Appendix: Effective Mass Theorem

For solving a Schrödinger equation with a slowly varying perturbation $\delta V(\mathbf{r})$ in a crystal,

$$[H_0 + \delta V(\mathbf{r})]\psi(\mathbf{r}) = E\psi(\mathbf{r}), \tag{A.1}$$

with $H_0 = \frac{p^2}{2m_0} + V(\mathbf{r})$ the unperturbed Hamiltonian, we may expand the new eigenstates as the linear superposition of the perfect bulk eigenstates $\psi_{j\mathbf{k}}(\mathbf{r})$, thus we look for a solution in the form of

$$\psi(\mathbf{r}) = \sum_j \int f_j(\mathbf{k})\psi_{j\mathbf{k}}(\mathbf{r})\mathrm{d}\mathbf{k}, \tag{A.2}$$

where

$$f_j(\mathbf{k}) = \int_{\Omega} \psi^*_{j\mathbf{k}}(\mathbf{r})\psi(\mathbf{r})\mathrm{d}\mathbf{r} \tag{A.3}$$

is the projection of $\psi(\mathbf{r})$ on the bulk eigenstates $\psi_{j\mathbf{k}}(\mathbf{r})$. We integrate over k because that with the breaking of the translational symmetry, now the eigenstates are the mixture from the original eigenstates over the whole Brillouin zone. The summation is over the band we include in our calculation. Sometimes one band is not very bad, such as for the donor states for GaAs, which are generally on the magnitude of meV below the conduction band edge. On the other occasions such as for the acceptor states or the valence subband structures in a quantum well, we need to include the HH, LH, and split-off hole states based on the Luttinger Hamiltonian, and sometimes we shall also put the conduction band into consideration in addition.

Before proceeding, we first consider the integral

$$I = \int_{\Omega} F(\mathbf{r})u(\mathbf{r})\mathrm{d}\mathbf{r}, \tag{A.4}$$

where Ω is the volume of the crystal, $F(\mathbf{r})$ is a slowly varying function at the scale of the primitive cell, and $u(\mathbf{r})$ is a periodic function with the periodicity

of the lattice. Varying "slowly" here means that in the scale of a primitive cell, the quantities it refers to can be assumed unchanged. There are typically two length scales in our considered systems. One is a relatively macroscopic scale such as the quantum well width, on which the perturbation and the envelope function vary. The other is the scale of the crystal primitive cell, or about the lattice constant, on which the periodic part of the Bloch function varies. Using these spatial properties of the functions, we can factorize an integral over the whole crystal into a product of two integrals as in the following,

$$\begin{aligned} I &= \int_{\Omega} F(\mathbf{r})u(\mathbf{r})d\mathbf{r} = \sum_{\mathbf{R_n}} \int_{\Omega_0} F(\mathbf{r}-\mathbf{R_n})u(\mathbf{r}-\mathbf{R_n})d\mathbf{r} \\ &= \sum_{\mathbf{R_n}} F(\mathbf{r}-\mathbf{R_n}) \int_{\Omega_0} u(\mathbf{r}-\mathbf{R_n})d\mathbf{r} \\ &= \frac{1}{\Omega}\int_{\Omega} F(\mathbf{r})d\mathbf{r} \int_{\Omega_0} u(\mathbf{r})d\mathbf{r}, \end{aligned} \tag{A.5}$$

where Ω_0 is the volume of the primitive cell. In the above derivation, the periodicity of $u(\mathbf{r})$ is used.

According to the discussions in the last chapter, the bulk eigenstates $\psi_{j\mathbf{k}}(\mathbf{r})$ are Bloch functions with the periodic part being superpositions of the band edge function u_{i0}, i.e.,

$$\psi_{j\mathbf{k}}(\mathbf{r}) = \mathrm{e}^{i\mathbf{k}\cdot\mathbf{r}} \sum_i c_{ji}(\mathbf{k})u_{i0}(\mathbf{r}). \tag{A.6}$$

Inserting the above equation into (A.2), we obtain

$$\begin{aligned} \psi(\mathbf{r}) &= \sum_{i,j} \int \mathrm{e}^{\mathrm{i}\mathbf{k}\cdot\mathbf{r}} c_{ji}(\mathbf{k}) f_j(\mathbf{k}) u_{i0}(\mathbf{r}) \mathrm{d}\mathbf{k} \\ &= \sum_i \left(\int \mathrm{e}^{i\mathbf{k}\cdot\mathbf{r}} F_{i\mathbf{k}} \mathrm{d}\mathbf{k} \right) u_{i0}(\mathbf{r}) \\ &= \sum_i F_i(\mathbf{r}) u_{i0}(\mathbf{r}), \end{aligned} \tag{A.7}$$

where we define

$$F_{i\mathbf{k}} = \sum_j c_{ji}(\mathbf{k}) f_j(\mathbf{k}) \tag{A.8}$$

and

$$F_i(\mathbf{r}) = \int \mathrm{e}^{\mathrm{i}\mathbf{k}\cdot\mathbf{r}} F_{i\mathbf{k}} \mathrm{d}\mathbf{k}. \tag{A.9}$$

So eventually we expressed the eigenstates of the perturbed system as a sum of modulated periodic band edge functions. The $F_i(\mathbf{r})$s are the envelope functions.

Inserting (A.7) into (A.1), then multiplying $\mathrm{e}^{-\mathrm{i}\mathbf{k}'\cdot\mathbf{r}}u^*_{i0}(\mathbf{r})$, and then integrating over the volume of the crystal, we obtain

$$\sum_j \frac{1}{\Omega}\int_\Omega \mathrm{d}\mathbf{r}\int \mathrm{d}\mathbf{k}\;\; F_{j\mathbf{k}}\mathrm{e}^{\mathrm{i}(\mathbf{k}-\mathbf{k}')\cdot\mathbf{r}}u^*_{i0}(\mathbf{r})\times \left[\frac{\hbar^2k^2}{2m_0}+E_j-E+\frac{\hbar}{m_0}\mathbf{k}\cdot\mathbf{p}+\delta V(\mathbf{r})\right]u_{j0}(\mathbf{r})=0. \tag{A.10}$$

Here we can use (A.5) to greatly reduce the complexity of the above equation. Following the same procedure, we have

$$\frac{1}{\Omega}\int_\Omega \mathrm{d}\mathbf{r}\;\; \mathrm{e}^{\mathrm{i}(\mathbf{k}-\mathbf{k}')\cdot\mathbf{r}}u^*_{i0}(\mathbf{r})\frac{\hbar}{m_0}\mathbf{k}\cdot\mathbf{p}u_{j0}(\mathbf{r})=\delta_{\mathbf{k},\mathbf{k}'}\frac{\hbar}{m_0}\mathbf{k}\cdot\mathbf{p}_{ij}, \tag{A.11}$$

where the identity

$$\frac{1}{\Omega}\int_\Omega \mathrm{d}\mathbf{r}\;\; \mathrm{e}^{\mathrm{i}(\mathbf{k}-\mathbf{k}')\cdot\mathbf{r}}=\delta_{\mathbf{k},\mathbf{k}'} \tag{A.12}$$

is used, and $\mathbf{p}_{ij}$ is the momentum matrix element between states $u_{i0}(\mathbf{r})$ and $u_{j0}(\mathbf{r})$. Similarly,

$$\frac{1}{\Omega}\int_\Omega \mathrm{d}\mathbf{r}\;\; \mathrm{e}^{\mathrm{i}(\mathbf{k}-\mathbf{k}')\cdot\mathbf{r}}u^*_{i0}(\mathbf{r})\delta V(\mathbf{r})u_{j0}(\mathbf{r})=\delta V_{\mathbf{k}-\mathbf{k}'}\delta_{i,j}, \tag{A.13}$$

where

$$\delta V_{\mathbf{k}-\mathbf{k}'}=\frac{1}{\Omega}\int_\Omega \mathrm{d}\mathbf{r}\;\; \mathrm{e}^{\mathrm{i}(\mathbf{k}-\mathbf{k}')\cdot\mathbf{r}}\delta V(\mathbf{r}) \tag{A.14}$$

is actually the Fourier transformation of $\Delta V(\mathbf{r})$, and we used the property that periodic Bloch states are orthonormal in a primitive cell, i.e.,

$$\frac{1}{\Omega}\int_\Omega u^*_{j0}u_{i0}\mathrm{d}\mathbf{r}=\frac{1}{\Omega_0}\int_{\Omega_0} u^*_{j0}u_{i0}\mathrm{d}\mathbf{r}=\delta_{ij}. \tag{A.15}$$

