

Contents

Foreword **vii**

Preface **ix**

1. Getting History Right	x
2. Importance of the IC Invention	x
3. What is an IC?	xi
4. Sole Credit to Kilby and Noyce	xii
5. Key Points to Get History Right	xiii
6. Key Points of Jack S. Kilby's Invention	xiv
7. Key Points of Robert (Bob) N. Noyce's Invention	xix
8. Other Contributors	xx
9. Lack of contributions of Kilby and the others to pursue monolithic-ICs	xxii
10. Historical Perspective and Accuracy	xxiii
11. My Experience	xxv
12. Useful Product	xxvi
13. Funding for putting all the facts of the invention of ICs on historical record	xxvii
14. Acknowledgments	xxvii

Chapter 1: Introduction **1**

1. What is an IC?	3
2. Key Requirements for making the IC and did Kilby and Noyce meet them?	4

3. Sole credit to Kilby and Noyce	6
4. A few facts in the mystery of the invention of ICs	8
5. My qualifications	13
6. Getting history right	13
7. The case of Einstein	14
8. Why getting history right is important?	15
9. Documented facts	16
10. What are documented facts?	17
11. All ICs sold from day one have been Si monolithic ICs	18
12. Three questions need to be answered up front	19
13. Victory/success and defeat/failure	19
14. Disclosure of the basic concept for ICs by others earlier than Kilby	23
15. Brief comments on the basic concepts of IC invention documented by Kilby, Dummer, Johnson and Stewart given above	25
16. Concepts given by Saxena in 1954	27
17. Inputs for Noyce's patent and investigation of Kilby's patents	27
18. Other aspects which contributed to the invention and fantastic success of ICs	28
19. Answers to three questions raised in Section 11	28
20. For whom is the book intended and at what level?	29

Chapter 2: Discovery, Invention, Improvement, Patents and Publications

31

1. Discovery	32
2. Invention	32
3. Improvement	36
4. Patents	37
5. Publications	38
6. Trade secrets	39

Chapter 3: Evolution of Miniaturization in Electronics: ICs to VLSICs to ULSICs and Beyond in the Future	41
1. Present status of miniaturization	42
2. Need for miniaturization and its evolution	43
3. When an electronic circuit is an IC?	45
4. When does a hybrid-IC become a monolithic-IC?	46
5. Fast evolution from early ICs to VLSICs to ULSICs	47
6. Beyond ULSICs into the future	52
7. Some of the advantages of 3D-Si-ICs over conventional over 2D-Si-ICs	54
8. Some of the advantages of UPICs over conventional 2D-Si-ICs	55
9. Future	57
Chapter 4: Monolithic vs. Hybrid Concepts in ICs	59
1. Hybrid-integrated circuits (hybrid-ICs)	60
2. Where do we draw the line in hybrid-ICs to define the onset of miniaturized Integrated Circuits?	62
3. Monolithic-integrated circuit (monolithic-IC)	65
Chapter 5: Summary of the IC Fabrication, Inventions, Relevant Patent Filings and Issue Dates, and Methodology of Analyses and Numbering	69
1. Summary of IC fabrication	69
2. Summary of the inventions of integrated circuit by Kilby and Noyce as documented in the literature	71
3. Sequence of relevant patent filings and issue dates	78

4. Comparison of the sequence of relevant patent filing and issue dates given above with that given in the earlier NSTI paper	81
5. Key features of Saxena's patent #3,687,722 on interconnects	82
6. Controversy over public disclosures and patent filing dates	83
7. Additional important facts from the published records	84
8. Figures from Kilby's and Noyce's patents and correspondence from USPTO	85
9. Methodology of Analyses of Patents and papers, and numbering of the Tables and Figures	92
Chapter 6: Hoerni and Lehovec Inventions	95
1. Importance of Hoerni and Lehovec inventions to the fundamental invention of ICs	95
2. Importance of choosing Si over Ge and other semiconductors	96
3. Sequence of important technical work and serendipity which led to the discovery of planar technology	97
4. Methodology to analyze Hoerni's and Lehovec's patents	103
5. Quotation of key points from Jean Hoerni's patent no. 3,025,589, "Method Of Manufacturing Semiconductor Devices"	104
6. Quotation of key points from Jean Hoerni's patent no. 3,064,167, "Semiconductor Device"	105
7. Quotation of key points from Kurt Lehovec's patent no. 3,029,366, "Multiple Semiconductor Assembly"	105

