Package Shift in Plastic-Packaged Bandgap References

Vishal Gupta

Prof. Gabriel A. Rincón-Mora

Abstract

What is package shift?

Offset in voltage of packaged bandgap reference from its unpackaged value.

Why is its elimination critical?

- One of the dominant sources of error in bandgap references.
- Cannot be trimmed conventionally since it is a post-package variation.

Causes of Package Shift

Systematic

- Difference in thermal coefficient of expansion of package and silicon causes a strain on die as system cools from molding temperature.
- Can be accounted for in design phase.

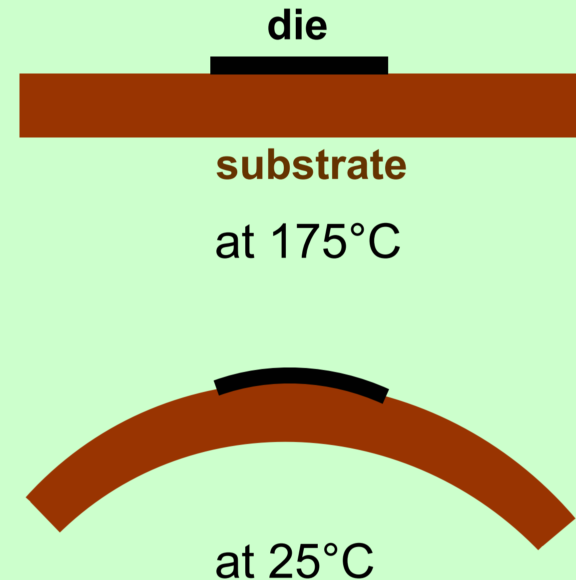
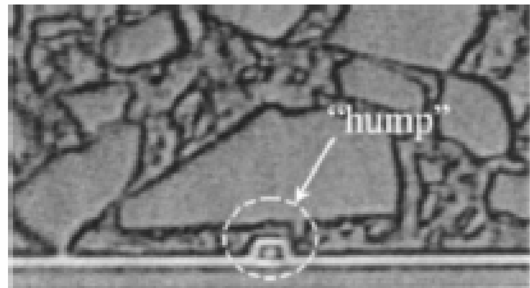


Fig. 1. Systematic stress imposed on die through difference in TCE of silicon and substrate.

Causes of Package Shift



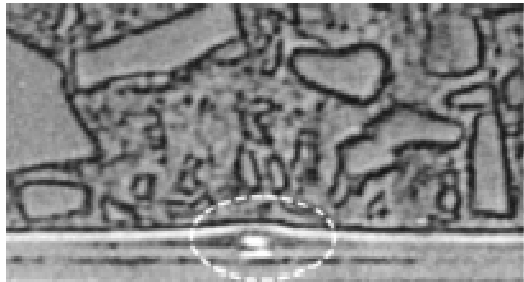


Fig. 2. Cross-sectional images of (a) non-planarized and (b) planarized dies [1].

Random

- Presence of filler in plastic packages produces intense vertical stress due to the pressure of filler particles on die surface.
- Is a random variation that varies from unit to unit.

1. *B. Abesinga, G. A. Rincón-Mora, and D. Briggs, "Voltage shift in plastic-packaged bandgap references,"* IEEE Trans. Circuits Sys. – II, *vol. 49, pp. 681-685, Oct. 2002.*

Characteristics of Package Shift

- Systematic lateral and random vertical component.
- Positive temperature coefficient.
- Typical 3-σ value is 5 - 7 mV.