Using these results, (A.10) finally becomes

$$\left(\frac{\hbar^2k^2}{2m_0}+E_i\right)F_{i\mathbf{k}}+\frac{\hbar}{m_0}\sum_j \mathbf{k}\cdot\mathbf{p}_{ij}F_{j\mathbf{k}}+\int \mathrm{d}\mathbf{k}'\;\; \delta V_{\mathbf{k}-\mathbf{k}'}(\mathbf{r})F_{i\mathbf{k}'}=EF_{i\mathbf{k}}. \tag{A.16}$$

This equation clearly shows that δV mixes the states with different k, but does not couple one state with the other. Next, we deal with the coupling from the other bands using perturbation theory. One approximation is to neglect the effects of the perturbative potential to the other bands. Then if we consider a singly degenerate band i, and assume that one band j only couples with band i, then for all the other bands, (A.16) becomes

$$\left(\frac{\hbar^2 k^2}{2m_0} + E_j\right) F_{j\mathbf{k}} + \frac{\hbar}{m_0}\mathbf{k}\cdot\mathbf{p}_{ij} F_{i\mathbf{k}} = EF_{j\mathbf{k}}. \tag{A.17}$$

By approximating $E \simeq E_i + \frac{\hbar^2 k^2}{2m_0}$, we have

$$F_{j\mathbf{k}} = \frac{\hbar}{m_0}\frac{\mathbf{k}\cdot\mathbf{p}_{ij}}{E_i - E_j} F_{i\mathbf{k}}. \tag{A.18}$$

Inserting the above equation into (A.16), we obtain the equation for band i,

$$\left(\frac{\hbar^2 k^2}{2m_0} + E_i + \frac{\hbar^2}{m_0^2}\sum_{j\neq i}\frac{|\mathbf{k}\cdot\mathbf{p}_{ij}|^2}{E_i - E_j}\right) F_{i\mathbf{k}} + \int \mathrm{d}\mathbf{k}' \;\; \delta V_{\mathbf{k}-\mathbf{k}'}(\mathbf{r}) F_{i\mathbf{k}'} = EF_{i\mathbf{k}}. \tag{A.19}$$

Comparing with (4.116), we can write the above equation as

$$\left(\frac{\hbar^2 k^2}{2m^*} + E_i\right) F_{i\mathbf{k}} + \int \mathrm{d}\mathbf{k}' \;\; \delta V_{\mathbf{k}-\mathbf{k}'}(\mathbf{r}) F_{i\mathbf{k}'} = EF_{i\mathbf{k}}, \tag{A.20}$$

where m^* is exactly the effective mass for band i in the prefect crystal. Taking a Fourier transform of the above equation from the reciprocal space to the real space, the above equation becomes

$$\left[-\frac{\hbar^2\nabla^2}{2m^*} + \delta V(\mathbf{r})\right] F_i(\mathbf{r}) = EF_i(\mathbf{r}), \tag{A.21}$$

which is an equation for the envelope function $F_i(\mathbf{r})$. Following the same procedure, a coupled second-order differential equation set can be obtained for the envelope functions for a degenerate set, written in a matrix form as $(H + \delta V)F = EF$, where F is the envelope function in a form of $1 \times n$ vector, if the band considered is n-fold degenerate, and H is in the same form as for a perfect crystal with k_i replaced by $-i\frac{\partial}{\partial x_i}$, where $x_i = x, y, z$.

References

Adachi A (1994) GaAs and related materials: bulk semiconducting and superlattice properties. World Scientific, New York

Ahn D, Chuang SL (1988) Optical gain in a strained-layer quantum-well laser. IEEE J Quantum Electron 24:2400–2406

Alieu J, Bouillon P, Gwoziecki R, Moi D, Bremond G, Skotnicki T (1998) Optimisation of $Si_{0.7}Ge_{0.3}$ channel heterostructures for 0.15/0.18 μm CMOS process. In: Proceedings of ESSDERC, Bordeaux, France, pp 144–147

Ando T (1982a) Self-consistent results for a gaas/al$_x$ga$_{1-x}$as heterojunction. II. Low temperature mobility. J Phys Soc Japan 51:3900–3907

Ando T (1982b) Self-consistent results for a GaAs/Al$_x$Ga$_{1-x}$As heterojunction. I. subband structure and light-scattering spectra. J Phys Soc Japan 51:3893–3899

Andrieu F, Ernst T, Romanjek K, Weber O, Renard C, Hartmann JM, Toffoli A, Papon AM, Truche R, Holliger P, Brévard L, Ghibaudo G, Deleonibus S (2003) SiGe channel p-MOSFETS scaling-down. In: Proceedings of ESSDERC, Grenoble, France, pp 267–270

Ang KW, Chui KJ, Tung CH, Balasubramanian N, Li MF, Samudra GS, Yeo YC (2007) Enhanced strain effects in 25-nm gate-length thin-body NMOSFETS with silicon-carbon source/drain and tensile-stress liner. IEEE Electron Dev Lett 28:301–304

Arkwright J, Wu B, Skinner I, Chu P (1994) Resonantly enhanced nonlinearity using stimulated down-pumping in neodymium doped twin-core fibre. Electron Lett 30:235–236

Arnold DP, Gururaj S, Bhardwaj S, Nishida T, Sheplak M (2001) A piezoresistive microphone for aeroacoustic measurements. In: ASME International Mechanical Engineering Congress and Exposition, New York, pp 23,841-1–23,841-8

Asada M, Adams AR, Stubkjaer KE, Suematsu Y, Itaha Y, Arai S (1981) The temperature dependence of the threshold current of GaInAsP/InP DH lasers. IEEE J Quantum Electron 17:611–619

Ashcroft NW, Mermin ND (1976) Solid state physics. Saunders College Publishing/Harcourt Brace College Publishers, Forth Worth, TX

Aspnes DE, Cardona M (1978) Piezoresistance and the conduction-band minima of GaAs. Phys Rev B 17:741–751

Assad F, Ren Z, Bendix P, Lundstrom MS (1999) Performance limits of Si MOSFETS. In: Tech. Dig. Int. Electron Device Meet., San Francisco, CA, pp 547–550

Assaderaghi F, Shahidi G (2000) SOI at IBM: current status of technology, modeling, design, and the outlook for the 0.1 μm generation. In: IEEE International SOI Conference, Wakefield, MA, pp 6–9

