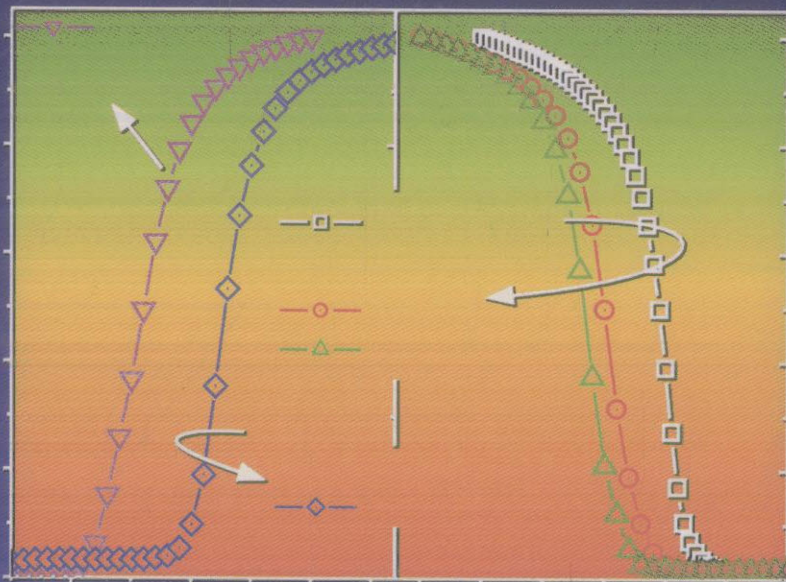
SELECTED SEMICONDUCTOR RESEARCH

Ming-Fu Li



Imperial College Press

Contents

Preface v

Introduction 1

Chapter 1. Defects in Semiconductors 15

1.1 M.F. Li and C.T. Sah, A new method for the determination of dopant and trap concentration profiles in semiconductors. IEEE Trans. ED., Vol.29, pp.306–315 (1982). 17

1.2 M.F. Li and C.T. Sah, New techniques of capacitance-voltage measurements of semiconductor junctions, *Solid State Electronics*, Vol.25, pp.95–99 (1982) 27

1.3 M.F. Li, D.Q. Mao and S.Y. Ren, Global predictions of T_2 symmetric deep level wavefunctions in semiconductors. *Solid State Commun.* Vol.48, pp.789–793 (1983). 32

1.4 M.F. Li, J.X. Chen, Y.S. Yao and G. Bai, Au acceptor levels in Si under pressure. *J. Appl. Phys.* Vol.58, pp.2599–2602 (1985). 37

1.5 M.F. Li, D.Q. Mao and S.Y. Ren, Binding energies of electrons by nitrogen pairs in GaP. *Phys. Rev. B*, Vol.32, pp.6907–6909 (1985). 41

1.6 M.F. Li and P.Y. Yu, A new proposed method for determining inner or outer crossing lattice relaxation of *DX* centers in $Al_xGa_{1-x}As$ based on pressure effects. *Solid State Comm.*, Vol.61, pp.13–15 (1987). 44

1.7 M.F. Li, P.Y. Yu, E.R. Weber and W. Hansen, Lattice relaxation of pressure-induced deep centers in GaAs:Si. *Appl. Phys. Lett.*, Vol.51. pp.349–351 (1987). 47

1.8 M.F. Li. P.Y. Yu. E.R. Weber and W. Hansen. Photocapacitance study of pressure-induced deep donors in GaAs:Si. *Phys. Rev. B*, Vol.36, pp.4531–4534 (1987). 50

1.9 G.G. Qin and M.F. Li, Some selected topics in high pressure semiconductor research in China. (**Invited** presentation on International Conference on High Pressure in Semiconductors, Warsaw, Poland, 1988), published in *Semiconductor Science and Technology*, Vol.4, pp.225–227 (1989). 54

1.10 M.F. Li, Y.B. Jia, P.Y. Yu, J. Zhou and J.L. Gao, Negative U property of the *DX* center in $Al_xGa_{1-x}As$:Si. *Phys. Rev. B*, Vol.40, pp.1430–1433 (1989). 57