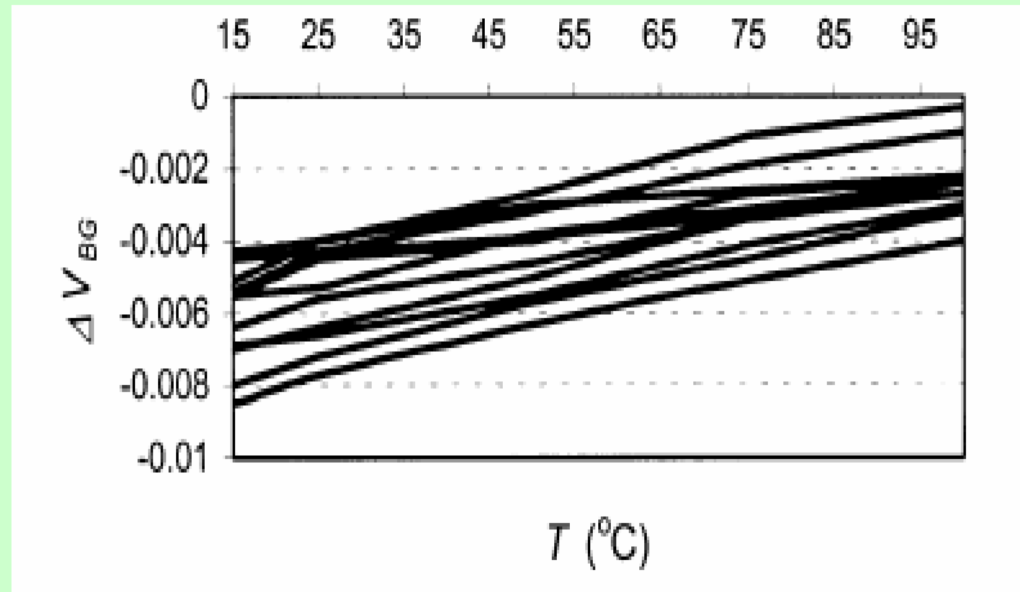


Fig. 3. Variation of package shift with temperature for various samples [1].

1. *B. Abesinga, G. A. Rincón-Mora, and D. Briggs, "Voltage shift in plastic-packaged bandgap references,"* IEEE Trans. Circuits Sys. – II, *vol. 49, pp. 681-685, Oct. 2002.*

Characteristics of Package Shift

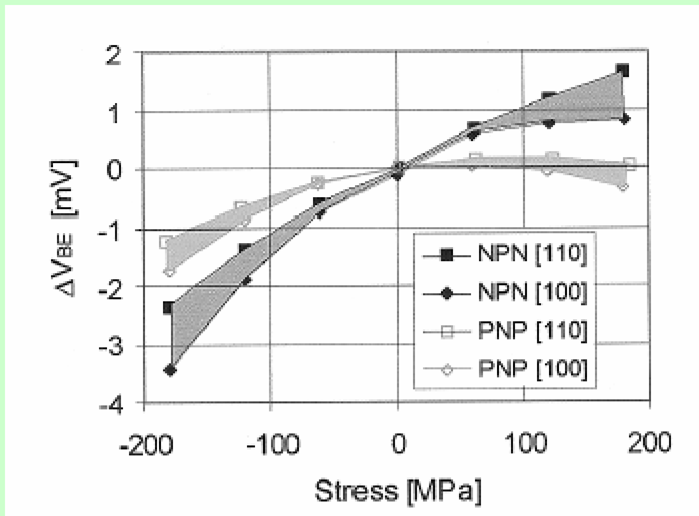


Fig. 4. Change in V_{BE} for substrate NPN and PNP for arbitrary stress orientations [1].

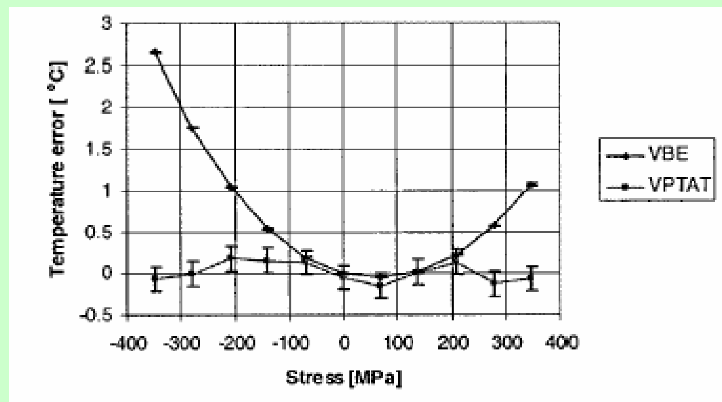


Fig. 5. Temperature error in V_{BE} and ΔV_{BE} [1].

