring-coupled gyroscope with 225 ppm initial driving/sensing mode frequency splitting," in *Tech. Dig.*, 18th Int. Conf. on Solid-State Sensors & Actuators (*Transducers*'15), Alaska, USA, June 21-25, 2015 (Accepted).
- [4] H.-C. Su, <u>M.-H. Li</u>, C.-Y. Chen, and S.-S. Li, "A single-chip oscillator based on a deep-submicron gap CMOS-MEMS resonator array with high-stiffness driving scheme," in *Tech. Dig.*, 18th Int. Conf. on Solid-State Sensors & Actuators (*Transducers'15*), Alaska, USA, June 21-25, 2015 (Accepted).
- [5] <u>M.-H. Li</u>, C.-S. Li, and S.-S. Li, "Exploring the *Q*-factor limit of temperature compensated CMOS-MEMS resonators," in *Proc.*, 28th IEEE Int. Conf. Micro Electro Mech. Syst. (*MEMS'15*), Estoril, Portugal, Jan. 18-22, 2015, pp. 853-856.
- [6] C.-H. Chin, C.-S. Li, <u>M.-H. Li</u>, and S.-S. Li, "A CMOS-MEMS arrayed RGFET oscillator using a band-to-band tunneling bias scheme," in *Proc.*, 28th IEEE Int. Conf. Micro Electro Mech. Syst. (*MEMS'15*), Estoril, Portugal, Jan. 18-22, 2015, pp. 988-991.
- [7] M.-H. Li, C.-Y. Chen, C.-H. Chin, C.-S. Li, and S.-S. Li, "Optimizing the close-to-carrier phase noise of monolithic CMOS-MEMS oscillators using bias-dependent nonlinearity," in IEEE Int. Electron Devices Mtg. (*IEDM'14*), San Francisco, USA, Dec. 15-17, 2014, pp. 22.3.1-22.3.4.
- [8] K.-H. Li, C.-C. Chen, <u>M.-H. Li</u>, and S.-S. Li, "A self-sustained nanomechanical thermal-piezoresistive oscillator with ultra-low power consumption," in IEEE Int. Electron Devices Mtg. (*IEDM'14*), San Francisco, USA, Dec. 15-17, 2014, pp. 22.2.1-22.2.4.
- [9] <u>M.-H. Li</u>, C.-Y. Chen, and S.-S. Li, "An experimental investigation on the *Q*-boosted CMOS-MEMS flexural-mode resonator circuits," *Proc.*, 2014 IEEE Int. Freq. Contr. Symp. (*IFCS'14*), Taipei, Taiwan, May 19-22, 2014, pp. 327-328.
- [10] J. Lee*, C.-S. Li*, Z. Wang, M.-H. Li, C.-H. Chin, S.-S. Li, P. X.-L. Feng "High-Frequency Parametric Bulk Mode Resonators in CMOS-MEMS Technology," *Proc.*, IEEE Int. Freq. Contr. Symp. (*IFCS'14*), Taipei, Taiwan, May 19-22, 2014, pp. 329-331. (*Equally Contribution)
- [11] J. Lee*, C.-S. Li*, Z. Wang, <u>M.-H. Li</u>, C.-H. Chin, S.-S. Li, P. X.-L. Feng "Multimode Characteristics of High-Frequency CMOS-MEMS Bulk-Mode Resonators," *Proc.*, IEEE Int. Freq. Contr. Symp. (*IFCS'14*), Taipei, Taiwan, May 19-22, 2014, pp. 478-480. (*Equally Contribution)
- [12] C.-Y. Chen, <u>M.-H. Li</u>, C.-H. Chin, C.-S. Li, and S.-S. Li, "Combined electrical and mechanical coupling for mode-reconfigurable CMOS-MEMS filters," *Proc.*, 27th IEEE Int. Conf. Micro Electro Mech. Syst. (*MEMS'14*), San Francisco, USA, Jan. 26-30, 2014, pp. 1249-1252.
- [13] M.-H. Li, C.-Y. Chen, C.-S. Li, C.-H. Chin, C.-C. Chen, and S.-S. Li, "Foundry-CMOS integrated oscillator circuits based on ultra-low power ovenized CMOS-MEMS resonators," *Tech. Dig.*, IEEE Int. Electron Devices Mtg. (*IEDM'13*), Washington DC, USA, Dec. 9-11, 2013, pp. 18.4.1-18.4.4.
- [14] M.-H. Li, C.-Y. Chen, C.-S. Li, C.-H. Chin, and S.-S. Li, "Enhanced temperature sensitivity of a single CMOS-MEMS resonator via resonant modes in orthogonal axes," *Proc.*, 2013 Joint UFFC, EFTF and PFM Symposium (*UFFC'13*), Prague, Czech Republic, July 21-25, 2013, pp.539-542.
- [15] C.-S. Li, M.-H. Li, C.-H. Chin, C.-Y. Chen, Philip X.-L. Feng, and S.-S. Li, "A piezoresistive CMOS-MEMS resonator with high Q and low TCF," *Proc.*, 2013 Joint UFFC, EFTF and PFM Symposium (*UFFC'13*), Prague, Czech Republic, July 21-25, 2013, pp. 425-428.
- [16] C.-H. Chin, C.-S. Li, <u>M.-H. Li</u>, and S.-S. Li, "A CMOS-MEMS resonant-gate transistor," *Tech. Dig.*, 17th Int. Conf. on Solid-State Sensors & Actuators (*Transducers'13*), Barcelona, Spain, June 16-20, 2013, pp. 2284-2287.
- [17] C.-Y. Chen, <u>M.-H. Li</u>, C.-S. Li, and S.-S. Li, "Design and characterization of mechanically-coupled CMOS-MEMS filters," *Tech. Dig.*, 17th Int. Conf. on Solid-State Sensors & Actuators (*Transducers'13*), Barcelona, Spain, June 16-20, 2013, pp. 2288-2291.
- [18] H. Zhu, C.-H. Chuang, C.-S. Li, <u>M.-H. Li</u>, J. E.-Y. Lee, and S.-S. Li, "The effects of tight capacitive coupling on phase noise performance: A LAMÉ-mode MEMS oscillator study," *Tech. Dig.*, 17th Int. Conf. on Solid-State Sensors & Actuators