1.11 M.F. Li, P.Y. Yu and E.R. Weber, Simulation of effects of uniaxial stress on the deep level transient spectroscopy spectra of the *DX* center in AlGaAs alloys. *Appl. Phys. Lett.* Vol.59, pp.1197–1199 (1991). 61

1.12 M.F. Li. and P.Y. Yu, Probing the DX center in GaAs and related alloys by capacitance transient measurements under stress. (**invited** presentation on 5th Int. Conf. on High Pressure in Semiconductor Physics (HPSP), Kyoto, Japan, 1992), published in *Jap. J. Appl. Physics*, Vol.32, Supplement, pp.200–205, (1993) 64

1.13 M.F. Li, Y.Y. Luo, P.Y. Yu, E.R. Weber, H. Fujioka, A.Y. Du, S.J. Chua and Y.T. Lim, Two electron state and negative U property of sulfur *DX* centers in $GaAs_{1-x}P_x$. *Phys. Rev. B*, Vol.50, pp.7996–7999 (1994). 70

1.14 A.Y. Du, M.F. Li, T.C. Chong and S.J. Chua. Observation of carrier concentration saturation effect in n-type $Al_xGa_{1-x}As$. *Appl. Phys. Lett.*, Vol.66, pp.1391–1393 (1995). 74

1.15 M.F. Li and P.Y. Yu, High pressure study of DX centers using capacitance techniques (**invited** review paper). in High Pressure in Semiconductor Physics I. eds. T. Suski and W. Paul, **Semiconductors and Semimetals**, Vol.54, pp.457–484 Academic Press, 1998. 77

Chapter 2. Semiconductor Band Structures 105

2.1 M.F. Li, M.P. Surh and S.G. Louie, Spin-orbit interaction effects in Zincblende semiconductors: ab initio pseudopotential calculations. *Proc. 19th Int. Conf. on The Physics of Semiconductors*, ed. W. Zawadzki, pp.857 860 (1988), Warsaw, Poland. 107

2.2 Z.G. Gu, M.F. Li, J.Q. Wang and B.S. Wang, Deformation potentials at the top of valence bands in semiconductors: *Ab Initio* pseudopotential calculations. *Phys. Rev. B*, Vol.41, pp.8333 8339 (1990). 111

2.3 M.F. Li, X.S. Zhao, Z.G. Gu, J.X. Chen, Y.J. Li and J.Q. Wang, Shear-deformation- potential constant of the conduction-band minima of Si: Experimental determination by the deep-level capacitance transient method. *Phys. Rev. B*, Vol.43, pp.14040–14046 (1991). 118

2.4 J.Q. Wang, Z.Q. Gu, B.S. Wang and M.F. Li, First-principles calculations for quasiparticle energies of GaP and GaAs. *Phys. Rev. B*, Vol.44, pp.8707–8712, (1991). 125

2.5 W.J. Fan, M.F. Li, T.C. Chong and J.B. Xia, Electronic properties of zinc-blende GaN, AlN and their alloys $Ga_{1-x}Al_xN$. *J. Appl. Phys.*, Vol.79, pp.188–194 (1996). 131

2.6 W.J. Fan, M.F. Li, T.C. Chong and J.B. Xia, Valence hole subbands and optical gain spectra of $GaN/Ga_{1-x}Al_xN$ strained quantum wells. *J. Appl. Phys.*, Vol.80, pp.3471–3478 (1996). 138

2.7 Y.C. Yeo, T.C. Chong and M.F. Li, Electronic band structures and effective-mass parameters of wurtzite GaN and InN. *J. Appl. Phys.* Vol.83, pp.1429–1436 (1998). 146

2.8 Y.C. Yeo, T.C. Chong, M.F. Li and W.J. Fan, Analysis of optical gain and threshold current density of wurtzite InGaN/GaN/AlGaN quantum well lasers. *J. Appl. Phys.* Vol.84, pp.1813-1819 (1998) 154

Chapter 3. Analog Integrated Circuit Design 161

3.1 M.F. Li, X. Chen and Y.C. Lim, Linearity improvement of CMOS transconductors for low supply applications. *Electronics Letters*, Vol.29, pp.1106–1107 (1993). 163

