

Semiconductor Manufacturing Technology

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Technical Errata List First Edition

Note from the authors: The errata list covers errors found from the first printing. Some of these errors will have been corrected in textbooks from the second printing (sometime around third quarter, 2001).

The authors would like to thank the many contributors who have provided feedback about errors, including Professor Zhijian Pei, Kansas State University, and John Zvonar, AMD.

Chapter/Page	Error Location	Error and Correction
Ch. 1, p. 11	Figure 1.10	Last two dates are reversed. They should be 2009 and 2012.
Ch. 2, p. 22	Figure 2.1	No "+" sign for atomic number of carbon. It should be C 6.
Ch. 2, p. 24	Figure 2.5	Add a negative sign, "-", to the dotted circle in the valence shell of the chlorine ion.
Ch. 2, p. 25	Figure 2.6	1) The dotted lines for Lanthanides and Actinides are not aligned properly and should be removed, 2) the correct spelling for element 43 is Technetium, and 3) the correct spelling for element 91 is Protactinium.
Ch. 2, p. 26	Definition of atomic mass number.	Atomic mass number: The sum of the protons and neutrons in an atom. Isotopes of the same element have the same number of protons but a different number of neutrons; therefore, isotopes have a different mass number.
Ch. 2, p. 28	Figure 2.10	The electron symbols (3x) should be changed to e^- with a superscripted "-".
Ch. 2, p. 30	Formula for resistance, definition of area	For the definition of area, replace "= width x thickness" with "in cm^2 ."
Ch. 2, p. 31	Figure 2.13	The electron notation requires a superscript negative sign: " e^- ".
Ch. 2, p. 33	Second-to-last sentence in "Pure Silicon" section	Replace "window glass" with "a diamond." The sentence should read: "An example of a crystal material is a diamond." Note that glass is an amorphous solid and not a crystal.
Ch. 2, p. 39	Second-to-last paragraph, last sentence	Replace "Groups IIA and VIA" with "Groups IIB and VIA."

Ch. 3, p. 48	Figure 3.6	Label vertical axis of plot as “Charge distribution.”
Ch. 3, p. 48	Third sentence of last paragraph	Replace “Note the breakdown voltage...” with “Note the forward conduction voltage...”
Ch. 4, p. 75	Table 4.2	Change the superscript for very lightly doped material to n^{--} or p^{--} (it requires 2 raised negative signs to signify “very lightly doped”).
Ch. 4, p. 82	Midway through second paragraph, “wafer sawing.”	Replace “Wafer sawing reduces” with “Wire saws reduce.”
Ch. 4, p. 82	Second sentence of second-to-last paragraph on page	This sentence should read: “The final wafer thickness of a 300-mm wafer is currently specified at a thickness of 775 ± 25 microns.”
Ch. 4, p. 83	Second paragraph (line 3 of page)	This is to clarify terminology of edge polish, edge grind and edge profile. The polished wafer edge (or edge polish) actually occurs after the etch process. An edge grind, also referred to as an edge profile, is done before etching.
Ch. 4, pages 85-86	Figures 4.27 and 4.28	The artwork in Figure 4.27 belongs with Figure 4.28. The artwork in Figure 4.28 does not apply to this topic and should not be used.
Ch. 4, p. 86	Sixth line from bottom of the page	Replace “grain structure” with “crystal structure.”
Ch. 5, p. 97	First sentence at top of the page	Note that the more correct term for changing a vapor into a liquid is condensation.
Ch. 5, p. 99	Figure 5.12	Stress arrows should be redrawn to show tensile and compressive loads applied to a wafer under a bending load (compressive at the small wafer radius and tensile at the large wafer radius).
Ch. 5, p. 102	Figure 5.14	Indicator lines are not correctly drawn for labels “Chemical control and leak detection” and “Filter.” The chemical control line drops down to point at the control box, and the filter line moves to left slightly to point at the filter.
Ch. 5, p. 108	Table 5.7	This table lists TEOS as a gas, but it is actually a liquid. (See page 271 for a description of TEOS.)
Ch. 6, p. 116	Figure 6.4	Below wafer on right side of Figure, delete the word “initial” at the beginning of the sentence.