8. Copy of the original patent no. 3,025,589 of Jean Hoerni: “Method of Manufacturing Semiconductor Devices”	107
9. Copy of the original patent no. 3,064,167 of Jean Hoerni: “Semiconductor Device”	113
10. Copy of the original patent no. 3,029,366 of Kurt Lehovec: “Multiple Semiconductor Assembly”	119
11. Copy of Kurt Lehovec’s paper, “Invention of p-n Junction Isolation in Integrated Circuits”	123
12. Copy of the first page of the final hearing on March 16, 1966, of Kilby vs. Lehovec	124

Chapter 7: Kilby’s Invention of IC: Key Patents, Claims and Analyses **127**

1. Introductory comments on Kilby’s invention	127
2. A few important facts and comments on the invention of ICs by Kilby	130
3. Original Patents	134
4. Summary of the invention	134
5. Key figures	134
6. Key claims	135
7. Reduction to practice	135
8. Choice of semiconductor	137
9. Fabrication method of devices	138
10. Insulating layers	138
11. Interconnects	139
12. Impact of 35 USC 112	139
13. Overall comments	140
14. Kilby’s OA (Original Application)	140
15. Kilby’s Patent No. 3,138,743	152
16. Kilby’s Patent No. 3,138,744	159

17. Summary of comparisons between Kilby’s two IC Patent Nos. 3,138, 743 and 3,138,744, and a few additional comments	166
18. Detailed analyses of all the Claims of 3,138,744	169
19. Kilby’s Patent No. 3,261,081	179
20. Jack Kilby: Original Application no. 791,602, “Miniaturized Electronic Circuits and Method of Making”	189
21. Jack Kilby: US patent no., 3,138,743, “Miniaturized Electronic Circuits”	211
22. Jack Kilby: US patent no. 3,138,744, “Miniaturized Self-contained Circuit Modules and Method of Fabrication”	220
23. Jack Kilby: US patent no. 3,261,081, “Method of Making Miniaturized Electronic Circuits”	226

**Chapter 8: Noyce’s Invention of IC: Key Patent,
Claims, and Analyses**

237

1. Original patent	237
2. Summary of the invention	238
3. Key figures	239
4. Key claims	239
5. Reduction to practice	241
6. Choice of semiconductor	241
7. Fabrication method of devices	242
8. Insulating layers	242
9. Isolation of devices	243
10. Interconnects	244
11. Impact of 35 USC 112	245
12. Overall comments	245
13. Detailed analyses of all the claims	246
14. Copy of the original Patent No. 2,981,877 of Bob Noyce: “Semiconductor Device-and-Lead Structure”	252

Chapter 9: Other Efforts to Invent and/or Contribute to the Invention of ICs	261
1. Geoffrey Dummer	262
2. Harwick Johnson	267
3. Arjun Saxena	269
4. Richard Stewart	269
5. Jay Last	276
6. Reprint of the paper presented by Geoffrey Dummer, “Electronic Components in Great Britain”	278
7. Reprint of the paper by G. W. A. Dummer, “Integrated Electronics Development in the United Kingdom and Western Europe”	284
8. Harwick Johnson, “Semiconductor Phase Shift Oscillator and Device”, US Patent No. 2,816,228	298
9. Richard Stewart, “Integrated Semiconductor Circuit Device”, US Patent No. 3,138,747	301
10. J. T. Last, “Solid State Circuitry Having Discrete regions of Semi-Conductor Material Isolated by an Insulating Material”, US Patent No. 3,158,788	305
Chapter 10: Contributions of Kilby and Noyce beyond the Invention and to Next Generation ICs	313
1. Kilby	313
2. Noyce	317
Chapter 11: Discussion	321
1. Noyce’s patent	321
2. Kilby’s original application (OA) and patents	322

