Table of Contents

1 REPORT AIMS AND OBJECTIVES 17

2 EXECUTIVE SUMMARY 18

2.1 The Mini-LED market 18
2.2 The MicroLED market 18
2.2.1 Market in 2021 19
2.2.2 Market in 2022 20
2.3 The global display market 20
2.3.1 Display technologies assessment 22
2.4 Motivation for use of MiniLEDs and MicroLEDs 23
2.5 MiniLED and MicroLEDs applications 24
2.6 Market and technology challenges 27
2.7 Industry developments 2020-2022 29
2.8 CES 2021 display innovations 33
2.9 CES 2022 and Display Week 2022 displays innovations 34
2.10 Market activity in China 36
2.11 Global shipment forecasts for Mini-LEDs and Micro-LEDs to 2027 37
2.11.1 Mini-LEDs 37
2.11.1.1 Units 37
2.11.2 Micro-LEDs 39
2.11.2.1 Units 39

3 TECHNOLOGY BACKGROUND 41

3.1 MiniLED (mLED) vs MicroLED (µLED) 41
3.1.1 Display configurations 41
3.2 MiniLED displays 42
3.2.1 Comparison to LCD and OLED 43

Copyright © Future Markets, Inc 2022. All rights reserved.

3.2.2 Advantages and disadvantages 44
3.2.3 Backplane types 45
3.2.4 Costs 47
3.2.5 High dynamic range miniLED displays 47
3.2.6 Quantum dot films for miniLED displays 48
3.2.7 Perovskite colour enhancement film in MiniLEDs 49
3.3 MicroLED 50
3.3.1 Development 50
3.3.1.1 Sony 50
3.3.2 Types 51
3.3.3 Production 52
3.3.3.1 Integration 52
3.3.3.2 Transfer technologies 53
3.3.4 Comparison to LCD and OLED 57
3.3.5 MicroLED display specifications 58
3.3.6 Advantages 59
3.3.6.1 Transparency 60
3.3.6.2 Borderless 61
3.3.6.3 Flexibility 62
3.3.7 Costs 62
3.3.8 Manufacturing 62
3.3.8.1 Epitaxy and Chip Processing 63
3.3.8.1.1 Uniformity 63
3.3.8.2 Assembly Technologies 64
3.3.8.2.1 Monolithic fabrication of micro displays 64
3.3.8.2.2 Mass transfer 65
3.3.8.2.3 Mass Transfer Processes 67
3.3.8.2.3.1 Elastomer Stamp Transfer 68
3.3.8.2.3.2 Roll-to-Roll or Roll-to-Panel Imprinting 69

Copyright © Future Markets, Inc 2022. All rights reserved.

3.3.8.2.3.3 Laser-induced forward transfer (LIFT) 70
3.3.8.2.3.4 Electrostatic Transfer 71
3.3.8.2.3.5 Micro vacuum-based transfer 72
3.3.8.2.3.6 Adhesive Stamp 72
3.3.8.2.3.7 Fluidically Self-Assembled Transfer 72
3.3.8.3 Full colour conversion 73
3.3.8.3.1 Phosphor Colour Conversion LEDs 74
3.3.8.3.2 Quantum dots colour conversion 75
4 DISPLAY BACKLIGHTS 76
4.1 TVs 76
4.1.1 The market in 2021 76
4.1.2 The market in 2022 77
4.1.3 MiniLED Quantum Dot TV 78
4.1.4 Products 79
4.2 Smartwatches and wearables 81
4.3 Smartphones 82
4.4 Samsung 82
4.4.1 Wall display 82
4.4.2 Neo QLED TV range 83
4.5 LG 84
4.5.1 LG mini QNED range 84
4.5.2 MAGNIT MicroLED TV 85
4.6 TCL 86
4.6.1 8 Series and 6 Series 86
5 LAPTOPS, MONITORS AND TABLETS 87
5.1 MiniLED 87
5.2 MiniLED and MicroLED laptop, monitor and tablet products and prototypes 89
6 FLEXIBLE, STRETCHABLE AND FOLDABLE MICROLED 96

Copyright © Future Markets, Inc 2022. All rights reserved.