3.2 X.W. Zhang, M.F. Li and U. Dasgupta, Low voltage linear OTA with rail-to-rail differential mode input signal capability. *The* 6th *IEEE Int. Conf. on Electronics, Circuits and Systems (ICECS'99)*, Cyprus, Sept, 1999. pp.603–606. 165

3.3 Y.J. Ha, M.F. Li and A.Q. Liu, A new CMOS buffer amplifier design used in low voltage MEMS interface circuits. presented at the 6th *IEEE Int. Conf. on Electronics, Circuits and Systems (ICECS'99)*, Cyprus, 1999. pp.1313–1316, Published in *Analog Integrated Circuits and Signal Processing*, Vol.27, pp.7–17 (2001). 169

3.4 M.F. Li, U. Dasgupta, X.W. Zhang and Y.C. Lim, A low-voltage CMOS OTA with rail-to-rail differential input range. *IEEE Trans. Circuits and Systems* - I, Vol.47, pp.1–8 (2000). 180

3.5 A.M. Xu and M.F. Li, A 1.2 V Rail-to-rail differential mode input linear CMOS transconductor. *Proceedings of the 2002 IEEE ISCAS*, May, 2002, Phoenix, Arizona, Vol.1, pp.337–340. 188

3.6 Luo Zhenying, M.F. Li, Yong Lian and S.C. Rustagi, A new low voltage CMOS transconductor for VHF filtering applications. presented at *IEEE ISCAS*, May, 2003, Bangkok, Thailand. Published in *Analog Integrated Circuits and Signal Processing*, Vol.37, pp.233–342 (2003). 192

Chapter 4. CMOS Device Reliability 203

4.1 B.B. Jie, M.F. Li, C.L. Lou, W.K. Chim, D.S.H. Chan and K.F. Lo, Investigation of Interface Traps in LDD pMOST's by the DCIV Method. *IEEE Electron Device Lett.*,Vol.18, pp.583–585 (1997). 205

4.2 H. Guan, Y.H. Zhang, B.B. Jie, Y.D. He, M.F. Li, Z. Dong, J. Xie, J.L.F. Wang, A.C. Yen, G.T.T. Sheng and W.D. Li, Nondestructive DCIV method to evaluate plasma charging damage in ultrathin gate oxides. *IEEE Electron Device Lett.*, Vol.20, pp.238–240 (1999). 208

4.3 M.F. Li, Y.D. He, S.G. Ma, B.J. Cho, K.F. Lo and M.Z. Xu, Role of hole fluence in gate oxide breakdown. *IEEE Electron Device Lett.*, Vol.20, pp.586–588 (1999). 211

4.4. B.B. Jie, K.H. Ng, M.F. Li and K.F. Lo, Correlation between charge pumping method and direct-current current voltage method in p-type Metal-Oxide-Semiconductor Field-Effect Transistors. *Jpn. J. Appl. Phys.*, Vol.38, pp.4696–4698 (1999). 214

4.5 H. Guan, M.F. Li, Y.D. He, B.J. Cho and Z. Dong, A thorough study of quasi-breakdown phenomenon of thin gate oxide in dual-gate CMOSFET's. *IEEE Trans. ED.*, Vol.47, pp.1608–1616 (2000). 217

4.6 C. Gang, M.F. Li and X. Yu, Interface traps at high doping drain extension region in sub-0.25- μm MOSTs. *IEEE Electron Device Lett.*, Vol.22, pp.233–235 (2001). 226

4.7 G. Chen, M.F. Li, C.H. Ang, J.Z. Zhen and D.L. Kwong, Dynamic NBTI of p-MOS Transistors and Its Impact on MOSFET scaling. *IEEE Electron Device Lett.*, Vol.23, pp.734–736 (2002). 229

4.8 G. Chen, K.Y. Chuah, M.F. Li, D.S.H. Chan, C.H. Ang, J.Z. Zheng, Y. Jin and D.L. Kwong, Dynamic NBTI of pMOS transistors and its impact on device lifetime. *IEEE Int. Reliability Physics Symposium Proceeding*, Dallas, TX, pp.196–202 (2003). 232

