A comparison of plastic versus metal packaging for infrared sensors and emitters.

Introduction

Recent advances in optoelectronic packaging technology have resulted in the development of plastic infrared sensors and emitters which are in many ways superior to their metal counterparts. While the metal package is still the right choice for some applications, plastic devices offer decided advantages in cost, output power, reliability, power dissipation, and optical quality. This application bulletin will compare the two packages and show how the better performance of the plastic part is obtained.

Cost

The lower cost of the plastic package is a result of reduced labor costs (due mainly to automation of the assembly process) and reduced materials cost. Plastic device construction lends itself to automation, and the expensively tooled piece parts characteristic of metal devices are simply not required.

Mounting the chip and attaching the bond wire are two of the most labor intensive phases in the manual assembly of optoelectronic semiconductors. The problem is especially acute for LEDs as the chips are small and relatively delicate, and they must be mounted in a reflective well to utilize their lateral emission. Automation of these processes requires extremely precise mechanical placement, which is difficult with the individual headers used in metal devices. In contrast, the "strip" lead frame (Figure 1) used in making plastic devices can be stepped through automatic chip mount and wire bond machines so that precision locating of the mounting surface is readily performed.

Figure 1A. IR LED 20 Unit Lead Frame

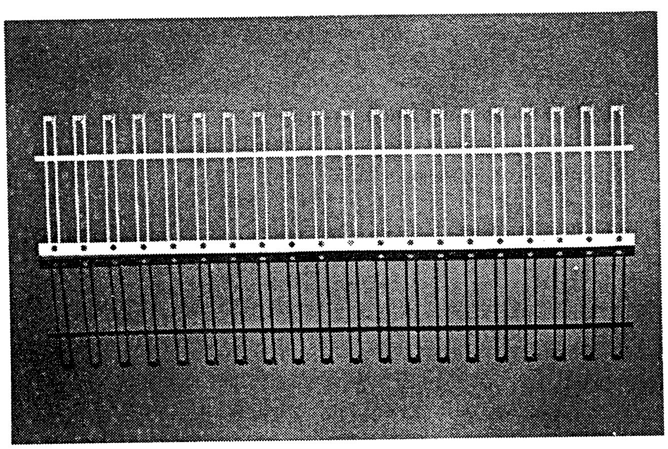


Figure 1B. Detail Enlargement of LED Chip Mounting Area

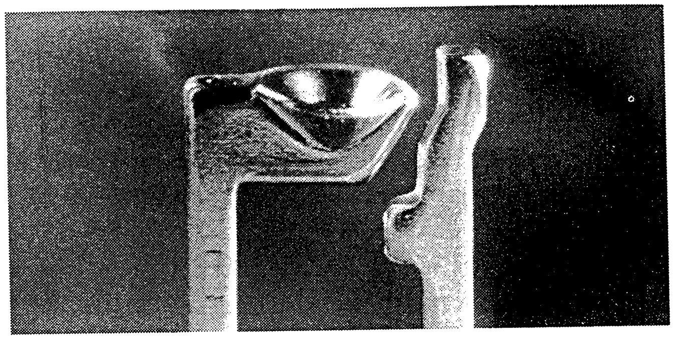


Figure 2A shows the detail of an IR LED that has been mounted, bonded and coated with the silicone gel that enhances the energy emitted. Figures 2B, 2C, and 2D show examples of the production machines used for hand mounting, semiautomatic mounting, and fully automated mounting of the IR LED chips on different headers or lead frames.