6.1 Foldable microLED displays 98
6.2 Product developers....98
7 BIOTECHNOLOGY AND MEDICAL DISPLAYS 99
7.1 MicroLEDS 99
7.1.1 MicroLEDs for medical applications 99
7.2 Product developers....100
8 AUTOMOTIVE....101
8.1 MiniLED....101
8.2 MicroLED....102
8.2.1 Head-up display (HUD)....104
8.2.2 Headlamps 105
8.3 Product developers....106
9 VIRTUAL (VR) AND AUGMENTED REALITY (AR) 108
9.1 MiniLED....108
9.2 MicroLED....108
9.2.1 AR/VR Smart glasses and head-mounted displays (HMDs) 109
9.2.2 MicroLED contact lenses 109
9.2.3 Products and prototypes....110
10 TRANSPARENT DISPLAYS 114
10.1 Applications 114
10.2 MicroLEDs 115
10.3 Product developers 116
11 SUPPLY CHAIN....117
11.1 miniLEDs 117
11.2 microLEDs 118
12 COMPANY PROFILES 120
12.1 [redacted]....120

Copyright © Future Markets, Inc 2022. All rights reserved.

12.2 [redacted] 122
12.3 [redacted] 123
12.4 [redacted] 125
12.5 [redacted] 127
12.6 [redacted] 128
12.7 [redacted] 131
12.8 [redacted] 133
12.9 [redacted] 133
12.10 [redacted] 134
12.11 [redacted] 135
12.12 [redacted] 137
12.13 [redacted] 138
12.14 [redacted] 139
12.15 [redacted] 139
12.16 [redacted] 140
12.17 [redacted] 141
12.18 [redacted] 142
12.19 [redacted] 143
12.20 [redacted] 144
12.21 [redacted] 144
12.22 [redacted] 145
12.23 [redacted] 146
12.24 [redacted] 146
12.25 [redacted] 148
12.26 [redacted] 148
12.27 [redacted] 149
12.28 [redacted] 150
12.29 [redacted] 152
12.30 [redacted] 155

Copyright © Future Markets, Inc 2022. All rights reserved.

12.31 156
12.32 157
12.33 158
12.34 159
12.35 160
12.36 161
12.37 161
12.38 162
12.39 163
12.40 164
12.41 166
12.42 168
12.43 168
12.44 169
12.45 170
12.46 171
12.47 172
12.48 172
12.49 174
12.50 174
12.51 175
12.52 176
12.53 177
12.54 178
12.55 182
12.56 183
12.57 184
12.58 185
12.59 186

Copyright © Future Markets, Inc 2022. All rights reserved.

12.60 [redacted] 186
12.61 [redacted] 187
12.62 [redacted] 188
12.63 [redacted] 191
12.64 [redacted] 192
12.65 [redacted] 194
12.66 [redacted] 196
12.67 [redacted] 197
12.68 [redacted] 197
12.69 [redacted] 198
12.70 [redacted] 198
12.71 [redacted] 200
12.72 [redacted] 200
12.73 [redacted] 202
12.74 [redacted] 204
12.75 [redacted] 205
12.76 [redacted] 208
12.77 [redacted] 210
12.78 [redacted] 211
12.79 [redacted] 212
12.80 [redacted] 212
12.81 [redacted] 214
12.82 [redacted] 215
12.83 [redacted] 215
12.84 [redacted] 216

13 REFERENCES 218

List of Tables

Copyright © Future Markets, Inc 2022. All rights reserved.

Table 1. Announced microLED fabs. 20
Table 2. Summary of display technologies. 22
Table 3. MiniLED applications. 24
Table 4. MicroLED applications. 25
Table 5. Market and technology challenges for miniLED and microLED. 27
Table 6. Micro and MicroLED industry developments 2020-2022. 29
Table 7. MiniLED and microLED product announcements at CES 2021. 33
Table 8. MiniLED and microLED product announcements at CES 2022 and Display Week 2022. 34
Table 9. Mini/microLED activity in China. 36
Table 10. Mini-LEDs backlights global market 2020-2033, by market (Million units). 37
Table 11. Global Micro-LED display market (thousands of units) 2020-2033. 39
Table 12. Comparison between miniLED and microLED. 42
Table 13. Comparison between miniLED displays and other display types. 43
Table 14. Advantages and disadvantages of MiniLEDs. 44
Table 15. Comparison of AM and PM driving. 45
Table 16. MicroLED backlight costs. 47
Table 17. Comparison to conventional LEDs. 51
Table 18. Types of microLED. 51
Table 19. Summary of monolithic integration, monolithic hybrid integration (flip-chip/wafer bonding), and mass transfer technologies. 52
Table 20. Summary of different mass transfer technologies. 54
Table 21. Comparison to LCD and OLED. 57
Table 22. Schematic comparison to LCD and OLED. 58
Table 23. Commercially available microLED products and specifications. 58
Table 24. microLED-based display advantages and disadvantages. 60
Table 25. Mass transfer methods, by company. 66
Table 26. Comparison of various mass transfer technologies. 67
Table 27. Comparison of LED TV technologies. 76
Table 28. MiniLED and MicroLED TVs launched in 2022. 77
Table 29. MiniLED and microLED TV products. 79

Copyright © Future Markets, Inc 2022. All rights reserved.