Ch. 6, p. 136	Figure 6.27, (2) and (3)	Replace HO ⁻ with OH ⁻ .
Ch. 6, p. 137	Section on Modifications to RCA Clean	Note that lower temperatures for RCA clean are now common, even as low as 45°C.
Ch. 6, p. 137	Section on Piranha Mixture	Another common name for Piranha Clean is Caros Clean.
Ch. 7, p. 153	Denominator in second line of sheet resistance equation.	There should be an “l” instead of “w”: $R_s = \rho(l) / l \times t$
Ch. 7, p. 170	Figure 7.28	Replace the bottom “C _{max} ” on the vertical axis with “C _{min} .”
Ch. 9, p. 203	Figure 9.5	Electron notation requires a superscript for the negative sign: “e ⁻ ”.
Ch. 9, p. 205	List for CMOS manufacturing steps, #3 and #11.	Make the following changes: Step #3: Poly Gate Structure Process Step #11: Via-2 and Plug-2 Formation
Ch. 9, p. 210	Heading for Section 3	Replace “Poly Gate Structural Process” with “Poly Gate Structure Process.”
Ch. 9, p. 211	Heading for Section 4	Delete “s” from Implants, making the title: “Lightly Doped Drain (LDD) Implant Process.”
Ch. 9, p. 215	Process step 1 and Figure 9.21	Replace SiN ₃ chemical symbol for nitride with Si ₃ N ₄ .
Ch. 9, p. 218	Heading for Step 11	Replace heading with “Via-2 and Plug-2 Formation.”
Ch. 10, p. 235	Formula for rate of linear oxide growth	Replace the linear rate constant “(B/A hr)” with “(B/A).”
Ch. 10, p. 235	Diagram in Figure 10.11	This drawing should show in the interface region that oxygen and silicon atoms are bonded with two oxygen atoms attached to one silicon atom.
Ch. 11, p. 276	Chemical reaction equation for polysilicon deposition	Delete helium gas. The chemical reaction should read: SiH ₄ (g) → Si(s) + 2H ₂ (g)
Ch. 11, p. 279	Two chemical reaction equations for PECVD nitride film	Remove all coefficients from these two chemical reactions, since the silicon nitride is non-stoichiometric. The reactions are: SiH ₄ (g) + NH ₃ (g) → Si _x N _y H _z (s) + H ₂ (g) SiH ₄ (g) + N ₂ (g) → Si _x N _y H _z (s) + H ₂ (g)
Ch. 12, p. 305	List of needs for copper	Correct the numbering scheme of the list to read from 1 through 5.
Ch. 12, p. 315	Figure 12.16	Electron notation requires superscript “-” sign: e ⁻ .
Ch. 12, p. 316	Figure 12.17	The symbol for positive argon ion should read: Ar ⁺ .
Ch. 12, p. 317	Figure 12.18	There are two changes. Change 1) “+ ions” to “- ions”, and 2) the electron symbol