(Transducers'13), Barcelona, Spain, June 16-20, 2013, pp. 2304-2307.

- [19] W.-C. Chen, <u>M.-H. Li</u>, Y.-C. Liu, D. Weinstein, W. Fang, and S.-S. Li, "Fully differential CMOS-MEMS square-plate oxide resonators with embedded poly-silicon electrodes," *Tech. Dig.*, 17th Int. Conf. on Solid-State Sensors & Actuators (*Transducers*'13), Barcelona, Spain, June 16-20, 2013, pp. 2292-2295.
- [20] M.-H. Li, C.-S. Li, C.-H. Chin, C.-Y. Chen and S.-S. Li, "An ultra-low power ovenized CMOS-MEMS resonator monolithically integrated with interface circuits," *Proc.*, 26th IEEE Int. Conf. Micro Electro Mech. Syst. (*MEMS'13*), Taipei, Taiwan, Jan. 20-24, 2013, pp. 753-756.
- [21] M.-H. Li, C.-S. Li, L.-J. Hou, Y.-C. Liu and S.-S. Li, "A 1.57mW 99dBΩ CMOS transimpedance amplifier for VHF micromechanical reference oscillators," *Proc.*, 2012 IEEE Int. Symp. on Circuits and Systems (*ISCAS'12*), Seoul, Korea, May 20-23, 2012, pp. 209-212.
- [22] C.-S. Li, <u>M.-H. Li</u>, and S.-S. Li, "Differential measurement of piezoresistive transduction for silicon-based MEMS resonators," *Proc.*, 2012 IEEE Int. Freq. Contr. Symp. (*IFCS'12*), Baltimore, MD, USA, May, 2012, 21-24.
- [23] C.-C. Chen, <u>M.-H. Li</u>, W.-C. Chen, H.-T. Yu, and S.-S. Li, "Thermally-actuated and piezoresistively-sensed CMOS-MEMS resonator array using differential-mode operation," *Proc.*, 2012 IEEE Int. Freq. Contr. Symp. (*IFCS'12*), Baltimore, MD, May, 2012, 21-24.
- [24] M.-H. Li, W.-C. Chen, and S.-S. Li, "CMOS-MEMS transverse-mode square plate resonator with high Q and low motional impedance," *Tech. Dig.*, 16th Int. Conf. on Solid-State Sensors & Actuators (*Transducers'11*), Beijing, China, June 5-9, 2011, pp. 1500-1503.
- [25] M.-H. Li, W.-C. Chen, and S.-S. Li, "Mechanically-coupled CMOS-MEMS free-free beam resonator arrays with two-port configuration," *Proc.*, 2011 Joint Conf. of the IEEE Int. Freq. Contr. Symp. – Eur. Freq. Time Forum (*IFCS-EFTF'11*), San Francisco, California, USA, May 1-5, 2011, pp.16-19. (*Best Student Paper Award Winner*)
- [26] W.-C. Chen, <u>M.-H. Li</u>, W. Fang, and S.-S. Li, "High-Q integrated CMOS-MEMS resonators with deep-submicron gaps," *Proc.*, IEEE Int. Freq. Contr. Symp. (*IFCS'10*), Newport Beach, California, USA, June 1-4, 2010, pp. 340-343.
- [27] W.-C. Chen, <u>M.-H. Li</u>, W. Fang, and S.-S. Li, "Realizing deep-submicron gap spacing for CMOS-MEMS resonators with frequency tuning capability via modulated boundary conditions," *Proc.*, 23rd IEEE Int. Conf. Micro Electro Mech. Syst. (*MEMS'10*), Hong Kong, Jan. 24-28, 2010, pp. 735-738.

