Chapter 3

Flip Chip Technology

3-1 Development of flip chip technology

Flip chip technology has been developed from the IBM corporation to provide connections between bonding pads of the chips and the metallization on the substrates since 1960. It is first proposed technique called the Controlled Collapse Chip Connection (C4) to displace wire bonding, increased IO density, and decrease cost [19]. The so-called C4 process starts with depositing under bump metallurgy (UBM) on the bonding pads of chips to supply good adhesion between the bonding pads and the bumps. UBM usually consists of three layers: adhesion and/or barrier layer, wetting layer, and oxidation barrier layer. After that, solder bumps are formed on the UBM and reflow to become solder ball. The next step is to put down the top surface metallurgy (TSM) on the substrate. The chips are aligned and joined the substrate. Subsequently, it is developed many methods of connection between bonding pads of the chips and the metallization on the substrates, such as Solder Bump, Tape-Automated Bonding (TAB), Conductive Adhesives, Anisotropic Conductive Adhesives, Wire Bonding, Metal Bump, Polymer Bump, and Composite Bump.

3-2 Advantages of flip chip technology

- High packaging density
- Small substrate area
- Good electrical performance
- Good thermal performance

- Low cost
- Good reliability

3-3 Interconnection of flip chip bonding

A definition of flip chip technology is a chip mounted on the substrate with various interconnects materials and methods. Figure 3-1 shows various flip chip interconnection such as wire interconnects, fluxless solder bumps, tape-automated bonding, isotropic and anisotropic conductive adhesives, metal bumps, compliant bumps, and pressure contacts [19]. The common C4 process has advantages of low cost, small manufacture time, and good reliability. But C4 process has disadvantages of complicated process, flux paste residuum, and lead pollution.

Recently, new flip chip technologies are continuously developed against lead free and flux paste free. In our experiments, Thermo-Ultrasonic Flip Chip Bonding combined thermo-compression and ultrasonic techniques are used. It can be joined the gold bumps on the chips and gold pads on the substrate. Thermo-Ultrasonic Flip Chip Bonding has advantages of high precision, fine pitch and short bonding time at lower temperature (80~150 ℃) and pressure (50~100g/Bump) compared to Thermo-Compression technique. It also has simple process, rapid process, lead free, flux paste free, good interconnection strength, electrical performance, and reliability compared to Anisotropic Conductive Adhesion (ACA) technique.

3-4 Principle of ultrasonic flip chip bonding

Metal in the air has a metal oxide film on the surface due to the reaction between metal and oxide as figure 3-2 shown [20]. The oxidization rapid is determined by speed of oxide diffused into the metal [20]. This metal oxide film arrests contact between metal atoms and not to produce bonding force when we want to combine two metals. If two metal surfaces are rubbed between each other to remove the metal oxide film, it produces bonding force to join the two metals. This bonding force called the metallic bonds is attributed to interaction of metal atoms [21].

Thermo-Ultrasonic bonding process provides enough energy by rapid and high frequency relative motion at interface of metals. Figure 3-3 shows that the friction can remove the metal oxide film and make diffusion plow adhesion to accomplish metal bonding process [22]. Thermo-Ultrasonic bonding process can reduce bonding temperature and increase reliable compared to Thermo-Compression bonding technique.

3-5 Advantages of LEDs with flip chip technology

Figure 3-4 shows the structure of conventional GaN-based LED. Sapphire material is the common substrate to grow GaN film, but it is an insulator and poor thermal material. Therefore, n- and p- pads must be the same side and lead to bonding pads baffle light output to decrease light extraction efficiency.

Figure 3-5 shows the structure of flip chip GaN-based LED. It has high extraction efficiency compared to that of conventional LEDs due to the lower refraction index contrast between sapphire and air. This leads critical angle of light output to become larger and let total internal reflection reduce. Furthermore, n- and p- pads of flip chip LEDs don’t baffle light output and it could add a high reflective mirror on the sub-mount to direct downward light to sapphire substrate. Therefore, flip chip technique can provide 1.5~1.7 times of light output power enhancement compared to that of the conventional

GaN-based LEDs [22]. Finally, heat can be conducted to a high thermal conductivity sub-mount by bonding metal to lead better thermal dissipation. It is an important advantage for high power LEDs applications.