Figure 2A. Detail of Mounted and Bonded Chip

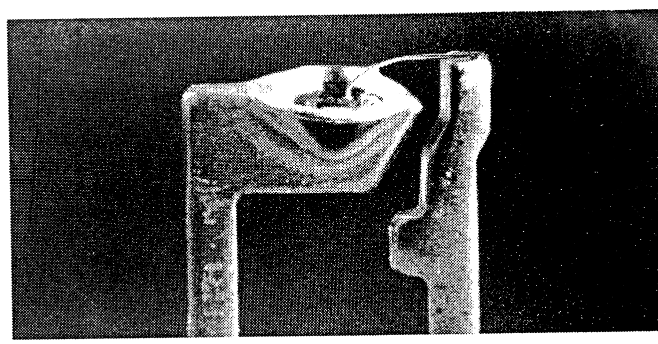


Figure 2B. Hand Mount Station ≈ 100 units/hour

Figure 2C. Semi-automated Mount Station ≈ 500 units/hour

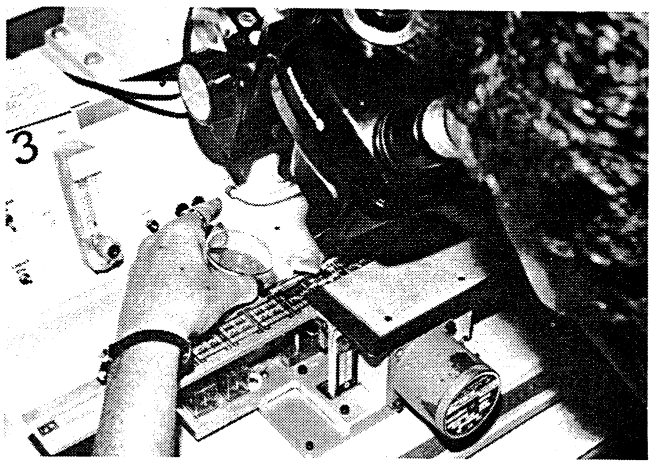
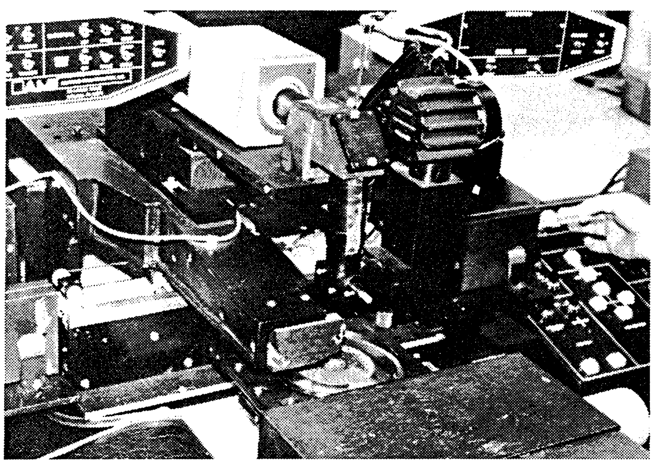


Figure 2D. Fully Automated Mount Station ≈ 5000 units/hour

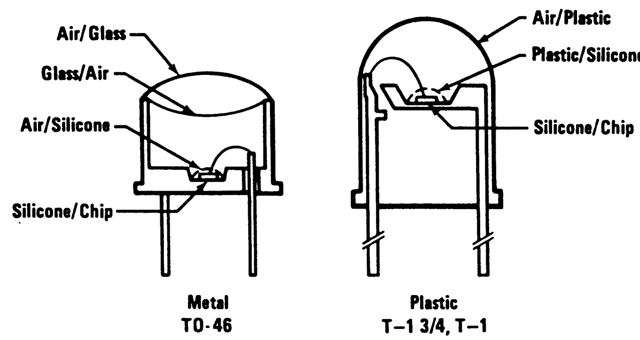


The initial cost of an automatic chip mount machine (Figure 2) or automatic bonder is high but the dramatic increase in throughput results in an overall cost reduction for the finished part. For example, manually dispensing conductive epoxy onto the lead frame and mounting the chip with tweezers produces typically 100 units per hour. Partial automation, by mechanically indexing the lead frame into position for a manual mount operation, increases this to about 500 units per hour. Fully automating the process results in 5000 to 6000 units per hour.