DOMESTIC **P**UBLICATIONS

- [1] M.-H. Li, and S.-S. Li, "Temperature Compensated Monolithic CMOS-MEMS Oscillators for Timing Reference and Sensor Applications," 第 18 屆奈米工程暨微系統技術研討會, 台南, Aug. 21-22, 2014. (Oral Presentation) (Honorable Mention)
- [2] 陳昭瑜、<u>李銘晃</u>、李昇憲,"具備電性與機械耦合技術之模態可重組式 CMOS-MEMS 濾波器," 第 18 屆奈米工程暨微系統技術研討會, 台南, Aug. 21-22, 2014. (Oral Presentation) (*Best Student Paper Award Winner*)
- [3] 陳昭瑜、<u>李銘晃、</u>、李承勳、李昇憲, "機械耦合式 CMOS-MEMS 濾波器之設計與特性探討,"第17 屆奈米工程暨微系統技術 研討會,台中, Aug. 22-23, 2013. (Oral Presentation)
- [4] 莊捷旭、李承勳、<u>李銘晃、李</u>昇憲, "高 Q 值微機械震盪器研製與探討差動機制對微機械震盪器的影響,"第17 屆奈米工程 暨微系統技術研討會,台中, Aug. 22-23, 2013. (Oral Presentation)
- [5] 陳文健、<u>李銘晃</u>、方維倫、李昇憲, "具次微米間隙之高 Q 值整合式 CMOS-MEMS 共振器," 第 14 屆奈米工程暨微系統 技術研討會, 高雄, Sept. 2-3, 2010. (Oral Presentation) (Honorable Mention)

RELEVANT COURSEWORK

Undergraduate: Statics, Dynamics, Mechanics of Materials, Thermodynamics, Control Systems, Machine Design, Mechanical Vibrations, Heat Transfer, Electrical Circuits, Microelectronics, Electromagnetics, Signals and Systems, Linear Control Systems, Communication Systems

Graduate: Microsystems Design, RF MEMS Theory and Applications, Microsensors and Signal Conditioning Circuits,
 Wave Propagation in Elastic Solids, Analog Circuit Design, Advanced Analog Integrated Circuit Design, Phase-Locked-Loop
 (PLL) and Frequency Synthesizer, Sensing and Actuating Integrated Circuits, Radio Frequency IC Design

LANGUAGES

English – Listening/ Reading/ Speaking/ Writing Japanese – Reading Mandarin – Listening/ Reading/ Speaking/ Writing (**Native speaker**)

PROFESSIONAL AFFILIATIONS

Student member, IEEE

2011-Present

References

- Professor Sheng-Shian Li (<u>ssli@mx.nthu.edu.tw</u>)
 Associate Professor, Institute of NEMS, National Tsing Hua University, Hsinchu, Taiwan (<u>Thesis Advisor</u>)
- Professor Chih-Chun Cheng (<u>imeccc@ccu.edu.tw</u>)

Professor, Department of ME, National Chung Cheng University, Chiayi, Taiwan

Last updated on Feb. 5, 2015