Choosing an Underfill Resin to Minimize Cost

Process Cost Savings as High as 90% Can be Achieved by Selecting Underfill Resins That Reduce Processing Time

UV light-curable urethanes flow rapidly and cure in seconds while epoxies and silicones can require hours at 150°C to fully cure. Fillers in epoxies may hinder wicking and flow under dies and around solder joints and heat cure unevenly. Higher viscosity epoxy and silicone resins must be heated in order to allow them to flow and underfill the die. Unless this heat is carefully controlled, the resultant partial cure may increase viscosity, lengthen wicking time, inhibit wetting and underfilling, and increase costs.

Resin Type	Wicking Time	Condition	Cure Time	Condition
Dymax 9001-E V3 Series	15-60 seconds	Room temperature	30-90 seconds	UV/Visible/IR Lamp
Silicone	5-15 minutes	Mix 2 parts, heating required to lower viscosity	1 to several hours	125°C or more
Epoxy	5-20 minutes	Heating required to lower viscosity	1 to several hours	150°C - 165°C

The three distinctly different types of underfill resins - epoxies, silicones, and UV-curable urethanes - use different strategies to eliminate stress and protect circuit integrity.

Only flexible resins with low modulii, high elongation, and gradually sloping TMA (thermal mechanical analysis) curves, provide a mechanism to dissipate thermal and mechanical shock and minimize stress on chips and bonds. Stress minimization also requires that there be no abrupt changes in the underfill resin's physical form. Unless the base resin (not the resin + the filler) has a T_g above or below device operating temperature, abrupt physical change can occur during thermal cycling, resulting in stress.

Flexible Dymax UV light-curable urethane resins reduce stress on solder joints during thermal cycling because their physical dimensions change only gradually when passing through T_g. The T_g is near or below the lower end of typical semiconductor operating ranges.

Epoxies are high T_g (80-100°C) resins that are then highly filled to lower the measured bulk CTE, (not the CTE of the base resin), in an attempt to match the CTE of the substrates. Theoretically, if T_g is above a device's thermal operating range, dimensional change and stress in the device may be avoided. However, silicon, solder, and substrates have a different CTE, making strain on adjacent components all but unavoidable. Rigid, high T_g polymers transfer stresses to less rigid solder bumps, joints and/or chips, potentially leading to failures.

To calculate how a filled epoxy stresses silicon over -55° to 125°C temperature:

Stress=(CTE Resin-CTE Silicon)(Temp)(Modulus)

$\text{Stress}=(20\times10^{-6})\times180\times1.5\times10^{6}=3780\text{ psi}$

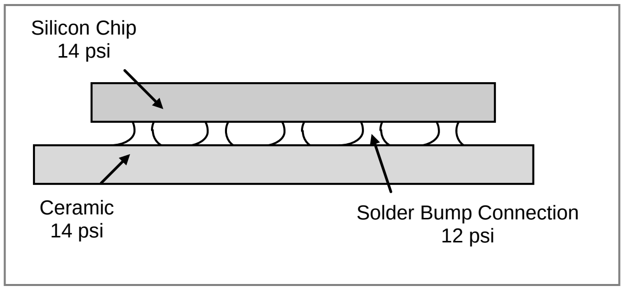
Low Modulus Means Low Stress

Resin	Silicon	Solder	PCB
UV Urethane	14 psi	12 psi	14 psi
Silicone	14 psi	12 psi	14 psi
Filled Epoxy	3,780 psi	2,160 psi	2,170 psi

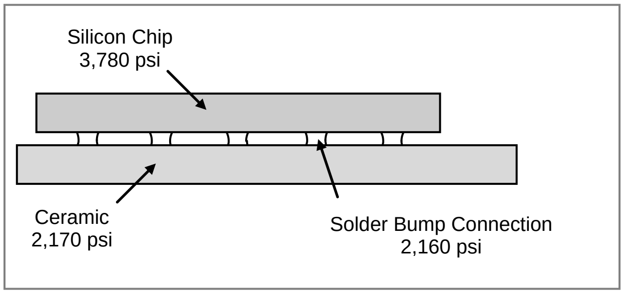
Urethanes and silicones exhibit the inherent advantages of low modulus polymers. Referencing the strain equation, low modulus can be more effective than low CTE in lowering stress. High elongation, soft, flexible underfill resins provide a mechanism, through which mechanical and thermal shock can be dissipated through vibration dampening and expansion of the underfill in the X, Y plane. The figures below compare the calculated differential stresses that high versus low modulus resins can transfer to adjacent component parts over a -55°C to + 125°C temperature range.

Stress on Components Arising From Different Encapsulants

Dymax UV Urethanes & Silicones



Epoxy



UV Urethanes Speed Processing - Lower Cost

Low Viscosity UV Urethanes Speed Flow and Ensure Complete Fill Under the Die

Low-viscosity underfill grades of Dymax UV light-curable urethanes dramatically lower costs by curing in 30-to-90 seconds under special UV/Visible lamps. Processing costs are further lowered because room-temperature wicking eliminates heating and lowers die underfill times to less than 1 minute depending on the size of the device and the number of solder connections.

Voids, especially in the resin/chip or resin/solder interface, concentrate stress and can interfere with the dissipation of thermal and mechanical energy, lowering chip performance. It is more difficult to eliminate voids in high-viscosity resins. The wetting agents in low-viscosity Dymax UV light-curable urethanes help prevent voids in the underfill.

As filled resins are heated, the higher viscosity which is needed for uniform filler suspension is also decreased, creating the potential for leaving agglomerated filler at solder connections. The CTE, therefore, would vary in base-resin areas as compared to “filled” areas, causing major stress in the silicon. Voids and air gaps resulting from incomplete fill represent several potential mechanisms for additional failure sites. Dymax 9001-E V3 Series encapsulants are not filled in order to minimize wick times and avoid filler separation.

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