4.9 M.F. Li, B.J. Cho, G. Chen, W.Y. Loh and D.L. Kwong, New Reliability Issues of CMOS transistors with 1.3 nm thick gate oxide. (**invited**), 7th International Symp. on Silicon Nitride and Silicon Dioxide thin insulating films, 203rd Electrochemical Society Meeting, Paris, April, 2003. *ECS Proceedings* Vol.2003-02. pp.228–240. 239

4.10 M.F. Li, G. Chen, C. Shen, X.P. Wang, H.Y. Yu, Y.C. Yeo and D.L. Kwong, Dynamic bias-temperature instability in ultrathin SiO_2 and HfO_2 metal-oxide-semiconductor field effect transistors and its impact on device lifetime. (**invited** presentation at *International workshop on dielectric thin films for future ULSI devices-science and technology (IWDTF)*, Tokyo, May, (2004)) Published as a review paper in *Jp. JAP.* Vol.43, no.11B, pp.7807–7814 (2004). 252

4.11 C. Shen, M.F. Li, X.P. Wang, H.Y. Yu, Y.P. Feng, A.T.L. Lim, Y.C. Yeo, D.S.H. Chan and D.L. Kwong, Negative U traps in HfO_2 gate dielectrics and frequency dependence of dynamic BTI in MOSFETs. *Int. Electron Device Meeting (IEDM) Tech. Digest*, pp.733–736 (2004). 260

4.12 T. Yang, M.F. Li, C. Shen, C.H. Ang, C. Zhu, Y.C. Yeo, G. Samudra, S.C. Rustagi, M.B. Yu, and D.L. Kwong, Fast and slow dynamic NBTI components in p-MOSFET with SiON dielectric and their impact on device life-time and circuit application. *Symp. VLSI Tech.*, pp.92–93 (2005). 264

4.13 T. Yang, C. Shen, M.F. Li, C.H. Ang, C.X. Zhu, Y.C. Yeo, G. Samudra, and D.L. Kwong, Interface trap passivation effect in NBTI measurement for p-MOSFET with SiON gate dielectric. *IEEE Electron Device Lett.*, Vol.26, pp.758–760 (2005). 266

4.14 C. Shen, M.F. Li, X.P. Wang, Y.C. Yeo and D.L. Kwong, A fast measurement technique for MOSFET $I_d - V_g$ characteristics. *IEEE Electon Device Lett.*, Vol.27, pp.55–57 (2006). 269

4.15 C. Shen, M.F. Li, C.E. Foo, T. Yang, D.M. Huang, A. Yap, G.S. Samudra and Y.C. Yeo, Characterization and Physical Origin of Fast V_{th} transient in NBTI of pMOSFETs with SiON Dielectric. *IEDM Tech. Digest*, pp.333–336 (2006). 272

4.16 C. Shen, T. Yang, M.F. Li, X.P. Wang, C.E. Foo, G.S. Samudra, Y.C. Yeo and D.L. Kwong, Fast *Vth* instability in HfO_2 Gate Dielectric MOSFETs and its Impact on Digital Circuits. *IEEE Trans. ED.*, Vol.53, pp.3001–3011 (2006). 276

4.17 W.J. Liu, Z.Y. Liu, D.M. Huang, C.C. Liao, L.F. Zhang, Z.H. Gan, W. Wang, C. Shen and M.F. Li, On-the-fly interface trap measurement and its impact on the understanding of NBTI mechanism for p-MOSFETs with SiON Gate dielectric. *IEDM Tech. Digest*, pp.813–816 (2007). 287

4.18 M.F. Li, D.M. Huang, C. Shen, T. Yang, W.J. Liu and Z.Y. Liu Understand NBTI Mechanism by Developing Novel Measurement Techniques. *IEEE Trans. Device and Materials Reliability*, Vol.8, No.1, pp.62–71 (2008), (**invited** review paper). 291

4.19 D.M. Huang, W.J. Liu, Z.Y. Liu, C.C. Liao, L.F. Zhang, Z. Gan, W. Wong and M.F. Li, A modified charge-pumping method for the characterization of interface-trap generation in MOSFETs. *IEEE Trans. ED.* Vol.56, p.267–274 (2009). 301