Bai P, Auth C, Balakrishnan S, Bost M, Brain R, Chikarmane V, Heussner R, Hussein M, Hwang J, Ingerly D, James R, Jeong J, Kenyon C (2004) A 65nm logic technology featuring 35 nm gate lengths, enhanced channel strain, 8 Cu interconnect layers, low-k ild and 0.57 μm^2 SRAM cell. In: Tech. Dig. Int. Electron Device Meet., San Francisco, CA, pp 657–660

Ball CA, van der Merwe JH (1983) Dislocations in solids. North-Holland Press, Amsterdam

Bardeen J (1938) An improved calculation of the energies of metallic Li and Na. J Chem Phys 6:367–371

Bardeen J, Shockley W (1950) Deformation potentials and mobilities in nonpolar crystals. Phys Rev 80:72–80

Beattie AR, Landsberg PT (1958) Auger effect in semiconductors. Proc R Soc A 249:16–29

Bernard MGA, Duraffourg G (1961) Phys Status Solodi 1:699

Bernardini F, Fiorentini V (1997) Spontaneous polarization and piezoelectric constants of III–V nitrides. Phys Rev B 56:R10,024–R10,027

Berz F (1985) The bethe condition for thermionic emission near an absorbing boundary. Solid State Electron 28:1007–1013

Boermans MJB, Hagen SH, Valster A, Finke MN, der Heyden JMMV (1990) Investigation of TE and TM polarised laser emission in GaInp/AlGaInp lasers by growth-controlled strain. IEEE Electron Lett 26:1438–1439

Bonno O, Barraud S, Mariolle D, Andrieu F (2008) Effect of strain on the electron effective mobility in biaxially strained silicon inversion layers: an experimental and theoretical analysis via atomic force microscopy measurements and kubo-greenwood mobility calculations. J Appl Phys 103:063,715-1–063,715-9

Boresi AP, Schmidt RJ (2003) Advanced mechanics of materials. Wiley, New York

Bour DP, Treat DW, Beernink KJ, Krusor BS, Geels RS, Welch DF (1994) 610-nm band AlGaInp single quantum well laser diode. IEEE Photon Tech Lett 6:128–131

Braga N, Buczkowski A, Kirk HR, Rozgonyi GA (1994) Formation of cylindrical *n/p* junction diodes by arsenic enhanced diffusion along interfacial misfit dislocations in *p*-type epitaxial Si/Si(Ge). Appl Phys Lett 64:1410–1412

Brantley WA (1973) Calculated elastic-constants for stress problems associated with semiconductor devices. J Appl Phys 44:534–535

Bufler FM, Fichtner W (2003) Scaling of strained-Si n-MOSFETS into the ballistic regime and associated anisotropic effects. IEEE Trans Electron Devices 50:278–284

Burns FP (1957) Piezoresistive semiconductor microphone. J Acoust Soc Amer 29:248–253

Callaway J (1976) Quantum theory of the solid state, 2nd edn. Academic, Boston, MA

Chadi DJ, Cohen ML (1975) Tight-binding calculations of the valence bands of diamond and zincblende crystals. Phys Stat Sol (B) 68:405–491

Chan V, Rengarajan R, Rovedo N, Wei J, Hook T, Nguyen P, Chen J, Nowak E, Xiang-Dong C, Lea D, Chakravarti A, Ku V, Yang S, Steegen A, Baiocco C, Shafer P, Hung N, Shih-Fen H, Wann C (2003) High speed 45nm gate length CMOSFETS integrated into a 90nm bulk technology incorporating strain engineering. In: Tech. Dig. Int. Electron Device Meet., Washington, DC, pp 3.8.1–3.8.4

Chang CS, Chuang SL (1995) Universal curves for optical-matrix elements of strained quantum wells. Appl Phys Lett 66:795–797

Chang RPH, Coleman JJ (1978) A new method of fabricating gallium arsenide MOS devices. Appl Phys Lett 32:332–333

Chelikowsky JR, Cohen ML (1976) Calculations for the electronic structures of eleven diamond and zinc-blende semiconductors. Phys Rev B 14:556–582

Chidambaram PR, Smith BA, Hall LH, Bu H, Chakravarthi S, Kim Y, Samoilov AV, Kim AT (2004) 35 percent drive current improvement from recessed-SiGe drain extensions on 37 nm gate length PMOS. Hawaii, USA, pp 48–49

Chien-Hao C, Lee TL, Hou TH, Chen CL, Chen CC, Hsu JW, Cheng KL, Chiu YH, Tao HJ, Jin Y, Diaz CH, Chen SC, Liang MS (2004) Stress memorization technique (SMT) by selectively strained-nitride capping for sub-65nm high-performance strained-Si device application. Honolulu, HI, pp 56–57

Cho YK, Kwon SK, Jung HB, Kim J (2005) High Performance Power MOSFETs with Strained-Si Channel. Proceedings-ISPSD, Santa Barbara, CA

Chu M, Nishida T, Lv XL, Mohta N, Thompson SE (2008) Comparison between high-field piezoresistance coefficients of Si metal-oxide-semiconductor field-effect transistors and bulk Si under uniaxial and biaxial stress. J Appl Phys 103:113,704-1–113,704-7

Chuang SL (1995) Physics of optoelectronic devices. Wiley-Interscience, Wiley, New York

Corzine SW, Yan RH, Coldren LA (1993) Optical gain in III–V bulk and quantum well semiconductors. In: Zory PS (ed) Quantum Well Lasers. Academic, San Diego, CA

Cui Y, Zhong Z, Wang D, Wang W, Lieber CM (2003) High performance silicon nanowire field effect transistors. Nano Lett 3:149–152

Currie MT, Samavedam SB, Langdo TA, Leitz CW, Fitzgerald EA (1998) Appl Phys Lett 72:1718

Currie MT, Leitz CW, Langdo TA, Taraschi G, Antoniadis DA, Fitzgerald EA (2001) Carrier mobilities and process stability of strained Si n- and p-MOSFETS on SiGe virtual substrates. J Vac Sci Technol B 19:2268–2279

Datta S, Dewey G, Doczy M, Doyle BS, Jin B, Kavalieros J, Kotlyar R, Metz M, Zelick N, Chau R (2003) High mobility Si/SiGe strained channel mos transistors with HfO_2/TiN gate stack. In: Tech. Dig. Int. Electron Device Meet., Washington, DC, pp 653–656

Davies JH (1998) The physics of low-dimensional semiconductors – an introduction. Cambridge University Press, New York

Dingle R, Wiegmann W, Henry CH (1974) Quantum states of confined carriers in very thin $Al_xGa_{1-x}As$-GaAs-$Al_xGa_{1-x}As$ heterostructures. Phys Rev Lett 33:827–830

Dingle R, Stormer H, Gossard AC, Wlegmann W (1978) Selective absorption of solar energy in ultrafine chromium particles. Appl Phys Lett 31:665–666

Dismukes JP, Ekstrom L, Steigmeier EF, Kudman I, Beers SD (1964) Thermal and electrical properties of heavily doped Ge-Si alloys up to 1300 k. J Appl Phys 35

Dries JC, Gokhale MR, Thompson KJ, Forrest SR, Hull R (1998) Strain compensated $In_{1-x}Ga_xAs$(x ¡ 0.47) quantum well photodiodes for extended wavelength operation. Appl Phys Lett 73:2263–2265

Özbay E, Kimukin Ï, Biyikli N, Aytür O, Gökkavas M, Ulu G, Ünlü MS, Mirin RP, Berthness KA, Christensen DH (1999) High-speed ¿90% quantum-efficiency *p–i–n* photodiodes with a resonance wavelength adjustable in the 795–835 nm range. Appl Phys Lett 74:1072–1074