		should have a superscript “ ⁻ ”.
Ch. 12, p. 321	Figure 12.22	There are three changes. Change 1) “+ Ar” to “Ar ⁺ ”, 2) “+ Ti” to “Ti ⁺ ”, and 3) the electron symbol should have a superscript “ ⁻ ”.
Ch. 12, p. 324	Reduction reaction equation for electroplating	The electron symbol is wrong (the “e” should not be superscripted). The reaction should read: $\text{Cu}^{2+} + 2\text{e}^{-} \rightarrow \text{Cu}^0$
Ch. 13, p. 337	Heading for photo	Change the heading to read: “Photomask and Reticle for Microlithography.”
Ch. 13, p. 342	First paragraph, second-to-last sentence	The end of the sentence should refer to the “following two chapters”, not three chapters.
Ch. 13, p. 359	Figure 13.27	Replace “cP” units with “cps.”
Ch. 14, p. 369	Figure 14.2	Mask #3 needs reticle alignment marks.
Ch. 14, p. 372	Figure 14.6	Above the excimer laser heading, replace the 197 nm wavelength with 193 nm.
Ch. 14, p. 375	Table 14.3	Pulse Length should be changed to "Pulse Duration" or "Pulse Width."
Ch. 14, p. 375	Paragraph 2, sentence 3	Pulse length should be changed to "pulse duration" or "pulse width."
Ch. 14, p. 381	Figure 14.21	The image results should show a severely fuzzy circle image for “Bad” and a moderately fuzzy circle image for “Poor.”
Ch. 14, p. 393	First paragraph, second-to-last sentence	Replace “25 x 33” with “26 x 33.”
Ch. 16, p. 440	Figure 16.6	Remove “Bias” and the width of the resist box should continue to W_b .
Ch. 16, p. 443	Figure 16.11	The 2 curved arrows from molecules in the center of the diagram should point to a “ λ .”
Ch. 16, p. 446	Table 16.4	The bottom right arrow (for Physical Etch and Electrode Size) should point upwards.
Ch. 16, p. 448	Figure 16.16	Replace the frequency of the microwave source as 2.45 GHz.
Ch. 16, p. 449	Figure 16.17	Replace the frequency of the RF generator with 13.56 MHz.
Ch. 16, p. 452	Figure 16.20	Replace the frequency of the microwave source as 2.45 GHz.
Ch. 16, p. 458	Figure 16.27	Replace “SiN ₃ ” for nitride with “Nitride.”
Ch. 16, p. 468	Figure 16.34	There are 3 changes: 1) the two curved lines in the center of the drawing should point toward the symbol “ λ ”, 2) in step 4, the “Os” should read “O”, and 3) in step 4, the symbol “+O” should read “O ⁺ .”
Ch. 17, p. 476	Figure 17.1	Some of the circled letters in the drawing are wrong. Replace the following circled letters in the drawing: 1) G with E, 2) H with F, 3)

		E with G and 4) F with H. Note that with these corrections, the letters correspond directly to the descriptions in Table 17.2.
Ch. 17, p. 483	Fourth sentence, first paragraph	Replace with: “The number of ions in the beam is related to the desired concentration of dopants to be introduced into the wafer.”
Ch. 17, p. 486	Table 17.6	Under Description and Applications, for Low/Medium current, the 3 rd bullet should read: “Most often the wafer is stationary and the ion beam is scanned.” For High Current, the 3 rd bullet should read: “Most often the ion beam is stationary and the wafer does the scanning.”
Ch. 17, p. 489	Second-to-last paragraph, fourth sentence	Replace with these two sentences: “When BF ₃ is used as the source of boron, many different ion species are generated in the ion source. These include B ⁺ , B ₁₀ ⁺ , B ₁₁ ⁺ , BF ⁺ , BF ₂ ⁺ , F ⁺ and F ₂ ⁺ .”
Ch. 17, p. 489	Last paragraph, first sentence	Replace with: “There are other designs for ion sources, such as RF (radio frequency) ion source, cold cathode source and microwave ion source.”
Ch. 17, p. 492	Figure 17.16	The vertical axis needs to have 10 ¹⁶ and 10 ¹⁷ swapped (to make ascending order).
Ch. 17, p. 493	Second paragraph, titled “High-Current and High-Energy Beam”	Delete the second-to-the-last sentence (“The linear accelerator...”). Add a new sentence at the end of the paragraph: “This added analysis magnet also aids in the removal of beam contaminants by removing masses other than the desired species.”
Ch. 17, p. 495	First paragraph, titled “Electrostatic Scanning”	Add the following to the last sentence of this paragraph: “..., and to reduce channeling effects.”
Ch. 17, p. 496	First paragraph, titled “Mechanical Scanning”	Delete fifth-to-the-last sentence (“Moving the wafers ...”). Delete second-to-the-last sentence (“Throughput is better ...”).
Ch. 17, p. 499	Third paragraph, titled “Dose Control”	Delete “modern” in the first sentence. It should read: “In ion implanters, real-time dose ...”
Ch. 17, p. 501	Fifth paragraph, titled “Channeling”	In the last sentence, delete the last 3 words “and lower diffusivity.”
Ch. 17, p. 502	Third paragraph, titled “Preamorphization”	Change this sentence to read: “A technique for reducing channeling is preamorphization of the single-crystal silicon lattice with an electrically inactive species, usually Si ⁺ .”
Ch. 18, p. 524	Figure 18.10	There are 3 changes: 1) represent the H ₂ O in