Chapter 5. CMOS Technology 309

5.1 H.Y. Yu, N. Wu, M.F. Li, C.X. Zhu, B.J. Cho, D.L. Kwong, C.H. Tung, J.S. Pan, J.W. Chai, W.D. Wang, D.Z. Chi, C.H. Ang, J.Z. Cheng and S. Ramanathan, Thermal stability of $(HfO_2)_x(Al_2O_3)_{1-x}$ on Si. *Applied Physics Letters*, Vol.81, pp.3618–3620 (2002). 311

5.2 H.Y. Yu, M.F. Li, B.J. Cho, C.C. Yeo, M.S. Joo, D.L. Kwong, J.S. Pan, C.H. Ang, J.Z. Zheng and S. Ramanathan, Energy Gap and Band Alignment for $(HfO_2)_x(Al_2O_3)_{1-x}$ on (100) Si. *Applied Physics Letters*, Vol.81, pp.376–378 (2002). 314

5.3 H.Y. Yu, H.F. Lim, J.H. Chen, M.F. Li, C.X. Zhu, D.L. Kwong, C.H. Tung, K.L. Bera and C.J. Leo, Robust HfN Metal Gate Electrode for Advanced MOS Devices Application. *Symp. VLSI Technology*, Kyoto, pp.151–152 (2003). 317

5.4 H.Y. Yu, J.F. Kang, J.D. Chen, C. Ren, Y.T. Hou, S.J. Whang, M.F. Li, D.S.H. Chan, K.L. Bera, C.H. Tung, A. Du and D.L. Kwong, Thermally Robust High Quality HfN/HfO_2 Gate Stack for Advanced CMOS Devices. *IEDM. Tech Digest*, pp.99-102 (2003). 319

5.5 H. Hu, S.J. Ding, H.F. Lim, C.X. Zhu, M.F. Li, S.J. Kim, X.F. Yu, J.H. Chen, Y.F. Yong, B.J. Cho, D.S.H. Chan, S.C. Rustagi, M.B. Yu, C.H. Tung, A. Du, D. My, P.D. Fu, A. Chin and D.L. Kwong, High Performance ALD HfO_2-Al_2O_3 Laminate MIM Capacitors for RF and Mixed Signal IC Applications. *IEDM, Tech Digest*, pp.379-382 (2003). 323

5.6 S.Y. Zhu, J. Chen, M.F. Li, S.J. Lee, J. Singh, C.X. Zhu, A. Du, C.H. Tung, A. Chin and D.L. Kwong, N-type Schottky barrier source/drain MOSFET using Ytterbium Silicide. *IEEE Electron Device Lett.*, Vol.25, pp.565-567 (2004). 327

5.7 S.Y. Zhu, H.Y. Yu, S.J. Whang, J.H. Chen, C. Shen, C. Zhu, S.J. Lee, M.F. Li, D.S.H. Chan, W.J. Yoo, A. Du, C.H. Tung, J. Singh, A. Chin and D.L. Kwong, Schottky-Barrier S/D MOSFETs with high-k gate dielectrics and metal-gate electrode. *IEEE Electron Device Lett.*, Vol.25, pp.268-270 (2004). 330

5.8 H.Y. Yu, C. Ren, Y.C. Yeo, J.F. Kang, X.P. Wang, H.H.H. Ma, M.F. Li, D.S.H. Chan and D.L. Kwong, Fermi Pinning-induced thermal instability of metal-gate work functions. *IEEE Electron Device Lett.*, Vol.25, pp.337–339 (2004). 333

5.9 M.F. Li, S. Lee, S. Zhu, R. Li, J. Chen, A. Chin and D.L. Kwong, New Developments in Schottky Source/Drain High-k/Metal Gate CMOS Transistors. (**invited** presentation at *207th Electrochemical Society Meeting, Symposium K*, Quebec City, Canada, May 16, 2005, *ECS Proceeding*, Vol.2005-05, p.301. 336

