Fabrication of High-Brightness Light-Emitting Diodes by Wafer Bonding Technology

謝其華、武東星 [韓斌]
E-mail: 9100407@mail.dyu.edu.tw

ABSTRACT

High-efficiency light-emitting diodes (LEDs) are desired for many applications such as brake lights, traffic lamps, and outdoor displays. It is well known that the AlGaInP LEDs lattice-matched GaAs substrates have the highest luminous efficiency in the yellow-to-red spectral region. However, the absorbing GaAs substrate significantly limits the light extracting performance. The inferior thermal conductivity (GaAs versus Si) also yields the joule-heating problem, which limits the luminous efficiency at high injection currents. In this thesis, a 2-inch-diameter Si wafer coated with a Au/AuBe reflector was fused to an AlGaInP LED epilayers grown on GaAs. After the wafer bonding process, the GaAs substrate was chemically removed. Here the Au/AuBe mirror can not only be used as an adhesive layer, but also as ohmic contacts to the p-AlGaInP in the LED structure. The optimum fusion process can be controlled below 450°C for the wafer-bonded AlGaInP LEDs. From the crack-opening method, the bonding surface energy of the fusion interface was determined to be 1.2155×10^6 erg/cm², which is greater than that of the Si-Si wafer bonding at 1400°C (2200 erg/cm²). The present adhesion property can afford the LED backend process including chip dicing and wire bonding. The effect of SiO₂ film in the wafer-bonded AlGaInP/Si LED structure was investigated. It is found that the Si substrate with a 500-nm-thick SiO₂ film can reduce the residual stress of the epilayer. From x-ray diffraction and cantilever beam methods, the wafer-bonded epilayer with a SiO₂ interlayer showed compressive stress from 17.6 to 39.2 MPa. For the sample without a SiO₂ interlayer, the AlGaInP epilayer suffers a tensile stress of 97.21 MPa as measured by the cantilever beam method. The results obtained were compared with the data measured by photoluminescence and the discrepancy was discussed. The wafer-bonded AlGaInP LEDs with mirror substrates show that the flux can reach to 7500 mlm and 25 mW at 100mA, resulting in the highest lumen efficiency of 84 lm/W. The light intensity is 8 times over than the conventional AlGaInP LED without the distributed Bragg reflector. By stressing 50mA at 80°C after 2000 hours, the voltage and light intensity variations of the wafer-bonded AlGaInP/Si LEDs were within ±10 % for an applied current of 20 mA. Furthermore, under an aging test condition 20 mA, 400°C, the wafer-bonded LED with a SiO₂ interlayer can withstand 9.5 hours, which is better than that without a SiO₂ interlayer (5.5 hours). Based on the results of this thesis, it can be concluded that the wafer-bonded AlGaInP epilayers with mirror substrates have high potential in high-brightness, high-power and large-area LED applications.

Keywords: AlGaInP; wafer bonding; LED; Reliability; mirror substrates
3.1.5 砷化鎵吸光基板去除 .......................... 25 3.2 元件製程 .......................... 26
3.2.1 平台蝕刻 .............................. 26 3.2.2 AuGe、Au, n-型歐姆接觸金屬蒸鍍與金屬-半導體合金化 .......................... 27
3.2.4 元件切割、打線與封裝 .......................... 28 3.3 元件特性與老化性量測 .......................... 28
第四章 結果與討論 .......................... 30 4.1 晶片黏貼製程 .......................... 30
4.1.1 改變黏貼扭力 .......................... 30 4.1.2 改變黏貼溫度 .......................... 31
4.1.3 改變晶片黏貼加熱時間 ................. 32 4.1.4 改變石墨片中金屬片、藍寶石片的放置 ................. 32
4.2 黏貼鍵結量測結果 .......................... 33 4.2.1 掃瞄式電子顯微鏡量測結果 ................. 33
4.2.2 歐傑電子能譜儀量測分析 ................. 34 4.2.3 破裂開口法量測結果 ................. 34
4.2.4 拉力鍵結強度量測結果 .................. 35
4.3 黏貼應力量測結果 .................. 36 4.3.1 Cantilevel bam量測結果 ................. 36
4.3.2 X光繞射量測結果 .................. 37 4.3.3 光子激光儀量測分析 ................. 39
4.3.4 應力量測結果討論 .................. 41 4.4 元件基本特性測結果 .................. 42
4.4.1 光強度 .................. 42 4.4.2 光通量 .................. 44
4.5 老化性測試結果 .................. 44
第五章 結論 .................. 49
參考文獻 .................. 51
REFERENCES
[16] 同[13], pp 73-100.

同[10], pp. 115-116.