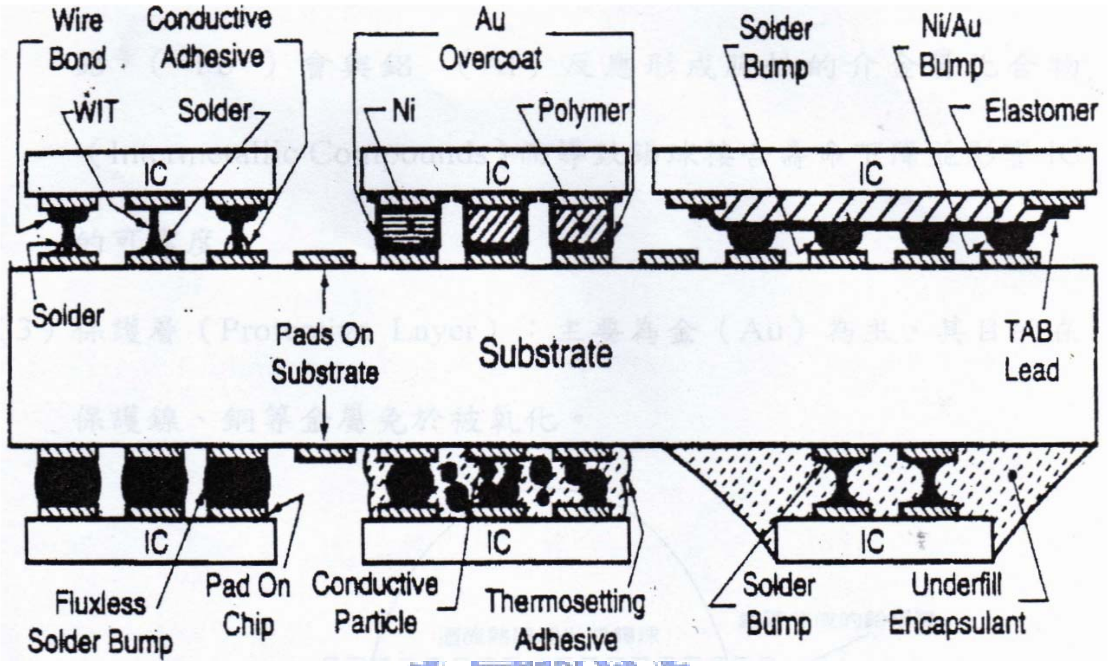

Figure 3-1 Various flip chip technologies [19].

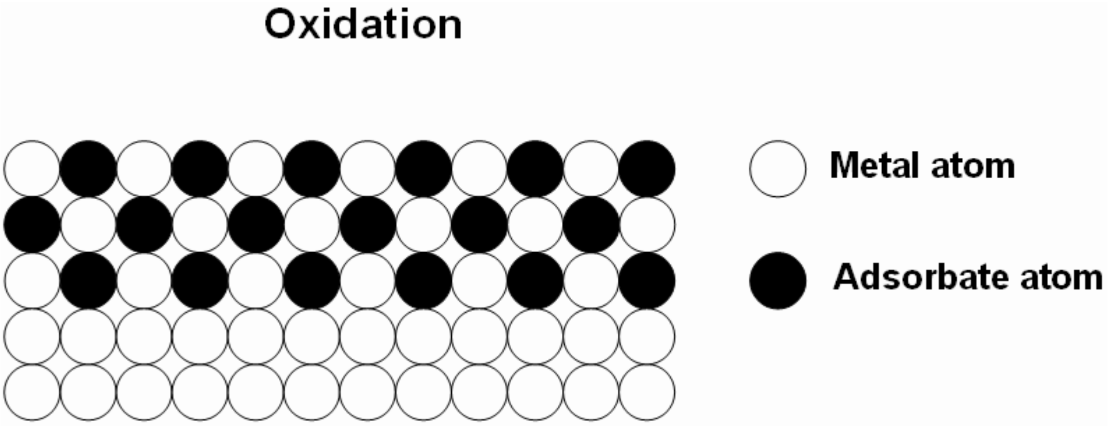

Figure 3-2 Diffusion type of metal oxide film.