5.10 S.Y. Zhu, R. Li, S.J. Lee, M.F. Li, A. Du, J. Singh, C. Zhu, A. Chin and D.L. Kwong, Germanian P-MOSFETs with Schottky-barrier germanide S/D, high-K gate dielectric and metal gate. *IEEE Electron Device Lett.*, Vol.26, pp.81-83 (2005). 346

5.11 M.F. Li, C. Zhu, C. Shen, X.F. Yu, X.P. Wang, Y.P. Feng, A.Y. Du, Y.C. Yeo, G. Samudra, A. Chin and D.L. Kwong, New Insights in Hf Based High-k Gate Dielectrics in MOSFETs.(**invited** presentation at 208th ECS Meeting, Los Angeles, G3 Symposium Proceeding, 2005), published in *ECS Transactions* Vol.1, p.717–730 (2006). 349

5.12 J.D. Chen, H.Y. Yu, M.F. Li, D.L. Kwong, M.J.H.van Dal, J.A. Kittl, A. Lauwers, P. Absil, M. Jurczak and S. Biesmans, Yb-Doped Ni FUSI for the n-MOSFETs gate electrode application. *IEEE Electron Device Lett.*, Vol.27, pp.160–162 (2006). 363

5.13 X.P. Wang, M.F. Li, C. Ren, X.F. Yu, C. Shen, H.H. Ma, A. Chin, C.X. Zhu, J. Ning, M.B. Yu and D.L. Kwong, Tuning Effective Metal Gate Work Function by a Novel Gate Dielectric HfLaO for nMOSFETs. *IEEE Electron Device Lett.*, Vol.27, pp.31–33 (2006). 366

5.14 X.P. Wang, C. Shen, M.F. Li, H.Y. Yu, Y. Sun, Y.P. Feng, A. Lim, H.W. Sik, A. Chin, Y.C. Yeo, P. Lo and D.L. Kwong, Dual Metal Gates with Band-Edge Work Functions on Novel HfLaO High-κ Gate Dielectric. *Symp. VLSI Tech.* pp.9–10 (2006). 369

5.15 J. Chen, X.P. Wang, M.F. Li, S.J. Lee, M.B. Yu, C. Shen and Y.C. Yeo, NMOS compatible work function of TaN metal gate with Erbium-oxide-doped Hafnium oxide gate dielectric. *IEEE Electron Device Lett.*, Vol.28, pp.862–864 (2007). 371

5.16 X.P. Wang, H.Y. Yu, M.F. Li, C.X. Zhu, S. Biesemans, A. Chin, Y.Y. Sun, Y.P. Feng, A. Lim, Y.C. Yeo, W.Y. Loh, G.Q. Lo and D.L. Kwong, Wide V_{fb} and V_{th} tunability for Metal-Gated MOS Devices with HfLaO Gate dielectrics. *IEEE Electron Device Lett.*,Vol.28, pp.258–260 (2007). 374

5.17 M.F. Li, C. Zhu, X.P. Wang and X. Yu, Novel Hafnium-Based Compound Metal Oxide Gate Dielectrics for Advanced CMOS Technology. (**Keynote Speech** on Japan 12th Workshop on Gate Stack Technology and Physics, Japan Society of Applied Physics, Mishima, Japan, pp.1 6 (2007). 377

5.18 X.P. Wang, M.F. Li, H.Y. Yu, J.J. Yang, J.D. Chen, C.X. Zhu, A.Y. Du, W.Y. Loh, S. Biesmans, A. Chin, G.Q. Lo and D.L. Kwong, Widely tunable work function TaN/Ru stacking layer on HfLaO gate dielectric. *IEEE Electron Device Lett.*, Vol.29, pp.50–52 (2008). 383

Chapter 6. Nano CMOS Device Quantum Simulation 387

6.1 Y.T. Hou and M.F. Li, Hole quantization effects and threshold voltage shift in pMOSFETAssessed by improved one-band effective mass approximation. *IEEE Trans. ED.*, Vol.48, pp.1188–1193 (2001). 389

6.2 Y.T. Hou and M.F. Li, A simple and efficient model for quantization effects of hole inversion layers in MOS devices. *IEEE Trans. ED.*, Vol.48, pp.2893–2898 (2001). 395