Evans MH, Zhang XG, Joannopoulos JD, Pantelides ST (2005) First-principles mobility calculations and atomic-scale interface roughness in nanoscale structures. Phys Rev Lett 95:106,802-1–160,802-4

Fang FF, Howard WE (1966) Negative field-effect mobility on (100) Si surfaces. Phys Rev Lett 16:797–799

Ferrier M, Clerc R, Ghibaudo G, Boeuf F, Skotnicki T (2006) Analytical model for quantization on strained and unstrained bulk NMOSFET and its impact on quasi-ballistic current. Solid State Electron 50:69–77

Fiorenza JG, Braithwaite G, Leitz CW, Currie MT, Yap J, Singaporewala F, Yang VK, Langdo TA, Carlin J, Somerville M, Lochtefeld A, Badawi H, Bulsara MT (2004) Film thickness constraints for manufacturable strained silicon CMOS. Semicond Sci Technol 19:L4–L8

Fischetti MV, Laux SE (1996) Band structure, deformation potentials, and carrier mobility in strained Si, Ge, and SiGe alloys. J Appl Phys 80:2234–2252

Fischetti MV, Gámiz F, Hänsch W (2002) On the enhanced electron mobility in strained-silicon inversion layers. J Appl Phys 92:7320–7324

Fischetti MV, Ren Z, Solomon PM, Yang M, Rim K (2003) Six-band k·p calculation of the hole mobility in silicon inversion layers: dependence on surface orientation, strain, and silicon thickness. J Appl Phys 94:1079–1095

Fortuna V, Bournel A, Dollfus P, Retailleau S (2006) Ultra-short n-mosfets with strained Si: device performance and the effect of ballistic transport using monte carlo simulation. Semiconductor Sci Technol 21:422–428

Fossum ER (1995) CMOS image sensors: electronic camera on a chip. In: Tech. Dig. Int. Electron Device Meet., Washington, DC, pp 17–25

Fossum JG, Weimin Z (2003) Performance projections of scaled CMOS devices and circuits with strained Si-on-SiGe channels. IEEE Trans Electron Devices 50:1042–1049

Frank DJ, Laux SE, Fischetti MV (1992) Mente carlo simulation of a 30 nm dual-gate mosfet: how short can Si go? In: Tech. Dig. Int. Electron Device Meet., Washington, DC, pp 553–556

Froyen S, Harrison WA (1979) Elementary prediction of linear combination of atomic orbitals matrix elements. Phys Rev B 20:2420–2422

Ridley BK (1999) Quantum Processes in Semiconductors, frouth edn. Clarendon Press Oxford, New York

Gámiz F, Roldán JB, López-Villanueva JA, Cartujo-Cassinello P, Carceller JE (1999) Surface roughness at the Si–SiO_2 interfaces in fully depleted silicon-on-insulator inversion layers. J Appl Phys 86:6854–6863

Gannavaram S, Pesovic N, Ozturk C (2000) Low temperature (800°c) recessed junction selective silicon–germanium source/drain technology for sub-70 nm CMOS. In: Tech. Dig. Int. Electron Device Meet., San Francisco, CA, pp 437–440

Gaworzewski P, Tittelbach-Helmrich K, Penner U (1998) Electrical properties of lightly doped p-type silicon–germanium single crystals. J Appl Phys 83

Gershoni D, Temkin H, Panish MB (1988) Strained-layer $ga_{1-x}in_xAs$/InP avalanche photodetectors. Appl Phys Lett 53:1294–1296

Ghani T, Armstrong M, Auth C, Bost M, Charvat P, Glass G, Hoffmann T, Johnson K, Kenyon C, Klaus J, McIntyre B, Mistry K, Murthy A, Sandford J, Silberstein M, Sivakumar S, Smith P, Zawadzki K, Thompson S, Bohr M (2003) A 90nm high volume manufacturing logic technology featuring novel 45nm gate length strained silicon CMOS transistors. In: Tech. Dig. Int. Electron Device Meet., Washington, DC, pp 11.6.1–11.6.3

Gnani E, Reggiani S, Gnudi A, Parruccini P, Colle R, Rudan M, Baccarani G (2007) Band-structure effects in ultrascaled silicon nanowires. IEEE Trans Electron Devices 54:2243–2254

Goo JS, Xiang Q, Takamura Y, Wang H, Pan J, Arasnia F, Paton EN, Besser P, Sidorov MV, Adem E, Lochtefeld A, Braithwaite G, Currie MT, Bulsara RHMT, Lin MR (2003) Scalability of strained-Si NMOSFETS down to 25 nm gate length. IEEE Electroc Dev Lett 24:351–353

Goodnick SM, Gann RG, Sites JR, Ferry DK, Fathy D, Krivanek OL (1983) Surface roughness scattering at the Si-sio_2 interface. J Vac Sci Technol B 1:803–808

Goodnick SM, Ferry DK, Wilmsen CW, Liliental Z, Fathy D, Krivanek OL (1985) Surface roughness at the Si(100)-SiO_2 interface. Phys Rev B 32:8171–8186

Hackbarth T, Herzog HJ, Rinaldi F, Soares T, Holländer B, Manti S, Luysberg M, Fichtner PF (2003) High frequency n-type modfets on ultra-thin virtual SiGe substrates. Solid State Electronics 47:1179–1182

Hadjisavvas G, Tsetseris L, Pantelides ST (2007) The origin of electron mobility enhancement in strained MOSFETS. IEEE Electron Dev Lett 28:1018–1020

Hamada H, Tominaga K, Shono M, Honda S, Yodoshi K, Yamaguchi T (1992) Room-temperature cw operation of 610 nm band AlGaInp strained multiquantum well laser diodes with multiquantum barrier. Electron Lett 28:1834–1836

Harley JA, Kenny TW (2000) 1/F noise considerations for the design and process optimization of piezoresistive cantilevers. J Microelectromech Syst 9:226–235

Harrison WA (1976) Pseudopotential theory of covalent bonding. Phys Rev B 14:702–711

Harrison WA (1989) Electronic structure and the properties of solids. Dover, New York

Harrison WA (1999) Elementary electronic structure. World Scientific, Singapore

Hasegawa H (1963) Theory of cyclotron resonance in strained silicon crystals. Phys Rev 129:1029–1040

He R, Yang P (2006) Giant piezoresistance effect in silicon nanowires. Nat Nanotechnol 1:42–46

Hensel JC, Hasegawa H, Nakayama M (1965) Cyclotron resonance in uniaxially stressed silicon. II. nature of the covalent bond. Phys Rev 138:A225–A238

Herring C, Vogt E (1956) Transport and deformation-potential theory for many-valley semiconductors with anisotropic scattering. Phys Rev 101:944–961

Höck G, Kohn E, Rosenblad C, von Känel H, Herzog HJ, König U (2000) High hole mobility in $Si_{0.17}Ge_{0.83}$ channel metal-oxide-semiconductor field-effect transistors grown by plasma-enhanced chemical vapor deposition. Appl Phys Lett 76

Homeijer B, Griffin B, Nishida T, Cattafesta L, Sheplak M (2006) Design optimization of a microelectromechanical piezoresisitive microphone for use in aeroacoustic measurements. J Acoust Soc Am 120:3330

Hong M, Ren F, Kuo JM, Hobson WS, Kwo J, Mannaerts JP, Lothian JR, Chen YK (1997) Depletion mode GaAs metal-oxide-semiconductor field effect transistors with $Ga_2O_3(Gd_2O_3)$ as the gate oxide. J Vac Sci Technol B 16:1398–1400