Output Power

A typical plastic LED has approximately 40% more output power than its metal equivalent (see Table I). There are two reasons for this. One is that metal LED headers allow some of the chip's output power to be radiated into the opaque wall of the package. Perfect reflectivity at these surfaces is not attainable and much of this radiation is absorbed before it can escape through the lens. The other problem with the metal package is that the lens has two surfaces. Some of the optical radiation which does reach the lens is reflected back into the package and absorbed. Figure 3 shows a comparison of the optical properties of the two package types.

Figure 3. Optical Interfaces in Metal and Plastic Packages for IR LED



The following table shows a comparison of total output power on the metal package and the mechanically equivalent plastic package.

Table 1. Output Power (P_O) in Metal and Plastic Packages @ I_F = 100 mA

Device Type		P_O
Metal TO-46	Low Range	8.0 mW
	Mid Range	10.0 mW
	High Range	12.0 mW
Plastic TO-46	Low Range	12.0 mW
	Mid Range	15.0 mW
	High Range	18.0 mW

Power Dissipation

The power dissipation rating for a device is a function of its thermal impedance, which is the ability of the package to get rid of heat generated by the chip. This varies from a maximum with an infinite heat sink to a minimum with no heat sink. (Applications Bulletin 121 covers in detail the techniques used to measure these quantities.) In practice, TO-46 LEDs, TO-18 sensors, and their plastic equivalents are used in a socket or soldered in a PC board; this results in a thermal impedance somewhere between the two extremes. The primary heat flow path for a device under these conditions is via the leads, and some heat sinking is provided by the socket or PC board.

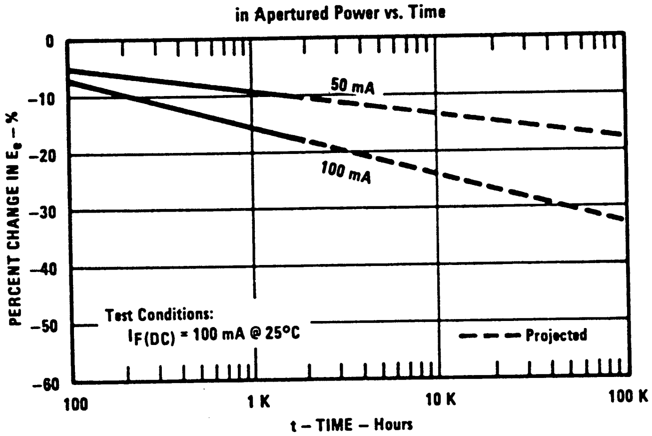
Since the leads of plastic devices have a larger cross-sectional area (.020" x .020" vs. .017" dia.) and are made from a more thermally conductive material (copper-silver vs. nickel-iron alloy), the thermal path of the plastic part is normally about 40% better than that of its metal equivalent. This results in significantly improved power dissipation ratings for the plastic part. Infinite heat sink ratings will show the metal part to be equal or superior since these ratings take advantage of the better thermal conductivity of the metal package body; however, since a heat sink is rarely used, the plastic part usually offers better thermal performance.

Reliability

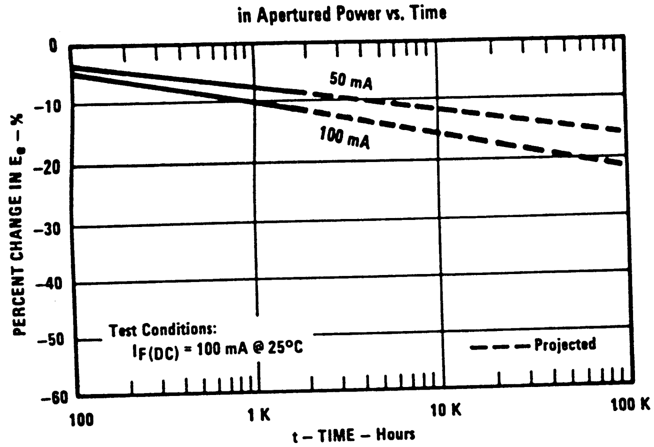
In optoelectronic technology the two main reliability considerations are long term LED degradation and catastrophic failure of LEDs or sensors due to thermal and mechanical stress. In the case of long term LED degradation, the plastic device has a definite advantage due to its improved power dissipation characteristics and the lower junction temperatures which result. Figure 4 shows life test data for the metal OP231 and the plastic equivalent OP298 operated at 100 mA.