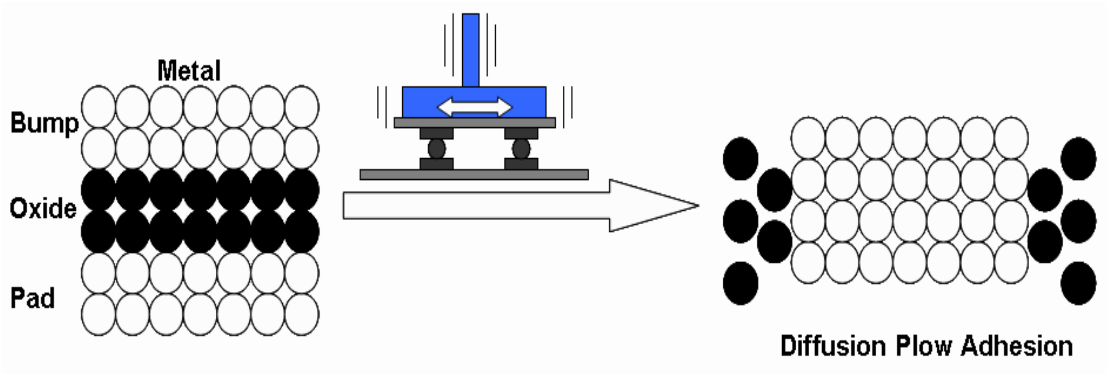

Figure 3-3 Principle of Thermo-Ultrasonic bonding process.

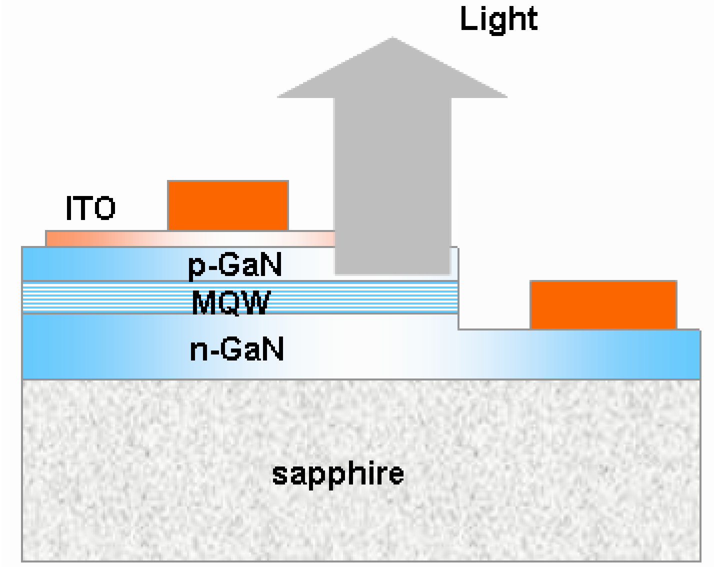

Figure 3-4 Structure of conventional GaN-based LED.

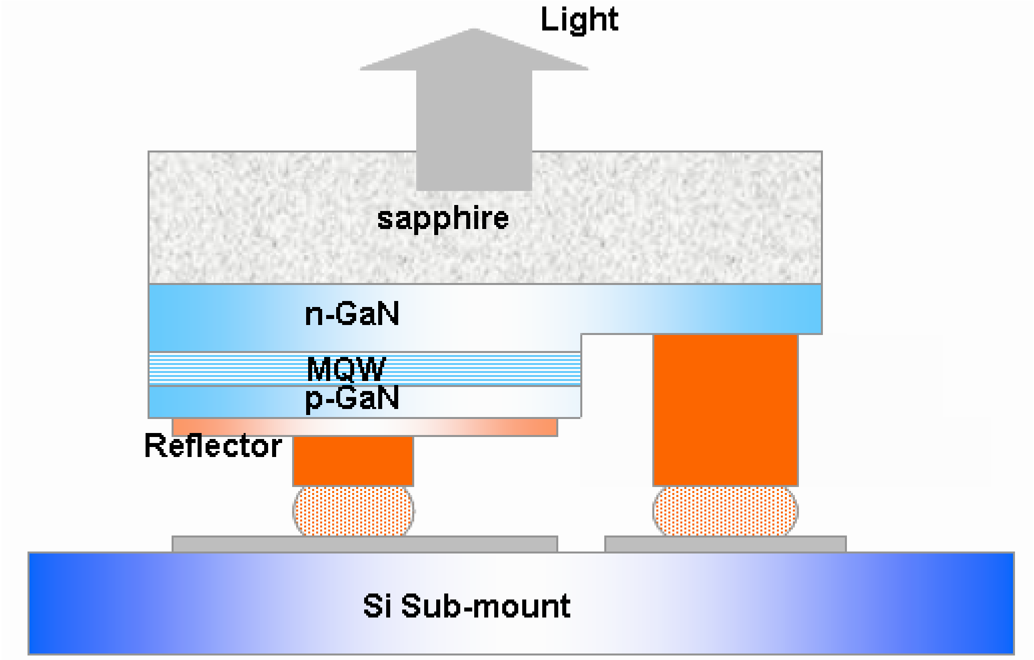

Figure 3-5 Structure of Flip chip GaN-based LED.