6.3 Y.T. Hou, M.F. Li, H.Y. Yu, Y. Jin and D.L. Kwong, Quantum Tunneling and Scalability of HfO_2 and HfAlO Gate Stacks. *IEDM Technical Digests*, pp.731–734 (2002). 401

6.4 Y.T. Hou, M.F. Li, Y. Jin and W.H. Lai, Direct Tunneling Hole Currents through Ultrathin Gate Oxides in Metal-Oxide-Semiconductor Devices. *Journal of Applied Physics*, Vol.91, pp.258–264 (2002). 405

6.5 H.Y. Yu, Y.T. Hou, M.F. Li and D.L. Kwong, Investigation of Hole-Tunneling Current through Ultrathin Oxynitride/Oxide Stack Gate Dielectrics in p-MOSFETs. *IEEE Trans. ED.*, Vol.49, pp.1158–1164 (2002). 412

6.6 T. Low, Y.T. Hou and M.F. Li, Improved one-band self-consistent effective mass methods for hole quantization in p-MOSFET. *IEEE Trans. ED.*, Vol.50, pp.1284–1289 (2003). 419

6.7 T. Low, Y.T. Hou, M.F. Li, C.X. Zhu, A. Chin, G. Samudra, L. Chan and D.L. Kwong, Investigation of performance limits of Germanium double-gated MOSFETs. *IEDM 2003, Tech Digest*, pp.691–694. 425

6.8 T. Low, Y.T. Hou, M.F. Li, C. Zhu, D.L. Kwong and A. Chin, Germanium MOS: An Evaluation from Carrier Quantization and Tunneling Current. *Symp. VLSI Tech.*, 9A.2. Kyoto (2003). 429

6.9 Y.T. Hou, M.F. Li, T. Low and D.L. Kwong, Metal gate work function engineering on gate leakage of MOSFETs. *IEEE Trans. ED.*, Vol.51, pp.1783–1789 (2004). 431

6.10 T. Low, M.F. Li, C. Shen, Y.C. Yeo, Y.T. Hou, C. Zhu, A. Chin and D.L. Kwong, Electron Mobility in Ge and Strained-Si Channel UltraThin-Body metal-oxide semi conductor field-effect transistors. *Appl. Phys. Letts.*, Vol.85, pp.2402–2404 (2004). 438

6.11 T. Low, M.F. Li, W.J. Fan, S.T. Ng, Y.C. Yeo, C. Zhu, A. Chin, L. Chan and D.L. Kwong, Impact of surface roughness on Silicon and Germanium ultra-thin-body MOSFETs. *IEDM Tech. Digest*, pp.151–154 (2004). 441

6.12 T. Low, C. Shen, M.F. Li, Y.C. Yeo, Y.T. Hou, C. Zhu, A. Chin, L. Chan and D.L. Kwong, Study of mobility in strained Silicon and Germanium ultra thin body MOSFETs. *Solid State Device and Materials (SSDM)*, Tokyo, Japan, pp.776–777 (2004). 445

6.13 T. Low, M.F. Li, Y.C. Yeo, W.J. Fan, S.T. Ng and D.L. Kwong, Valence band structure of ultrathin silicon and germanium channels in metal-oxide-semiconductor field-effect transistors. *J. Appl. Phys.*, Vol.98, pp.024504-1-024504-8 (2005). 447

6.14 T. Low, M.F. Li, G. Samudra, Y.C. Yeo, C. Zhu, A. Chin and D.L. Kwong, Modeling study of the impact of surface roughness on silicon and germanium UTB MOSFETs. *IEEE Trans. ED.*, Vol.52, pp.2430–2439 (2005). 455

6.15 Y.P. Feng, A.T.L. Lim and M.F. Li, Negative-U property of oxygen vacancy in cubic HfO_2. *Appl. Phys. Lett.*, Vol.87, pp.062105-1-062105-3 (2005). 465

6.16 Z.G. Zhu, T. Low, M.F. Li, W.J. Fan, P. Bai, D.L. Kwong and G. Samudra, Modeling study of InSb thin film for advanced III-V MOSFET Applications. *IEDM Tech. Digest*, pp.807–810 (2006). 468

Complete List of Publications 473

Biography 507