High Power Plastic Packaging with GaN

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INTRODUCTION

For many years high power RF packaging has been dominated by metal and ceramic package construction and assembly processes, with GaN being no exception to this trend. The resulting products have been reliable, consistent, and capable of dissipating heat out of the device. However, the material and assembly costs have been very high and throughput limited. Plastic overmolded parts, on the other hand, can be made at a fraction of the cost but have historically been limited to lower power applications and not considered seriously for high power GaN.

Recent advances in plastic packaging have enabled higher power dissipation of the device while still maintaining a low cost approach to the materials and assembly processes. This has been achieved through package design, material selection, and process optimization. This paper will show examples of packages that use these different aspects to overcome historical shortcomings of plastic packaging and enable high power GaN devices to operate with good performance and high reliability in plastic packages.

ADVANCES IN PLASTIC OVERMOLD PACKAGING

Most plastic overmolded parts are designed so that the source and pins are coplanar on the backside of the package, allowing the part to be surface mounted onto the printed circuit board (PCB) along with all other components. While this allows for a simple and fast board assembly process, it creates a problem getting the heat out of the device because of the high thermal resistance of the PCB. Metal-ceramic air cavity packages have overcome this problem by creating a flange and leads at different levels so that the electrical connections can be made through the leads on top of the board while the flange is resting directly on a heat sink near the bottom of the board, drawing heat more effectively out of the device (see Fig. 1).

A newer generation of plastic packages has been designed to take advantage of this concept. The TO-270/272 family of packages uses a thick heat slug and downset leadframe to create a design similar to the air cavity packages with the leads significantly higher than the bottom of the flange (see Fig. 2). This allows the part to be inserted into the customer's board with the bottom of the flange in direct contact with a metal heatsink. GaN devices operating in CW mode above ~20W require this level of heatsinking to prevent the junction temperature (T_j) from exceeding the maximum limits.

GaN devices are capable of running at junction temperatures of 200°C or higher. Traditional mold compounds for plastic parts have a glass transition temperatue (T_g) between 115°C and 140°C. As the plastic is heated above the T_g it transitions from a hard state to a soft "rubbery" state. The accompanying changes in coefficient of thermal expansion and flexural modulus can damage the device, wire bonds, or other features in contact with the plastic overmold material. New overmold materials with a T_g up to 235°C have been used to prevent this from happening. The TO270/272 packages with high Tg mold compound have been used for over a decade with Si LDMOS and are now becoming adopted by GaN semiconductor manufacturers.

One of the single largest advances in high power plastic packaging has come from die attach technologies. The vast majority of plastic packages use epoxy die attach because the room temperature dispensing and pick and place process is most compatible with the leadframe format and equipment used to assemble plastic packages. Epoxies have generally been inferior to eutectic die attach in thermal conductivity resulting in plastic parts with lower performance than their air cavity counterparts, where eutectic die attach is more common. Recent advances in sintered die attach materials have changed this. New materials from several manufactures contain silver, gold, or copper particles embedded in an epoxy/organic matrix that, when properly cured, sinter together to form a strong bond with excellent thermal conductivity, up to 200 W/m-K (see Table 1). Parts assembled with these epoxies have demonstrated thermal performance comparable to or even better than eutectic die attach. This further enables GaN devices to be attached in low cost plastic packages and still maintain their excellent power densities and high efficiencies.

CONCLUSION

Advances in plastic packaging have paved the way for GaN devices to achieve a new level of cost without sacrificing performance. Package design, materials technologies, and process development have made it possible to use the existing process flow and equipment for plastic overmold packaging for GaN devices, and produce a part that can perform equivalent to or better than a similar air cavity part. These advances are enabling GaN to enter new markets, capture customers, and expand its reach into semiconductor applications.

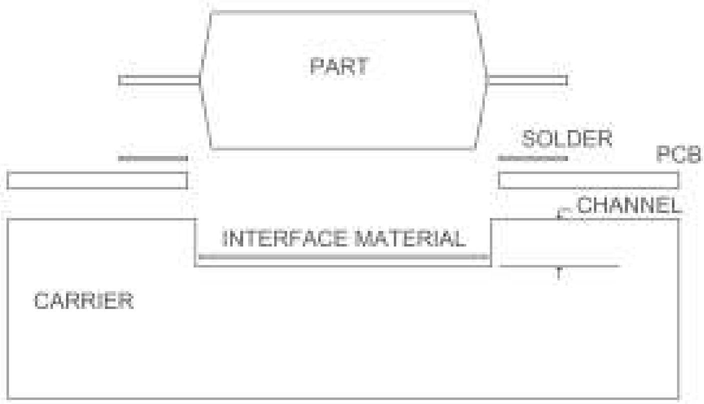

Fig. 1: TO-272 package, PCB, and carrier (heatsink) stack-up. Leads of package make electrical connections to the top of PCB while the bottom of package is in direct contact with the carrier to extract heat from the device.

Fig. 2: TO-272 package successfully qualified by MACOM

Manufacturer / Product	Technology	Thermal Conductivity (W/m-K)
NAMICS / XH9890 series	Ag nano-particles in organic matrix	60-160
Tanaka / Aurofuse TR-191R	Au sub-micron particle paste	150
Loctite Ablestik / SSP 2020	Ag sintering paste	>100
Alpha / Argomax	Ag nano-particle sintering	200-300
Heraeus / mAgic Sintering Material	Ag sintering	150-200
Reference	AuSn	59
Reference	AuSi	190

Table 1: Comparison of sintered silver to other common die attach technologies