

# Contents

|          |   |           |
|----------|---|-----------|
| <b>1</b> | <b>Introduction</b>   | <b>8</b>  |
| 1.1      | Motivation . . . . .  | 8         |
| 1.2      | Scope and Outline . . . . .   | 9         |
| <b>2</b> | <b>Sub-mm Wave Flip-Chip Interconnect</b>                           | <b>12</b> |
| 2.1      | Microwave and mm-Wave Packaging . . . . .                           | 12        |
| 2.1.1    | Types of mm-Wave Packages . . . . .                                 | 14        |
| 2.1.1.1  | mm-Wave Packages with High Electrical Performance . . . . .         | 14        |
| 2.1.1.2  | Low-Cost Packages . . . . .   | 17        |
| 2.2      | Planar Transmission Lines for High-Frequency Applications . . . . . | 19        |
| 2.2.1    | Microstrip . . . . .  | 20        |
| 2.2.2    | Coplanar Waveguide . . . . .  | 21        |
| 2.2.3    | Stripline . . . . .   | 23        |
| 2.3      | Loss Mechanisms in Transmission Lines . . . . .                     | 24        |
| 2.3.1    | Conductor Loss . . . . .  | 24        |
| 2.3.2    | Dielectric Loss . . . . .   | 26        |
| 2.3.3    | Radiation Loss . . . . .  | 26        |
| 2.4      | Sub-mm Wave Interconnects . . . . .                                 | 27        |
| 2.4.1    | Wire Bond and Flip-Chip . . . . .                                   | 27        |
| 2.4.2    | State-of-the-Art Sub-mm Wave Flip-Chip . . . . .                    | 28        |

## CONTENTS

|          |  |           |
|----------|--|-----------|
| 2.4.3    | AuSn Soldering Material . . . . .                      | 31        |
| 2.4.4    | Flip-Chip Bonding . . . . .                            | 34        |
| <b>3</b> | <b>AuSn Flip-Chip Interconnections Using CPW Lines</b> | <b>40</b> |
| 3.1      | Concept Design . . . . .                               | 41        |
| 3.2      | Fabrication . . . . .                                  | 44        |
| 3.2.1    | Transmission Line Processing . . . . .                 | 44        |
| 3.2.2    | Fabrication of Miniaturized AuSn Bumps . . . . .       | 47        |
| 3.2.3    | Flip-Chip Mounting . . . . .                           | 51        |
| 3.3      | Measurement Results and Discussion . . . . .           | 54        |
| <b>4</b> | <b>Stripline-to-CPW Flip-Chip Interconnects</b>        | <b>59</b> |
| 4.1      | Flip-Chip Structure Design . . . . .                   | 60        |
| 4.2      | Process Technology . . . . .                           | 62        |
| 4.2.1    | Chip Fabrication . . . . .                             | 62        |
| 4.2.2    | Substrate Fabrication . . . . .                        | 72        |
| 4.2.3    | Flip-Chip Bonding . . . . .                            | 73        |
| 4.3      | Measurement Results . . . . .                          | 74        |
| 4.4      | Lateral Alignment of Vias and Bumps . . . . .          | 75        |
| <b>5</b> | <b>Stripline-to-Stripline Interconnect</b>             | <b>78</b> |
| 5.1      | 500 GHz Interconnect Design Approach . . . . .         | 78        |
| 5.2      | Fabrication Process of Chips and Substrates . . . . .  | 81        |
| 5.3      | Measurement Results . . . . .                          | 89        |
| 5.4      | Design Robustness Versus Process Tolerances . . . . .  | 91        |
| 5.4.1    | Influence of Bump Height . . . . .                     | 91        |
| 5.4.2    | Bump Displacement . . . . .                            | 93        |
| 5.4.3    | Stripline Width . . . . .                              | 95        |
| 5.4.4    | Lateral Alignment of G1 Stripline Layer . . . . .      | 97        |

*CONTENTS*

|          |   |            |
|----------|---|------------|
| 5.4.5    | BCB1 Thickness (dielectric between Gd bottom ground and G1 stripline layer) . . . . . | 99         |
| 5.4.6    | BCB2 Thickness (dielectric between G1 stripline and G2 top ground layer) . . . . .    | 101        |
| 5.4.7    | Diamond Thickness . . . . .   | 103        |
| <b>6</b> | <b>Active InP HBT Amplifier Flip-Chip Assembly</b>                                    | <b>105</b> |
| <b>7</b> | <b>Summary and Outlook</b>  | <b>113</b> |
|          | <b>Bibliography</b>   | <b>118</b> |