- Vertical PNPs are less sensitive than vertical NPNs.
- Offset in V_{BE} smaller for tensile stress than compressive stress.
- ΔV_{BE} less sensitive than V_{BE}.

1. F. Fruett, G. Meijer, and A. Bakker, "Minimization of the mechanical-stress-induced inaccuracy in bandgap voltage references," IEEE Jour. Solid-State Circuits, *vol. 38, pp. 1288-1291, July 2003.*

Reducing Package Shift

- Dynamic element matching (to average out variations).
- Mechanically compliant layer (to absorb vertical stress).
- Ceramic, metal can packages (no filler).
- Post-package trim.
- Designing for package shift TC.
- PNP devices (less sensitive to lateral stress).

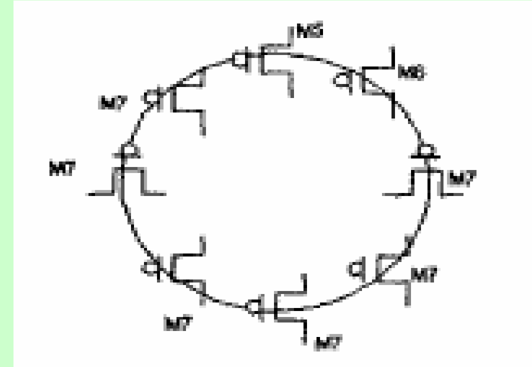


Fig. 5. Cycling devices to reduce random variations [1].

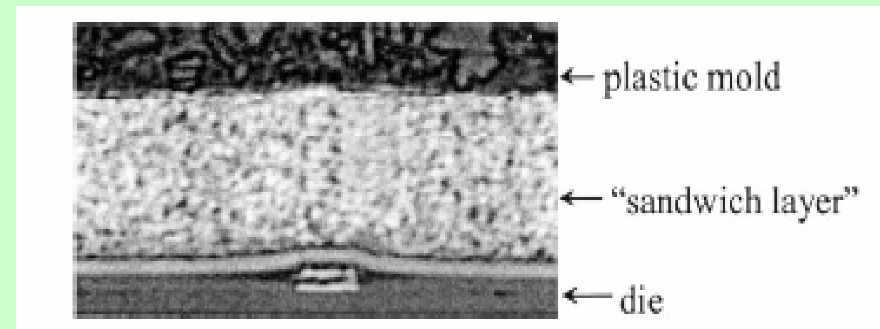


Fig. 6. Cross-sectional image of a mechanically compliant layer die [2].

1. *V. Ceekala,* et. al*, "A method for reducing the effects of random mismatch in CMOS bandgap references" in* ISSCC, *vol. 2, pp. 318-319, 2002.*

2. *B. Abesinga, G. A. Rincón-Mora, and D. Briggs, "Voltage shift in plastic-packaged bandgap references,"* IEEE Trans. Circuits Sys. – II, *vol. 49, pp. 681-685, Oct. 2002.*

Reducing Package Shift

METHOD	INCREASES CIRCUIT COMPLEXITY	INCREASES COST	ERROR COMPONENT COMPENSATED	
			SYSTEMATIC	RANDOM
Dynamic element matching	**Y**	**N**	**N**	**Y**
Mechanically compliant layer	**N**	**Y**	**Y**	**Y**
Ceramic, metal can packages	N	Y	Y	Y
Post-package trim	N	Y	Y	Y
Designing for package shift TC	N	Y	Y	N
PNP devices	N	N	Y	N

Conclusions

- Though the systematic component of package shift can be designed for, the random component is difficult to compensate.
- Current solutions – use of mechanically compliant layer, post-package trim, and/or ceramic packages add manufacturing cost and time to IC.
- Package shift needs to be compensated at circuit and layout level.