Houghton DC, Gibbings CJ, Tuppen CG, Lyons MH, Halliwell MAG (1990) Equilibrium critical thickness for $Si_{1-x}Ge_x$ strained layers on (100) Si. Appl Phys Lett 56:460–462

Huang L, Chu JO, Goma SA, D'Emic CP, Koester SK, Canaperi SF, Mooney PM, Cordes SA, Speidell JL, Anderson RM, Wong HSP (2002) Electron and hole mobility enhancement in strained SOI by wafer bonding. IEEE Trans Electron Devices 49

Huet K, Chassat C, Nguyen DP, Retailleau S, Bournel A, Dollfus P (2007) Full band Monte Carlo study of ballistic effects in nanometer-scaled strained p channel double gate MOSFETS. Physica Status Solidi (c) 5:43–46

Inoue K, Sakaki H, Yoshino J, Hotta T (1985) Self-consistent calculation of electronic states in AlGaAs/GaAs/AlGaAs selectively doped double-heterojunction systems under electric fields. J Appl Phys 58:4277–4281

Irisawa T, Numata T, Toyoda E, Hirashita N, Tezuka T, Sugiyama N, Takagi S (2007) Physical understanding of strain effects on gate oxide reliability of MOSFETS. In: VLSI Symp. Tech. Dig., Hawaii, USA, pp 36–37

Ito S, Namba H, Yamaguchi K, Hirata T, Ando K, Koyama S, Kuroki S, Ikezawa N, Suzuki T, Saitoh T, Horiuchi T (2000) Mechanical stress effect of etch-stop nitride and its impact on deep submicron transistor design. In: Tech. Dig. Int. Electron Device Meet., Washington, DC, pp 247–250

Jogai B (1998) Effect of in-plane biaxial strains on the band structure of wurtzite GaN. Phys Rev B 57:2382–2386

Kahng AB, Sharma P, Topaloglu R, Rasit O (2007) In: Proc. IEEE Intl. Conf. on CAD

Kanda Y (1982) A graphical representation of the piezoresistance coefficients in silicon. IEEE Trans Electron Dev 29:64–70

Kane EO (1957) Band structure of indium antimonide. J Phys Chem Solids 1:249–261

Kash JA, Zachau M, Tischler MA, Ekenberg U (1994) Optical measurements of warped valence bands in quantum wells. Surf Sci 305:251–255

Kettel C (1996) Introduction to solid state physics, 7th edn. Wiley, New York

Kikuchi A, Kishino K, Kaneko Y (1991) 600 nm-range GaInP/AlInP multi-quantum-well (MQW) lasers grown on misorientation substrates by gas source molecular beam epitaxy (gs-mbe). Jpn J Appl Phys 30:3865–3872

Kim BW (2001) Piezoelectric-field effect on electronic and optical properties of [111] $In_xGa_{1-x}As/GaAs$ superlattices. J Appl Phys 89:1197–1204

Kohn W, Luttinger JM (1954) Quantum theory of cyclotron resonance in semiconductors. Phys Rev 96:529–530

Krivanek OL, Sheng TT, Tsui DC (1978) A high-resolution electron microscopy study of the Si-SiO_2interface. Appl Phys Lett 32:437–439

Lammers D (2001) IBM banks on SOI, SiGe. EE Times: Columns

Lammers D (1998) IBM takes SOI technology to market. EE Times: Columns

Lee BH, Mocuta A, Bedell S, Chen H, Sadana D, Rim K, O'Neil P, Mo R (2002) Performance enhancement on sub-70 nm strained Si SOI MOSFETS on ultra-thin thermally mixed strained Si/SiGe on insulator (TM-SGOI)

substrate with raised S/D. In: Tech. Dig. Int. Electron Device Meet., San Francisco, CA, pp 946–948

Lee WH, Waite A, Nii H, Nayfeh HM, McGahay V, Nakayama H, Fried D, Chen H, Black L, Bolam R, Cheng J (2005) High performance 65 nm SOI technology with enhanced transistor strain and advanced-low-k BEOL. In: Tech. Dig. Int. Electron Device Meet., Washington, DC, pp 56–59

Leitz CW, Currie MT, Kim AY, Lai J, Robbins E, Fitzgerald EA (2001) J Appl Phys 90

Leu PW, Svizhenko A, Cho K (2008) *Ab initio* calculations of the mechanical and electronic properties of strained Si nanowires. Phys Rev B 77:235,305-1–235,305-14

Lim J, Thompson SE, Fossum JG (2004) Comparison of threshold-voltage shifts for uniaxial and biaxial tensile-stressed n-MOSFETS. IEEE Electron Device Lett 25:731–733

Lime F, Andrieu F, Derix J, Ghibaudo G, Boeuf F, Skotnicki T (2005) Low temperature characteriztion of effective mobility in uniaxially and biaxially strained n-MOSFETS. In: Proceedings of ESSDERC, Grenoble, France, pp 525–528

Lindgren AC, Hellberg PE, von Haartman M, Wu D, Menon C, Zhang S, Östling M (2002) Enhanced intrinsic gain (g_m/g_d) of pMOSFETS with a $Si_{0.7}Ge_{0.3}$ channel. In: Proceedings of ESSDERC, Firenze, Italy, pp 175–178

Liu YC, Pan JW, Chang TY, Liu PW, Lan BC, Tung CH, Tsai CH, Chen TF, Lee CJ, Wang WM, Chen YA, Shih HL, Tung LY, Cheng LW, Shen TM, Chiang SC, Lu MF, Chang WT, Luo YH, Nayak D, Gitlin D, Meng HL, Tsai CT (2005) Single stress liner for both NMOS and PMOS current enhancement by a novel ultimate spacer process. In: Tech. Dig. Int. Electron Device Meet., Washington, DC, pp 836–839

Lochtefeld A, Antoniadis DA (2001) On experimental determination of carrier velocity in deeply scaled NMOS: How close to the thermal limit? IEEE Electron Device Lett 22:95–97

Loo R, Collaert N, Verheyen P, Caymax M, Delhougne R, Meyer KD (2004) Fabrication of 50 nm high performance strained-SiGe pMOSFETS with selective epitaxial growth. Appl Surf Sci 224

Löwdin P (1951) A note on the quantum-mechanical perturbation theory. J Chem Phys 19:1396–1401

Luisier M, Schenk A, Fichtner W (2006) Atomistic simulation of nanowires in the $sp^3d^5s^*$ tight-binding formalism: From boundary conditions to strain calculations. Phys Rev B 74:205,323-1–205,334-12

Lundstrom MS (1997) Elementary scattering theory of the Si mosfet. IEEE Electron Device Lett 18:361–363

Lundstrom MS (2001) On the mobility versus drain current relation for a nanoscale mosfet. IEEE Electron Device Lett 22:293–295

Lundstrom MS, Ren Z (2002) Essential physics of carrier transport in nanoscale MOSFETS. IEEE Trans Electron Devices 49:133–141

Luttinger JM (1956) Quantum theory of cyclotron resonance in semiconductors: general theory. Phys Rev 102:1030–1041

Luttinger JM, Kohn W (1955) Motion of electrons and holes in perturbed periodic fields. Phys Rev 97:869–883

Manasevit HM, Gergis IS, Jones AB (1982) Electron mobility enhancement in epitaxial multilayer Si-$Si_{1-x}Ge_x$ alloy films on (100) Si. Appl Phys Lett 41:464–466

Mason WP, Thurston RN (1957) Use of piezoresistive materials in the measurement of displacement, force, and torque. J Acoust Soc Am 29:1096–1101