Figure 4. Operating Life Test Data on Metal and Plastic TO-46 Packages

Metal TO-46 OP230 Series Percent Change in Apertured Power vs. Time



Plastic TO-46 OP293/OP298 Percent Change in Apertured Power vs. Time



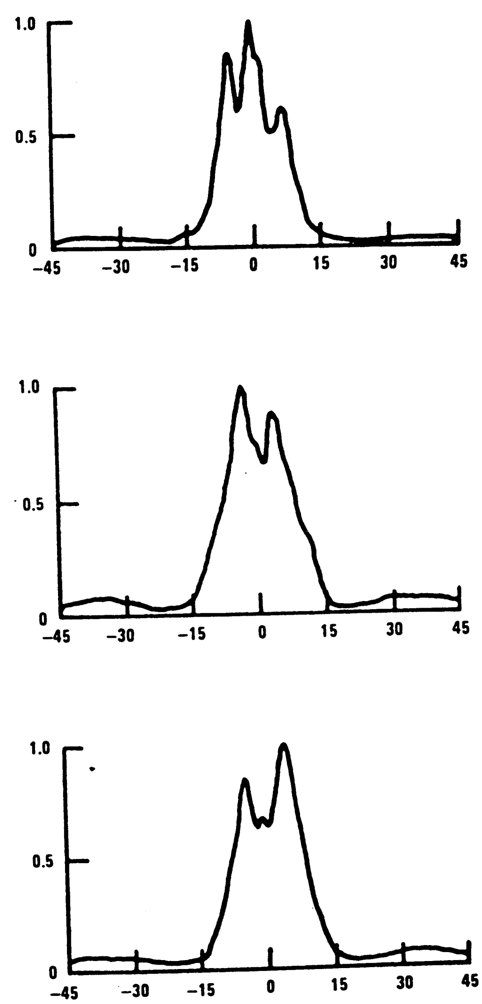
Catastrophic failure due to thermal or mechanical stress, which usually occurs early in the operating life of a device, results from forces on the chip or bond wire which can dismount or delaminate that chip, disconnect the wire bond, or break the bond wire. The design of the metal part gives it the advantage here as there are no such forces on the chip or bond wire. However, the machine fabrication of the plastic part is very repeatable and mechanically accurate so that there are fewer failures due to assembly variables. In the end, neither part has a clear cut advantage with respect to catastrophic failures.

Optical Quality

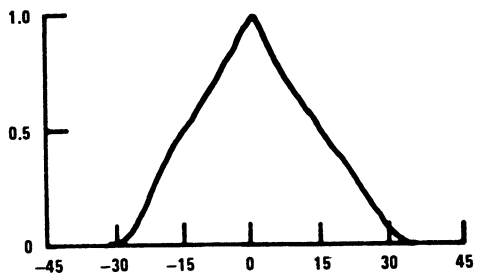
Lens performance is especially important for LEDs and in this respect the plastic part is distinctly superior. The automated chip placement is a contributing factor since inaccurate placement of the LED chip in its reflective well can cause power loss and a deviation between the optical and mechanical axes of the finished part. However, the most significant factor is the lens itself. In the plastic lens there is only one surface, which is controlled by the precisely machined and polished surface in which it is cast or molded. The glass lens used in metal packages is flame polished from a molded glass pellet, and the resulting lens exhibits variations in focal length and surface curvature so that the radiation pattern of the finished part is difficult to control. Figure 5 shows typical radiation patterns for OP131/OP231 metal parts and OP293 plastic parts. This illustrates the improved consistency of the plastic lens.

