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The Aluminum Packaging for LED using Selectively Anodizing Method

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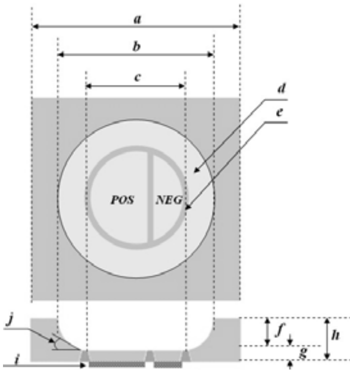
1. Introduction

With the LED market maturing from early growth rates of 40-50% to a more sustainable and slower 15-20% per year, LEDs are increasingly being adopted in LCDs as backlight systems. This fairly new application has large growth potential and will be a steady market until LEDs break into the illumination market in an estimated 5-10 years. While the High Brightness LED(HB LED) industry remains healthy and is projected to grow to as high as $7 billion in just three years, new applications are developing less quickly and focus is shifting towards the limitations of packaging. Without improved light output, greater efficiencies and better thermal management, LEDs may not reach the LED illumination market as anticipated [1]. In this paper, the novel high-power LED packaging is suggested using aluminum substrate and anodizing technology. Reflector and Electrical via were integrated in one packaging body with excellent heat dissipation and mechanical stability. The body of this packaging was composed of aluminum and anodized Al_2O_3, both of which are excellent thermal conductivity compared to other packaging materials, such as FR4 and LTCC. Table I show the thermal conductivity and thermal coefficient of expansion (TCE) of materials for packaging. The TCE mismatch of aluminum substrates can be compensated by thick Al_2O_3 anodized from the substrate.

Table I Thermal properties of materials used in packaging.

Material	Thermal Conductivity [W/m·K]	Thermal Coefficient of expansion [ppm/K]
Aluminum	230	23
Alumina	30	6.7
LTCC	2.5	4.5-7
FR4	0.2-0.4	x,y axis: 14, z axis: 80

The schematic diagram of proposed packaging structure is shown in Fig.1. The aluminum sheet with 500 µm thickness was utilized as a packaging substrate and anodized to 150~200 µm in an oxalic acid bath with patterns of electrode for electrical via. The Al_2O_3 barrier formed in aluminum acts as an electrical isolation. The other side of the aluminum body was chemically etched until anodic pattern was revealed. During isotropic etching, reflector with an angle of 55°~65° was formed. By simple 2-step chemical process, the LED package having reflector and electrical via with excellent heat dissipation was built up. The heat generated from LED will be directly dissipated through the whole body of aluminum substrate and the light emitted from LED can be reflected on reflector.



Substrate Material: 1050 Aluminum

	Description	Size variation
a	Packaging size	3500~4000 ㎛
b	Outer diameter of Reflector	3000~3500 ㎛
c	Inner diameter of Reflector	2000~2500 ㎛
d	Reflector	-
e	Anodized pattern	Width: 150~200 ㎛
f	Height of reflector	300~350 ㎛
g	Anodizing Thickness	150~200 ㎛
h	Total thickness	500 ㎛
i	Plated Cu	8 ㎛
j	Reflector's Angle	55° ~ 65°

Fig. 1 Proposed Structure of Aluminum LED packaging with the tolerance of size variation and description.

LED will be accommodated inside reflector by wire-bonding or flip-chip bonding. Finally lens will be built up by injecting epoxy in the form of dome.

2. The Process of Aluminum Packaging.

This packaging structure can be mainly fabricated by 2-step process. First process is electrode formation by anodizing technique, and the other is selective-etching technique. Each process step is described in detail as follows:

1. Electrode Formation by selective anodization

For experiment of the selective anodization to form a electrode, industry-grade 1050 aluminum sheet was used. These aluminum sheets with purity of 99.5% were cut into 130mm × 75 mm × 0.5mm pieces. To obtain aluminum oxide (Al_2O_3) with thickness of more than 150 µm, 5% oxalic acid was utilized as an electrolyte for anodization in this work. First of all, conventional metal cleaning process is used to degrease aluminum sheets. Masking layer with an excellent adhesion property is necessary in this process. Si_3N_4 is selected for the masking material. Mask is patterned as electrode as shown in Fig.1.e. To place LED chip in the center of packaging structure, Electrical isolation pattern is shifted from the center of the body for the case of wire-bonding. 5% oxalic acid has been used as an electrolyte. The Al_2O_3 with a height of 180 µm was grown at a constant current of 40mA/cm^2 for 90min in oxalic acid bath at 30°C with a controller capable of 0.1°C accuracy.Fig.2. shows a linear relation between the film thickness and anodizing time according to temperature change of bath. A growth rate of 2.0 μm/min was observed at 30^{o}C. During the anodizing process, the anodic barriers occupy a greater volume than the aluminum from which it is formed so that in most cases there is a tendency for overall dimensions to increase. In this experiment, a growth figure of 30~35% of the final coating thickness is often observed.