Table 30. Samsung Neo QLED TV range. 84
Table 31. LG mini QNED range 84
Table 32.TCL range of miniLED TVs....86
Table 33. MiniLED laptop, monitor and tablet products and prototypes. 89
Table 34. Flexible, stretchable and foldable miniLED and MicroLED products. 98
Table 35. Medical display miniLED and MicroLED products....100
Table 36. Automotive display & backlight architectures....101
Table 37. Applications of microLED in automotive. 103
Table 38. Automotive display miniLED and MicroLED products. 106
Table 39. Comparison of AR Display Light Engines. 108
Table 40. MicroLED based smart glass products. 110
Table 41. tooz technologies smart glasses....112
Table 43. Applications of miniLED and microLED transparent displays....114
Table 44. Companies developing MicroLED transparent displays. 116
Table 45. microLED supply chain. 118
Table 46. LG mini QNED range 165
Table 47. Samsung Neo QLED TV range. 190
Table 48. San'an Mini and Micro LED Production annual target....191
Table 49. NPQDTM vs Traditional QD based Micro-LEDs. 193
Table 50. TCL miniLED product range. 202

List of Figures

Figure 1. Blue GaN microLED arrays with 3um pixel pitch use polychromatic quantum dot integration to achieve full colour AR displays. 19
Figure 2. The progress of display technology, from LCD to MicroLED. 23
Figure 3. Mini-LEDs backlights global market 2020-2033, by market (Million units). 38
Figure 4. Global Micro-LED display market (thousands of units) 2020-2033. 40
Figure 5. Display system configurations. 42

Copyright © Future Markets, Inc 2022. All rights reserved.

Figure 6. Schematic of LCD with MicroLED backlight....43
Figure 7. Schematic for configuration of full colour microLED display 44
Figure 8. BOE glass-based backplane process....46
Figure 9. MSI curved quantum dot miniLED display....48
Figure 10. MicroLED schematic. 50
Figure 11. Pixels per inch roadmap of µ-LED displays from 2007 to 2019....52
Figure 12. Mass transfer for µLED chips. 54
Figure 13. Schematic diagram of mass transfer technologies. 56
Figure 14. Comparison of microLED with other display technologies. 59
Figure 15. Lextar 10.6 inch transparent microLED display. 61
Figure 16. Transition to borderless design. 61
Figure 17. Schematics of **a** elastomer stamping, **b** electrostatic/electromagnetic transfer, **c** laser-assisted transfer and **d** fluid self-assembly. 68
Figure 18. Schematics of Roll-based mass transfer. 70
Figure 19. Schematic of laser-induced forward transfer technology. 71
Figure 20. Schematic of fluid self-assembly technology. 73
Figure 21. Schematic of colour conversion technology....73
Figure 22. Process flow of a full-colour microdisplay. 74
Figure 23. LG QNED miniLED TV. 78
Figure 24. microLED wearable display prototype. 81
Figure 25. APHAEA Watch. 81
Figure 26. Samsung Wall display system. 83
Figure 27. Samsung Neo QLED 8K. 84
Figure 28. MAGNIT MicroLED TV. 85
Figure 29. AUO AmLED. 88
Figure 30. laptop ROG Zephyrus Duo 16. 88
Figure 31. Acer Predator X32 Mini-LED Gaming Monitor. 89
Figure 32. Acer EI491CRG9 curved miniLED display....89
Figure 33. AOC 27-inch Mini LED-backlit gaming monitor AG2740GM. 90
Figure 34. 12.9-inch iPad Pro....90

Copyright © Future Markets, Inc 2022. All rights reserved.