Matthews JW, Blakeslee AE (1974) Defects in epitaxial multilayers. I. Misfit dislocations. J Cryst Growth 27:118–125

Mheen B, Song YJ, Kang JY, Hong S (2005) Strained-SiGe complementary MOSFETS adopting different thickness of silicon cap layers for low power and high performance applications. ETRI J 27

Mimura T, Yokoyama N, Fukuta M (1979) Electrical characteristics of the plasma-grown native-oxide/GaAs interface. Appl Phys Lett 34:642–644

Mimura T, Hiyamizu S, Fujii T, Nanbu K (1980) A new field-effect transistor with selectively doped GaAs/n-$Al_xGa_{1-x}As$ heterojunctions. Jpn J Appl Phys 19:L225–L227

Mishima Y, Ochimizu H, Mimura A (2005) Strained-silicon formation on relaxed Silicon-germanium/Silicon-on-insulator substrate using laser annealing. Appl Phys Lett 86

Mistry K, Allen C, Auth C, Beattie B, Bergstrom D, Bost M, Brazier M, Buehler M, Cappellani A, Chau R, Choi CH, Ding G, Fischer K, Ghani T, Grover R, Han W, Hanken D, Hattendorf M, He J, Hicks J, Huessner R, Ingerly D, Jain P, James R, Jong L, Joshi S, Kenyon C, Kuhn K, Williams S, Zawadzki K (2007) A 45nm logic technology with high-k+metal gate transistors, strained silicon, 9 cu interconnect layers, 193nm dry patterning, and 100 percent pb-free packaging. In: Tech. Dig. Int. Electron Device Meet., Washington, DC, pp 247–250

Mizuno T, Sugiyama N, Tezuka T, Takagi S (2003) [110] strained-SOI n-MOSFETS with higher electron mobility. IEEE Electron Dev Lett 24

Moss TS, Hawkins TDF (1961) Infrared absorption in gallium arsenide. Infrared Phys 1:111–115

Murthy A, Chau R, Ghani T, Mistry K (2003) Semiconductor transistor having a stressed channel. Intel Corporation, USA

Nayak DK, Woo JCS, Park JS, Wang KL, MacWilliams KP (1993) High-mobility *p*-channel metal-oxide-semiconductor field-effect transistor on strained Si. Appl Phys Lett 62:2853–2855

Nicholas G, Grasby TJ, Parker EHC, Whall TE, Skotnicki T (2005) IEEE Electron Dev Lett 26: 684–686

Nishizawa J, Shiota I (1980) Inst Phys Conf Ser Chapt 4:289

Nye JF (1984) Physical properties of crystals: their representation by tensors and matrices. Oxford University Press, Oxford

Oberhuber R, Zandler G, Vogl P (1998) Subband structure and mobility of two-dimensional holes in strained Si/SiGe mosfets. Phys Rev B 58:9941–9948

Olsen SH, Escobedo-Cousin E, Varzgar JB, Agaiby R, Seger J, Dobrosz P, Chattopadhyay S, Bull SJ, O'Neill AG, Hellström PE, Edholm J, Östling M, Lyutovich KL, Oehme M, Kasper E (2006) Control of self-heating in thin virtual substrate strained Si MOSFETS. IEEE Trans Electron Devices 53:2296–2305

Omegacom OEI (2003–2009) Omega strain gauges. http://www.omega.com/tocasp/sectionsc.asp?book=pressure&section=e

Onsongo D, Kelly DQ, Dey S, Wise RL, Cleavelin CR, Banerjee SK (2004) Improved hot-electron reliability in strained-Si NMOS. IEEE Trans Electron Devices 51:2193–2199

Packan P, Cea S, Deshpande H, Ghani T, Giles M, Golonzka O, Hattendorf M, Kotlyar R, Kuhn K, Murthy A, Ranade P, Shifren L, Weber C, Zawadzki K (2008) High performance hi-k + metal gate strain enhanced transistors on (110) silicon. In: Tech. Dig. Int. Electron Device Meet., San Francisco, CA, pp 1–4

Passlack M, Hong M, Mannaerts JP, Chu SNG, Opila RL, Moriya N (1995) In-situ Ga_2O_3 process for GaAs inversion/accumulation device and surface passivation applications. In: Tech. Dig. Int. Electron Device Meet., Washington, DC, p 383

Passlack M, Hong M, Mannaerts JP, Opila RL, Chu SNG, Moriya N, Ren F, Kwo JR (1997) Low d_{it}, thermodynamically stable Ga_2O_3–GaAs interfaces: Fabrication, characterization, and modeling. IEEE Trans Electron Devices 44:214–225

Patel N, Ripper J, Brosson P (1973) Behavior of threshold current and polarization of stimulated emission of gaas injection lasers under uniaxial stress. IEEE J Quantum Electron 9:338–341

Persson C, Lindefelt U (1997) Relativistic band structure calculation of cubic and hexagonal SiC polytypes. J Appl Phys 82:5496–5508

Peterson KE (1982) Silicon as a mechanical material. Proc IEEE 70:420–457

Pfann WG, Thurston RN (1961) Semiconducting stress transducers utilizing transverse and shear piezoresistance effects. J Appl Phys 32:2008–2019

Phillips JC, Kleinman C (1959) New method for calculating wave functions in crystals and molecules. Phys Rev 116:287–294

Pidin S, Mori T, Inoue K, Fukuta S, Itoh N, Mutoh E, Ohkoshi K, Nakamura R, Kobayashi K, Kawamura K, Saiki T, Fukuyama S, Satoh S, Kase M, Hashimoto AK (2004) A novel strain enhanced CMOS architecture using selectively deposited high tensile and high compressive silicon nitride films. In: Tech. Dig. Int. Electron Device Meet., San Francisco, CA, pp 213–216

Price J (1981) Two-dimensional electron transport in semiconductor layers. I. phonon scattering. Ann Phys 133:217–239

Qiqing O, Min Y, Holt J, Panda S, Huajie C, Utomo H, Fischetti M, Rovedo N, Jinghong L, Klymko N, Wildman H, Kanarsky T, Costrini G, Fried DM, Bryant A, Ott JA, Meikei I, Chun-Yung S (2005) Investigation of CMOS devices with embedded SiGe source/drain on hybrid orientation substrates. Honolulu, HI, pp 28–29

Rajagopalan K, Drooopad R, Abrokwah J, Passlack M (2006) Compound semiconductor mosfet structure with high-κ dielectric. In: CS MANTECH Conference, Vancouver, BC, Canada, p 119

Rajagopalan K, Droopad R, Abrokwah J, Zurcher P, Fejes P, Passlack M (2007) 1-μm enhancement mode GaAs n-channel MOSFETS with transconductance exceeding 250 mS/mm. IEEE Electron Dev Lett 28:100–102

Reitz JR, Milford FJ, Christy RW (1979) Foundations of electromagnetic theory. Addison-Wesley, Reading, MA

Ren Z, Lundstrom MS (2000) Simulation of nanoscale MOSFETS: a scattering theory interpretation. Supperlattices Microstruct 27:177–189

Rim K, Gusev EP, D'Emic C, Kanarsky T, Chen H, Chu J, Ott J, Chan K, Boyd D, Mazzeo V, Lee BH, Mocuta A, Welser J, Cohen SL, Leong M, Wong HS (2002) Mobility enhancement in strained Si NMOSFETS with HfO_2 gate dielectrics. Honolulu, HI, pp 12–13