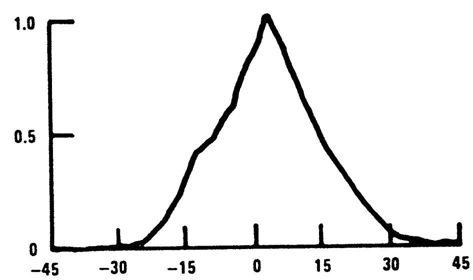
Figure 5. Radiation Patterns on Metal and Plastic TO-46 Packages

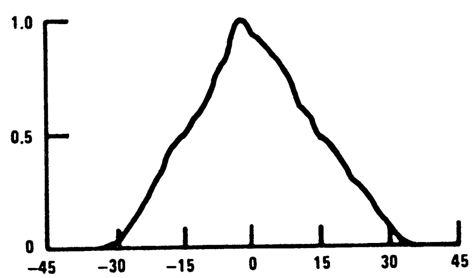
OP131/OP231 Metal TO-46



OP298 Plastic TO-46







Hermeticity

The metal packages of the TO-18 or TO-46 type can be leak tested utilizing the helium or radioactive systems and show a decided advantage in that they are hermetic. The seal or leak rate on the plastic parts is primarily a function of leak path. The moisture or harmful material must traverse along the lead/plastic interface from the outside world to the junction of the chip. Normally moisture is considered the culprit since increased leakage is the problem. The problem is much more severe on a phototransistor since it is operated with a reverse bias on the collector-base junction; increased leakage will result in a higher "off" level, with a decrease in gain in the "on" level. The small leakage due to non-hermeticity is not as big a problem on LEDs since they operate in the forward mode and increased leakage will appear as a very slight reduction in energy transmitted. Metal units offer an advantage in hermeticity. This primarily pertains to the receiver or sensor and is not a major factor in the LED.

Temperature Range

The normal temperature range for metal can type parts has been set from −55°C to +150°C. These limits are somewhat arbitrary but will satisfy what is required. They primarily come from limitations in a silicon transistor in that h_{FE} decreases with decreasing temperature and I_{CEO} increases with increasing temperature. The same temperature characteristics were utilized on metal can LEDs.

The primary stress mechanism with plastic parts is the result of "glass transition". This is the temperature at which plastic starts a recure cycle. The stresses that result are thermal expansion mismatches which can shear the chip from mount or shear the bond wire. In early plastics utilized in opto components, this "glass transition" occurred in the 100—110°C range. The maximum temperature was specified at 85°C, and sometimes to 100°C range. Improvement in plastics has now raised this to the 125-130°C range. Recent ratings reflect this in allowing a maximum package temperature of 100°C while allowing the chip to attain a 125°C temperature. The poor thermal conductivity of the plastic keeps it well below 125°C. In the future, this trend should continue, eventually allowing metal and plastic parts to carry the same ratings. At the present time, however, the advantage on temperature range remains with the metal can.

Solvents Affecting Plastic

Methanol and isopropanol alcohols are recommended cleaning agents. Plastic discrete components and assembly housings are soluble in chlorinated hydrocarbons and keynotes. Highly activated water soluble fluxes can attack discrete components and housings in some situations.

For purposes of cleaning or similar short term exposures, the plastic devices may be considered tolerant of standard chemicals that do not show obvious attack on a test sample. For long term exposures, such as immersed applications, or specific chemicals, contact the factory for more information.

Conclusion

A thorough analysis of the evidence shows that improved materials, processes, and automation give plastic housings a decided advantage over their metal counterparts for opto sensors and LEDs in most applications. Their use can reduce costs, provide improved reliability through longer life, and offer increased infrared power output. In summary, the plastic packages represent a significant technological advantage over their metal can predecessors.

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