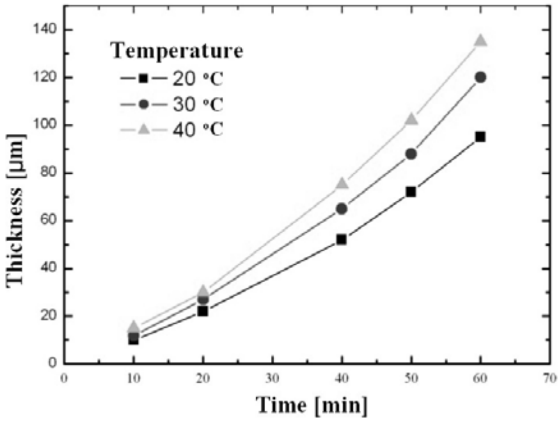


Fig.2 Thickness of anodic aluminum oxide vs. time.

55~65 μm of anodic barrier was protruded from the surface of aluminum, while anodizing aluminum to 180 μm. This rugged surface acts as an obstacle during following process. To remove this difficulty, Etching-anodization was developed to compensate the volume expansion. After masking, Aluminum body was etched to 60 μm in 5% hydrochloric acid before anodization. And then anodization was performed to 180 μm thickness. Using this process, surface flatness after anodization was improved as shown in Fig.3.

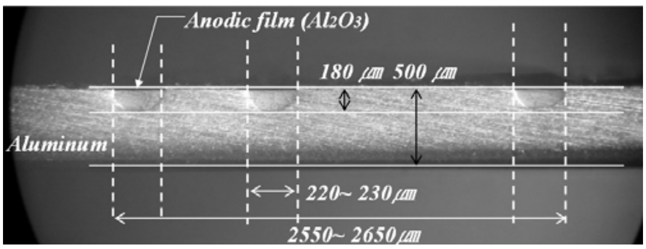
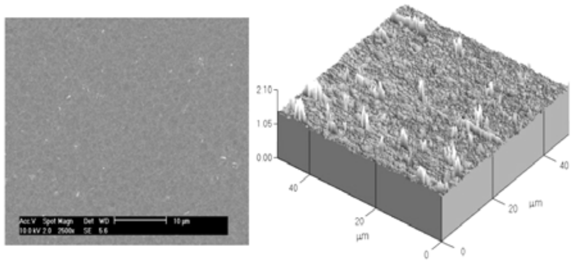


Fig.3. Cross Section view of Electrical Isolation by anodizing process.

After overall process, both AC and DC voltage withstanding test was carried out by *Kikusui TOS8750*. The breakdown voltage of oxalic anodic barrier with 150 μm thickness exceeded 3.0kV in the both AC and DC test. These values are enough to work as an Electrical Isolation.

2. Reflector Formation by selective etching

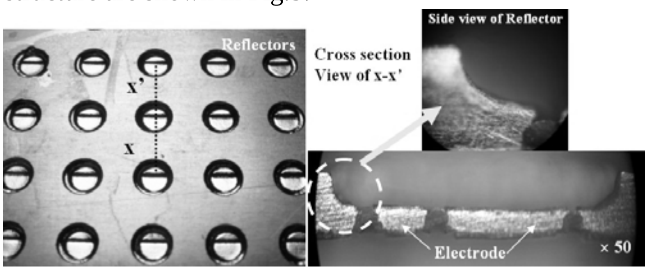
After electrode formation by anodizing process, the other side of the aluminum body was patterned as a circular with a diameter of 3000~3500 μm to form a reflector. The aluminum was etched to 200~250 μm with a vigorous agitation in a solution of D.I, HNO_3(70%)and H_3PO_4(85%) (2:1:7 in volume) mixture at 80^{o}C [2]. To have mirror-like surface of reflector, Electropolishing was carried out applying 27V for 200-250 sec in a 3^{o}C solution of perchloric acid(60%) and ethanol(1:4in volume) mixture until anodic pattern (Al_2O_3) was revealed [3]. The Surface roughness of 30-35 nm enough to act as a reflector was measured by AFM. Fig.4. shows the SEM photograph and surface profile measured by AFM after electropolishing.



(a) (b)

Fig.4. Surface state of the electropolished aluminum (a) SEM photograph, (b) AFM image (rms roughness=30nm at 40 μm ×40 μm)

The proposed packaging structure was successfully accomplished by two-major process. The top view (part of reflector) of packaging array and cross section view of packaging structure are shown in Fig.5.



(a) (b)

Fig.5. The photograph of aluminum LED packaging (a) top view, (b) cross section view of x-x'of (a).

3. Conclusions

The Aluminum LED packaging with reflector and electrode formed in one body was successfully demonstrated. Anodization process in an oxalic acid was utilized to form electrical via for electrode, which gives less design complexity. Isotropic etching and electropolishing can build up reflector with mirror-like surface. Anodic barrier with 150 μm thickness as an electrical isolation for electrode exceeds 3.0kV of breakdown voltage in both AC and DC test. The thermal crazing of Al_2O_3 by TCE mismatch was not observed after curing at 300^{o}C for 1 hour. This packaging technology has excellent heat dissipation compared to other package. Simple 2-step process completes LED packaging with high thermal conductivity and low-cost process.

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