Rim K, Chan K, Shi L, Boyd D, Ott J, Klymko N, Cardone F, Tai L, Koester S, Cobb M (2003) Fabrication and mobility characteristics of ultrathin strained Si directly on insulator (SSDOI) MOSFETS. In: Tech. Dig. Int. Electron Device Meet., Washington, DC, pp 49–52

People R, Bean JC, Lang DV, Sergent AM, Stormer HL, Wecht KW, Lynch RT, Baldwin K (1984) Appl Phys Lett 45:1231

Sacconi F, Carlo AD, Lugli P, Morkoç H (2001) Spontaneous and piezoelectric polarization effects on the output characteristics of AlGaN/GaN heterojunction modulation doped FETs. IEEE Trans Electron Dev 48:450–457

Sah CT (1991) Fundamentals of Solid-State Electronics. World Scientific, Singapore

Samavedam SB, Taylor WJ, Grant JM, Smith JA, Tobin PJ, Dip A, Phillips AM (1999) Relaxation of strained Si layers grown on SiGe buffers. J Vac Sci Technol B 17:1424–1429

Sanders GD, Chang YC (1985) Optical properties in modulation-doped GaAs-$Ga_{1-x}Al_xAs$ quantum wells. Phys Rev B 31:6892–6895

Schulz M, Klansmann E (1979) Transient capacitance measurements of interface states on the intentionally contaminated Si-SiO_2 interface. J Appl Phys 18:169–175

Seitz F (1940) The modern theory of solids. McGraw Hill, New York

Semikolenova NA, Nesmelowa IM, Khabarov EN (1978) Investigation of the impurity interaction mechanism in indium arsenide. Sov Phys Semicond 12:1139–1142

Senturia SD (2001) Microsystem design. Kluwer Academic, Boston

Sheplak M, Breuer KS, Schmidt MA (1998) A wafer-bonded, silicon-nitride membrane microphone with dielectrically-isolated, single-crystal silicon piezoresistors. In: Technical Digest, Solid-State Sensor and Actuator Workshop, Hilton Head, SC, pp 23–26

Sheplak M, Dugundji J (1998) Large deflections of clamped circular plates under initial tension and transitions to membrane behavior. J Appl Mech-Trans Asme 65:107–115

Shima M (2002) <100> strained-SiGe-channel p-mosfet with enhanced hole mobility and lower parasitic resistance. FUJITSU Sci Tech J 39

Shimizu A, Hachimine K, Ohki N, Ohta H, Koguchi M, Nonaka Y, Sato H, Ootsuka F (2001) Local mechanical-stress control (LMC): a new technique for CMOS-performance enhancement. In: Tech. Dig. Int. Electron Device Meet., San Francisco, CA, pp 433–436

Shiri D, Kong Y, Buin A, Anantram MP (2008) Strain induced change of bandgap and effective mass in silicon nanowires. Appl Phys Lett 93:073,114-1–073,114-3

Shiue CC, Sah CT (1979) New mobility-measurement technique on inverted semiconductor surfaces near the conduction threshold. Phys Rev 9:2149–2162

Shockley W, Bardeen J (1950) Energy bands and mobilities in monatomic semiconductors. Phys Rev 77:407–408

Silver M, O'Reilly EP (1994) Gain and radiative current density in InGaAs/lnGaAsP lasers with electrostatically confined electron states. IEEE J Quantum Electron 30:547–553

Slater JC, Koster GF (1954) Simplified LCAO method for the periodic potential problem. Phys Rev 94:1498–1524

Smith CS (1954) Piezoresistance effect in germanium and silicon. Phys Rev 94:42–49

Smith DL, Mailhiot C (1988) Piezoelectric effects in strained-layer superlattices. J Appl Phys 63:2717–2719

Stern F (1972) Self-consistent results for n-type Si inversion layers. Phys Rev B 5:4891–4899

Sugano T, Chen JT, Hamana T (1980) Morphology of Si-SiO_2 interface. Surf Sci 98:154–166

Sugii N, Washio K (2003) Low-temperature electrical characterization of strained-Si MOSFETS. Jpn J Appl Phys 42

Sun G, Sun Y, Nishida T, Thompson SE (2007) Hole mobility in silicon inversion layers: stress and surface orientation. J Appl Phys 102:084,501-1–084,501-7

Suzuki N, Hariu T, Shibata Y (1978) Effect of native oxide on the interface property of GaAs MIS structures. Appl Phys Lett 33:761–762

Takagi S (2003) Re-examination of subband structure engineering in ultrashort channel MOSFETS under ballistic carrier transport. Honolulu, HI, pp 115–116

Takagi S, Mizuno T, Tezuka T, Sugiyama N, Numata T, Usuda K, Moriyama Y, Nakaharai S, Koga J, Tanabe A, Hirashita N, Maeda T (2004) Channel structure design, fabrication and carrier transport properties of strained-Si/SiGe-on-insulator (strained-SOI) MOSFETS. In: Tech. Dig. Int. Electron Device Meet

Takagi S, Hoyt JL, Welser JJ, Gibbons JF (1996) Comparative study of phonon-limited mobility of two-dimensional electrons in strained and unstrained Si metal-oxide-semiconductor field-effect transistors. J Appl Phys 80:1567–1577

Takagi S, Mizuno T, Sugiyama N, Tezuka T, Kurobe A (2001) Strained -Si-on-insulator (strained-SOI) MOSFETS – concept, structures and device characteristics. IEICE Trans Electron E84-C

Takagi S, Mizuno T, Tezuka T, Sugiyama N, Numata T, Usuda K, Moriyama Y, Nakaharai S, Koga J, Tanabe A, Maeda T (2004) Fabrication and device characteristics of strained-Si-on-insulator (strained-SOI) CMOS. Appl Surf Sci 224

Tanaka SI, Lundstrom MS (1994) A compact model HBT device model based on a one-flux treatment of carrier transport. Solid State Electron 37:401–410

Tanaka T, Yanagisawa H, Minagawa S (1994) Comparison between tensile-strained AlGaInp SQW and MQW LDS emitting at 615 nm. Electron Lett 30:566–568

Taraschi G, Pitera AJ, Fitzgerald EA (2004) Strained Si, SiGe, and Ge on-insulator: review of wafer bonding fabrication techniques. Solid State Electron 48:1297–1305

Taur Y, Ning TH (1998) Fundamentals of modern VLSI devices. Cambridge University Press, New York

Taur Y, Buchanan DA, Chen W, Ismail DJF, Lo SH, SaiHalasz GA, Viswanathan RG, Wann HJC, Wind SJ, Wong HS (1997) CMOS scaling into the nanometer regime. Proc IEEE 85:486–504

Thompson SE, Anand N, Armstrong M, Auth C, Arcot B, Alavi M, Bai P, Bielefeld J, Bigwood R, Brandenburg J (2002) A 90 nm logic technology featuring 50 nm strained silicon channel transistors, 7 layers of cu interconnects, low κ ild, and 1 μm^2 SRAM cell. In: Tech. Dig. Int. Electron Device Meet., San Francisco, CA, pp 61–64

Thompson SE, Amstrong M, Auth C, Cea S, Chau R, Glass G, Hoffman T, Klaus J, Ma Z (2004a) A logic nanotechnology featuring strained-silicon. IEEE Electroc Dev Lett 25:191–193

Thompson SE, Sun G, Wu K, Lim J, Nishida T (2004b) Key differences for process-induced uniaxial vs. substrate-induced biaxial stressed Si and Ge channel MOSFETS. In: Tech. Dig. Int. Electron Device Meet., San Francisco, CA, pp 221–224