Figure 35. Apple Pro Display XDR. 91
Figure 36. Asus ProArt PA32UCX. 91
Figure 37. ROG Swift PG32UQXE. 92
Figure 38. Lenovo ThinkVision Creator Extreme P27. 93
Figure 39. Creator 17 gaming laptop. 93
Figure 40. Samsung Odyssey G9 Neo gaming monitor. 95
Figure 41. AU Optonics Flexible MicroLED Display. 96
Figure 42. Schematic of the TALT technique for wafer-level microLED transferring. 97
Figure 43. Foldable 4K C SEED M1. 98
Figure 44. MicroLEDs for medical applications. 99
Figure 45. 2023 Cadillac Lyriq EV incorporating mini-LED display. 102
Figure 46. MicroLED automotive display. 102
Figure 47. Issues in current commercial automotive HUD. 105
Figure 48. Rear lamp utilizing flexible MicroLEDs. 106
Figure 55. Mojo Vision smart contact lens with an embedded MicroLED display. 110
Figure 49. Cellid AR glasses, Exploded version. 110
Figure 50. Air Glass. 111
Figure 51. Panasonic MeganeX. 111
Figure 52. Thunderbird Smart Glasses Pioneer Edition. 112
Figure 53. Vuzix microLED microdisplay Smart Glasses. 113
Figure 54. Leopard demo glasses by WaveOptics. 113
Figure 56. Different transparent displays and transmittance limitations. 115
Figure 57. 7.56" high transparency & frameless MicroLED display. 115
Figure 58. Supply Chain of miniLED Backlight. 117
Figure 59. WireLED in 12” Silicon Wafer. 121
Figure 60. Typical GaN-on-Si LED structure. 122
Figure 61. 300 mm GaN-on-silicon epiwafer. 123
Figure 62. MicroLED chiplet architecture. 124
Figure 63. Concept Apple Vr Ar Mixed Reality Headset. 125

Copyright © Future Markets, Inc 2022. All rights reserved.

Figure 64. 1.39-inch full-circle microLED display....126
Figure 65. 9.4" flexible MicroLED display. 127
Figure 66. BOE MiniLED display TV. 129
Figure 67. BOE miniLED automotive display. 129
Figure 68. Image obtained on a blue active-matrix WVGA (wide video graphics array) microdisplay. 131
Figure 69. Fabrication of the 10-µm pixel pitch LED array on sapphire. 132
Figure 70. A 200-mm wafer with CMOS active matrices for GaN 873 × 500-pixel microdisplay at 10-µm pitch....132
Figure 71. IntelliPix™ design for 0.26″ 1080p microLED display. 134
Figure 72. C Seed 165-inch M1 microLED TV....136
Figure 73. N1 folding MicroLED TV. 136
Figure 74. C Seed outdoor TV. 137
Figure 75. Focally Universe AR glasses. 142
Figure 76. Flexible microLED. 151
Figure 77. Jade Bird Display microdisplays. 153
Figure 78. JBD's 0.13-inch panel. 154
Figure 79. 0.22” Monolithic full colour microLED panel and inset shows a conceptual monolithic polychrome projector with a waveguide. 154
Figure 80. Prototype microLED display. 156
Figure 81. APHAEA MicroLED watch. 157
Figure 82. Lextar 2021 micro LED and mini LED products. 163
Figure 83. LSAB009 microLED display. 165
Figure 84. LG MAGNIT 4K 136-inch TV. 166
Figure 85. Schematic of Micro Nitride chip architecture. 170
Figure 86. Nationstar Mini LED IMD Package P0.5mm. 175
Figure 87. 55” flexible AM panel. 178
Figure 88. 9.4" flexible MicroLED display. 179
Figure 89. 7.56-inch transparent Micro LED display. 180
Figure 90. PixeLED Matrix Modular MicroLED Display in 132-inch. 180
Figure 91. Dashboard - 11.6-inch 24:9 Automotive MicroLED Display. 181

Copyright © Future Markets, Inc 2022. All rights reserved.

Figure 92. Center Console - 9.38-inch Transparent MicroLED Display. 181
Figure 93. 48 x 36 Passive Matrix microLED display. 182
Figure 94. microLED microdisplay based on a native red InGaN LED. 184
Figure 95. Micro-LED stretchable display. 188
Figure 96. The Wall. 189
Figure 97. Samsung Neo QLED 8K. 190
Figure 98. NPQD™ Technology for MicroLEDs. 192
Figure 99. Wicop technology. 195
Figure 100. B-Series and C-Series displays. 199
Figure 101. A micro-display with a stacked-RGB pixel array, where each pixel is an RGB-emitting stacked microLED device (left). The micro-display showing a video of fireworks at night, demonstrating the full-colour capability (right). N.B. Areas around the display 201
Figure 102. TCL MiniLED TV schematic. 202
Figure 103. TCL 8K Mini-LED TV. 203
Figure 104. The Cinema Wall MicroLED display. 204
Figure 105. Photo-polymer mass transfer process. 205
Figure 106. 7.56” Transparent Display. 206
Figure 107. UMini0.9 4K. 209
Figure 108. VueReal Flipchip microLED (30x15 um2). 213
Figure 109. Vuzix uLED display engine. 214
Figure 110. Mi TV Master series. 216

Copyright © Future Markets, Inc 2022. All rights reserved.