		the slurry with 1 oxygen and 2 hydrogen, 2) in step 2, change the HO to OH ⁻ , and 3) the diagram for Si(OH) ₄ should show the small hydrogen on the outside.
App. C, p. 615	Unit Conversions	For description of an angstrom, it should read : “An angstrom is a common unit of measure for film thickness in wafer fabrication.”
App. C, p. 615	Table C.3	The SI Unit for 1 kWh of energy has an error (bottom right of the table). It should read 3.600 x 10 ³ kJ.
App. E, p. 621	Figure E.7	There are 2 major changes required: 1) The final chemical reaction arrow at the bottom-right of the drawing is wrong and should be replaced with a “+” (this is between PHS and H ⁺). 2) Inside the protecting group at the bottom-left of the drawing, a third CH ₃ should be added to the carbon.

Miscellaneous Errata List

First Edition

This list includes miscellaneous errors that have little or no technical impact on the book’s content.

Chapter/Page	Error Location	Correction
Ch. 1, p. 20	Website list	The correct acronym for Maricopa Advanced Technology Education Center is MATEC.
Ch. 2, p. 36	First sentence of page	The spelling for the noun “phosphorus” used in the first sentence should not have an “ous.” FYI, note that when used as an adjective, such as “the phosphorous atom,” there is an “ous.”
Ch. 3, p. 44	Heading for photo	This photo heading should read: “Components on a Printed Circuit Board.”
Ch. 3, p. 44	Last sentence of first paragraph	Replace “...as illustrated on page 30” with “as described on Pages 60-62.”
Ch. 4, p. 74	First sentence of second paragraph	The word “objective” is misspelled and needs an “i.”
Ch. 5, p. 108	Table 5.7	Under “Example of Use” for nitrogen trifluoride, replace “icons” with “ions.”
Ch. 6, p. 118	Figure 6.5	The word “transistor” is misspelled – it

		requires an “s.”
Ch. 6, p. 121	Photo	There should be an additional credit line that reads “James Minor, photographer, © 1990.”
Ch. 7, p. 152	Table 7.2	There should be an “*” next to Diffusion (signifying that the note at the bottom of the table applies only to the diffusion column).
Ch. 8, p. 192	First sentence, second paragraph	Add closing parenthesis to “(PECVD)”
Ch. 9, p. 207	First sentence, first paragraph of Section 2	Delete the word “is” after “alternative method”
Ch. 10, p. 231	First sentence following Wet Oxidation heading	Add a space between "the" and "oxidation."
Ch. 10, p. 231	Second sentence, last paragraph	Add a space between “as” and “pyrogenic steam.”
Ch. 11, p. 258	Heading for Figure 11.1	Replace NMOS with nMOS.
Ch. 11, p. 283	Table 11.4, remarks for HSQ	Replace FOX with FOx.
Ch. 12, p. 308	Last sentence of last paragraph on the page	Delete hyphen in “high-aspect.” This should read “high aspect ratio gaps”
Ch. 15, p. 419	Second sentence, second paragraph of section “Chemically Amplified DUV Resists”	Add space between “is” and “because.”
Ch. 16, p. 453	Figure 16.22	The source should read (Pennington, NJ: The Electrochemical Society, 1996).
Ch. 17, p. 476	Table 17.2	Under the remarks column for section E and F, the spelling of the noun phosphorus is incorrect. It should be “phosphorus.”
Ch. 17, p. 502	First paragraph, first sentence	Add “to” after photoresist mask.
Ch. 18, p. 530	Last line on this page	Add space between “or optical.”
Ch. 18, p. 532	Second sentence of first paragraph	Replace this sentence with: “The conventional head on older tools was not able to apply....”
App. A, p. 601	Hazard list	The spelling of pyrophoric gas is incorrect.
App. E, p. 618	Third sentence, second paragraph	Add “s” to the word consist.

October 30, 2001