3. Reference to patent by Kilby in his latest paper in 1998 and comments on monolithic concept	323
4. Kilby's filing dates and recent communications from USPTO	323
5. Monolithic concept	324
6. Monolithic interconnects	325
7. P-N junction isolation	325
8. Importance of keeping the filing date Feb. 6, 1959 by Kilby	325
9. Possible compromise of the laws of US Patent code 35 USC 112 and associated protocols	326
10. Stewart's patent no. 3,138,747	327
11. Were any of Kilby's patents ever used to manufacture ICs?	327
12. Four requirements to make monolithic-ICs	327
13. Noyce's invention covered all criteria	328
14. Kilby's invention(s) met only one out of four criteria	328
15. A recent report in 2007 by Moss for testing Kilby's "solid circuits" in 1960	328
16. Issues intricately entwined technically, chronologically and patent wise	329
17. Noyce invented the monolithic-IC	329
18. Copy of the original article by Jeffrey Marque, "Getting History is an Important Matter"	330
19. Copy of Marvin J. Moss, "Present for the Birth of the Integrated Circuit"	332

Chapter 12: Award of the Nobel Prize **333**

1. Excerpt from Nobel's Will	334
2. Highlights of the updated Nobel Awards	335
3. Award of the Nobel Prize for inventing ICs	335
4. Excerpts from recent communications by Dr. MNC-1 with me	338

5. Excerpts from recent communications by Dr. MNC-2 with me	339
6. Famous United States Patents	339
Chapter 13: Moore's Law	341
Chapter 14: Growth of ICs and Impact on the Quality of Human Life	349
Chapter 15: Conclusions, Combined Summary, Historical Facts and Unanswered Questions	355
1. Conclusions	355
2. Combined summary	358
3. Historical facts	362
4. Unanswered questions	368
USPTO response: File History of Kilby's patents is lost	370
5. Epilogue	374
Appendix 1: Developments in Physics, Microelectronics and a Few Other Technologies in The Past 55 Years — Dr. Arjun Saxena's Contributions	379
Appendix 2: Saxena Documents Regarding IC Invention, Discussions and Patents in Devices, ULSICs and Beyond	395
Appendix 3: "Monolithic Concept and the Inventions of Integrated Circuits by Kilby and Noyce"	419
Appendix 4: "Fundamentals of the Invention and Impact on Future Developments of Integrated Circuits and Nano-optoelectronic Devices"	435

Appendix 5: “Transistors to ICs to ULSICs and Beyond: Impact on Various Applications to Improve the Quality of Human Life” 451

Appendix 6: Alphabetical List of Acronyms and Abbreviations Used in This Book 461

Appendix 7: History of Nobel Prize in Physics and its Award to Alferov, Kroemer and Kilby in 2000 465

1. Introduction	465
2. Will of Alfred Nobel	468
3. Updated summary of the Nobel Prize award	473
4. The field of Engineering missing from the Nobel Award list	474
5. Difficult job of Nobel Committees; example of the Nobel Prize to Sir C. V. Raman	475
6. History of all the Nobel Awards in Physics from the very beginning in 1901 to 2007	476
7. The entire list of all Nobel Prize in Physics winners to 3-person awardees from the very beginning with their citations and distributions of the award money	480
8. Overall comments on the sequence of listing and the distribution of the financial amounts of 3-person awardees throughout the history of Nobel Awards	486
9. Discussion of the Sequence of Listing and the Distribution of the Financial amounts in the Nobel Prize Awarded in Physics in 2000 to Alferov, Kroemer and Kilby	487
10. Conclusion	492

List of References, Tables, Figures and Documents	495
References	495
List of Tables	504
List of Figures	506
List of Original Patents, Applications and Papers	508
Index	513
Acknowledgement to the Publishers	519
About the Author	523