5 ACCURATE PREDICTION OF PQFP WARPAGE

5.1 INTRODUCTION

The need to reduce the size and weight of packages is leading to the development of thinner packages with finer pitched leads (Tummala et al., 1997). While reducing package thickness results in lower die compressive stress as illustrated in section 3.9.2, it can lead to an increase in the warpage or bending of these packages when compared to thicker ones. Package warpage affects post-mold steps such as trim and form, and may seriously reduce production yield due to loss of coplanarity (Nguyen et al., 1994). Furthermore, the reduction in die compressive stress means that a tensile stress may be generated on the backside of the die if the package is excessively warped, which in the presence of flaws could lead to die cracks (Chen and Leipold, 1980).

It was shown analytically by Suhir (Suhir, 1993) that it is possible to influence, and thereby minimise PQFP warpage, by adjusting die paddle downset. Die paddle downset is the amount by which the top of the die paddle is depressed below the top of the leadframe, and is illustrated in figure 5.1. The ‘final’ downset of the die paddle may shift during molding, because of the molding pressure, or unequal filling of the mold, indicating that the molding process is not optimised. It is important for package manufacturers to know how sensitive package warpage is to changes in downset, in case tighter controls on the molding process and the die paddle downset are required, to keep post mold warpage within specification. Warpage is often used by manufacturers as an indicator of residual encapsulation stress when developing or evaluating new molding compounds (Oota and Shigeno, 1995). Non-uniform warpage may indicate...
that the die paddle has tilted and that a mold flow related problem occurred during mold filling.

![Die paddle downset](image)

**Figure 5.1.** Die paddle downset.

It is important for package manufacturers to be able to estimate the likely warpage or deformation of packages after encapsulation. Warpage can be readily determined from finite element simulations. In fact the deformed shape of structures is commonly used by structural engineers to help characterise the stress distribution in structures to which external loads have been applied. An accurate prediction of package warpage is likely to yield an accurate prediction of package encapsulation stress. While the aim of simulations is to help minimise package warpage, zero warpage does not necessarily indicate a stress free package, but indicates that the thermal shrinkage forces above the die and below the die paddle are in equilibrium.

Warpage is a quantity that can be easily and repeatably measured by a number of different techniques, such as non-contact laser scanning methods, or by direct contact methods. Often the direction of the warpage can be seen with the naked eye. Warpage measurements can be quickly taken on package samples chosen at random from a production line. It is a low cost, non-destructive quality analysis technique, and avoids the costs associated with the design, manufacture, packaging and assembly of test die with on-chip stress sensors.

The application of F.E. techniques to the prediction of the warpage of plastic packages is described in this chapter. The basic assumption adopted in such analyses is that the package is undeformed at the molding temperature and warpage occurs due to the TCE contraction of the materials as the package cools to room temperature. It is shown that this basic starting assumption can lead to incorrect predictions of package warpage. Measurements of the warpage of a thermally enhanced power package over a range of temperatures indicate that (a) package warpage increases with temperature, and (b) the package is significantly deformed at the molding temperature. This conflict with standard modelling assumptions and basic understanding of package behaviour is attributed to chemical shrinkage of the molding compound. A new F.E. model of package warpage after encapsulation is proposed, which incorporates both the TCE and chemical shrinkage of the molding compound, and leads to more accurate predictions