Thompson SE, Sun GY, Choi YS, Nishida T (2006a) Uniaxial-process-induced strained-Si: extending the CMOS roadmap. IEEE Trans Electron Devices 53:1010–1020

Thompson SE, Suthram S, Sun Y, Sun G, Parthasarathy S, Chu M, Nishida T (2006b) Future of strained Si/Semiconductors in nanoscale MOSFETS. In: Tech. Dig. Int. Electron Device Meet., San Francisco, CA, pp 11–13

Timbrell PY, Baribeau JM, Lockwood DJ, McCaffrey JP (1990) An annealing study of strain relaxation and dislocation generation in $Si_{1-x}Ge_x$/Si heteroepitaxy. J Appl Phys 67:6292–6300

Uchida K, Krishnamohan T, Saraswat KC, Nishi Y (2005) Physical mechanisms of electron mobility enhancement in uniaxial stressed MOSFETS and impact of uniaxial stress engineering in ballistic regime. In: Tech. Dig. Int. Electron Device Meet., San Francisco, CA, pp 129–132

Ueno Y, Fujii H, Sawano H, Kobayashi K, Hara K, Gomyo A, Endo K (1993) 30-mw 690-nm high-power strained-quantum-well AlGaInp laser. IEEE J Quantum Electron 29:1851–1856

Valster A, van der Poel CJ, Finke MN, Boermans MJB (1992) Effect of strain on the threshold current of GaInP/AlGaInP quantum well lasers emitting at 633 nm. In: Conference Digest 13th IEEE Inter. Semicond. Laser Conf., Takamatsu, Japan, pp 152–153

Vogl P, Hjalmarson HP, Dow J (1983) A semi-empirical tight-binding theory of the electronic structure of semiconductors. J Phys Chem Solids 44:365–378

de Walle CGV (1989) Band lineups and deformation potentials in the model-solid theory. Phys Rev B 39:1871–1883

Wand YP, Wu SL, chang SJ (2005) Optimized Si-cap layer thickness for tensile-strained-Si/compressively strained SiGe dual-channel transistors in 0.13 μm complementary metal-oxide-semiconductor technology. Jpn J Appl Phys 44

Wang YC, Hong M, Kuo JM, Mannaerts JP, Kwo J, Tsai HS, Krajewski JJ, Chen YK, Cho AY (1999) Demonstration of submicron depletion-mode GaAs MOSFETS with negligible drain current drift and hysteresis. IEEE Eletron Dev Lett 20:457–459

Washington L, Nouri F, Thirupapuliyur S, Eneman G, Verheyen P, Moroz V, Smith L, Xu X, Kawaguchi M, Huang T, Ahmed K, Balseanu M, Xia LQ, Shen M, Kim Y, Rooyachers R, Meyer KD, Schreutelkamp R (2006) PMOSFET with 200% mobility enhancement induced by multiple stressors. IEEE Electron Dev Lett 27

Weisstein E (1999–2009) Euler angles. In MathWorld-a Wolfram web resource. http://mathworld.wolfram.com/EulerAngles.html

Welser J, Hoyt JL, Gibbons JF (1992) NMOS and PMOS transistors fabricated in strained silicon/relaxed silicon-germanium structures. In: Tech. Dig. Int. Electron Device Meet., San Francisco, CA, pp 1000–1002

Wiley JD (1971) Polar mobility of holes in iii–v compounds. Phys Rev B 4:2485–2493

Xiang J, Lu W, Hu Y, Wu Y, Yan H, Lieber CM (2006) Ge/Si nanowire heterostructures as highperformance field-effect transistors. Nature 441: 489–493

Xiang Q, Goo JS, Pan J, Yu B, Ahmed S, Zhang J, Lin MR (2003) Strained silicon NMOS with nickel-silicide metal gate. In: Symposium on VLSI Technology Digest of Technical Papers, Kyoto, Japan, pp 101–102

Xie YH, Gilmer GH, Roland C, Silverman PJ, Buratto SK, Cheng JY, Fitzgerald EA, Kortan AR, Schuppler S, Marcus MA, Citrin PH (1994) Semiconductor surface roughness: dependence on sign and magnitude of bulk strain. Phys Rev Lett 73:3006–3009

Yamakawa S, Ueno H, Taniguchi K, Miyatsuji K, Masaki K, Ravaioli U (1998) Electron mobility and Monte Carlo device simulation of MOSFETS. VLSI Design 6:27–30

Yan L, Olsen SH, Escobedo-Cousin E, O'Neill AG (2008) Improved gate oxide integrity of strained Si n-channel metal-oxide-silicon field effect transistors using thin virtual substrates. J Appl Phys 103:094,508-1–094,508-10

Yang HS, Malik R, Narasimha S, Li Y, Divakaruni R, Agnello P, Allen S, Antreasyan A, Arnold JC, Bandy K, Belyansky M, Bonnoit A, Bronner G, Chan V, Chen X, Chen Z, Chidambarrao D, Chou A, Clark W, Crowder SW, Engel B, Harifuchi H, Huang SF, Jagannathan R, Jamin FF, Kohyama Y, Kuroda H, Lai CW, Lee HK, Lee WH, Lim EH, Lai W, Mallikarjunan A, Matsumoto K, McKnight A, Nayak J, Ng HY, Panda S, Rengarajan R, Steigerwalt M, Subbanna S, Subramanian K, Sudijono J, Sudo G, Sun SP, Tessier B, Toyoshima Y, Tran P, Wise R, Wong R, Yang IY, Wann CH, Su LT, Horstmann M, Feudel T, Wei A, Frohberg K, Burbach G, Gerhardt M, Lenski M, Stephan R, Wieczorek K, Schaller M, Salz H, Hohage J, Ruelke H, Klais J, Huebler P, Luning S, van Bentum R, Grasshoff G, Schwan C, Ehrichs E, Goad S, Buller J, Krishnan S, Greenlaw D, Raab M, Kepler N (2004) Dual stress liner for high performance sub-45nm gate length SOI CMOS manufacturing. In: Tech. Dig. Int. Electron Device Meet., San Francisco, CA, pp 1075–1077

Yang X, Lim J, Sun G, Wu K, Thompson SE (2006) Strain-induced changes in the gate tunneling currents in *p*-channel metal-oxide-semiconductor field-effect transistors. Appl Phys Lett 88:052,108-1–052,108-3

Yoshinobu T, Iwamoto A, Iwasaki H (1994) A self-consistent Monte Carlo simulation for two-dimensional electron transport in MOS inversion layer. Jpn J Appl Phys I 26:1447–1452

Yu PY, Cardona M (1996) Fundamentals of semiconductors. Spinger, Berlin

Zawadski W (1974) Electron transport phenomena in small-gap semiconductors. Adv Phys 23:435–522

Zhang D, Nguyen BY, White T, Goolsby B, Nguyen T, Dhandapani V, Hildreth J, Foisy M, Adams V, Shiho Y, Thean A, Theodore D, Canonico M, Zollner S, Bagchi S, Murphy S, Rai R, Jiang J, Jahanbani M, Noble R, Zavala M, Cotton R, Eades D, Parsons S, Montgomery P, Martinez A, Winstead B, Mendicino M, Cheek J, Liu J, Grudowski P, Ranami N, Tomasini P, Arena C, Werkhoven C, Kirby H, Chang CH, Lin CT, Tuan HC, See YC, Venkatesan S, Kolagunta V, Cave N, Mogab J (2005) Embedded SiGe S/D PMOS on thin body SOI substrate with drive current enhancement. Honolulu, HI, pp 26–27

Index