ENCAPSULATION ADHESIVES

ADVANCED TECHNOLOGY FOR RESEARCH & INDUSTRY

KNOWLEDGE BASE FACT SHEET

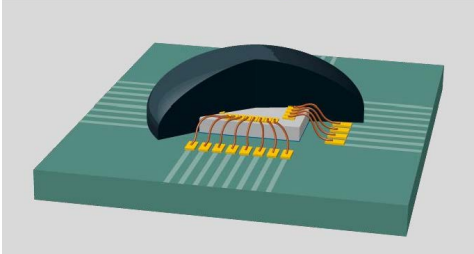
- SCOPE: Knowing which adhesives to use to protect sensitive IC's and wirebonds can be a little bit of a challenge! This article provides an overview of the options available to customers, and advises on how to cure the adhesives, what the properties of the cured adhesives are, and the advantages and disadvantages associated with the different options.

In the microelectronics industry, encapsulation adhesives are used solely to protect bare silicon and the associated wire bonds. There are usually two adhesive sets to choose from – heat-cured or light-cured! However, recent advances from Delo have combined the two curing mechanisms so that in certain instances, it is more beneficial to use these newer adhesives.

Dam & Fill, or Globtop!

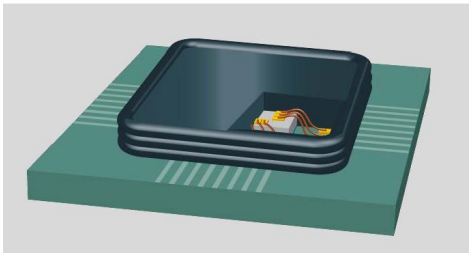
The "globtop" process consists of dispensing an encapsulation adhesive onto the top surface of the silicon and allowing it to form into a dome that covers both the IC and the wirebonds. The globtop is then cured, whether by heat or by light.

Glob top



However, as ICs get bigger, the area to be protected also increases, and then the dome becomes too high to control. In this case, a "Dam & Fill" process is then used: a high viscosity encapsulant adhesive is dispensed around the area to be protected, forming a wall or "Dam". A low viscosity, chemically-compatible encapsulant adhesive is then dispensed into the central area within the Dam, until the whole volume within the Dam is covered – this is the "Fill" process.

Dam&Fill



As a general rule-of-thumb, Globtop is used for areas up to 2mm x 2mm, and then Dam & Fill takes over.

Heat-Cured Encapsulation Adhesives

Inseto's heat-cured encapsulation adhesives are:

Globtop: DELOMONOPOX GE765

Dam: DELOMONOPOX GE785

Fill: DELOMONOPX GE725 & GE727

The properties of these encapsulant adhesives are summarised here:

	DELOMONOPOX				
	GE725	GE727	GE785	GE730	GE765
Application area	fill	fill	dam	glob top	glob top
Color	black				
Filler content [weight %]	65	80	68	65	67
Viscosity [mPas]	6,500	11,000	135,000	9,000	19,000
Processing time [h]	48	24	48	48	48
Curing conditions until final strength	4.5 h @ +100 °C or 1.5 h @ +125 °C or 20 min @ +150 °C				
Tensile strength [MPa]	50	60	55	60	60
Elongation at tear [%]	0.5	0.5	0.5	0.7	0.7
Young's modulus [MPa]	9,800	12,300	11,000	9,000	9,000
Glass transition temperature [°C]	+178	+165	+182	+179	+186
Coefficient of thermal expansion [ppm/K]	25	11	22	24	18
Water absorption [weight %]	0.1				
Halogen-free acc. to IEC 61249-2-21		HALOGEN FREE	HALOGEN FREE		

Note: GE730 is no longer available.

1. Properties of the uncured adhesives

These adhesives come in a range of viscosities depending on the use for which they are designed: low-medium viscosity for Globtop, low viscosity for Fill, and highly thixotropic materials for the Dam. They are normally supplied in 30ml syringes, and dispensed using simple time / pressure systems on X-Y tables – minimising capital expenditure. Because they need to be stored at -18C (and therefore shipped in dry ice), 30ml syringes need to be conditioned to room temperature for up to 60 minutes. **Never** force the thawing process – this induces moisture into the syringe, potentially leading to voids when cured.

Some encapsulation adhesives need the substrate to be heated up to ~80C in order to improve the flowing behaviour of the adhesives. This is not necessary with any of the Inseto materials. In addition, some Dam materials have a relatively low minimum dispense height before they start to slump, especially at the start of the curing process when heat is first added. With the GE785 from Inseto, this is not an issue – tests in the lab have shown that this adhesive is stable up to a height of at least 7mm, and heights of 3mm are standard in production environments.

2. Curing method

These adhesives cure over a wide temperature range: 100C to 180C. Picking which temperature to use will be decided by the materials being protected, and the throughput / cycle time required. The minimum cure temperature is 100C, but the adhesives then need 4.5 hours to cure (not including the time it takes for the adhesive to reach the required temperature). At the opposite end of the scale, they can be cured at 180C for approximately 10 minutes (again, not including heating-up time). Most applications will fall somewhere in between the two – a typical cure schedule is 150C for 20 minutes. Because the speed of cure can have an effect on the properties of the cured adhesive (too fast and stresses can be induced into the adhesive and materials being protected), for some very thin applications using 100C can actually be very beneficial, despite the long cure time.

3. Properties of the cured adhesives

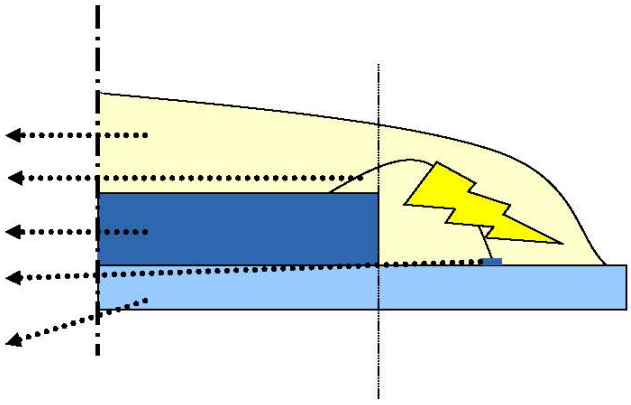
Heat-cured encapsulation adhesives offer the highest reliability of all materials. The properties of Inseto's family of heat-cured anhydride epoxies for Globtop and Dam & Fill are summarised here:

- Standard operating temperature range: -65C to +180C
- Glass transition temperature (Tg): >170C
- Coefficient of Thermal Expansion (CTE): ≤25ppm
- Decomposition temperature: >300C
- Ionically pure: <10ppm Na, Cl, K
- Excellent chemical resistance
- JEDEC MSL Level 1
- RoHS / REACH Compliant

The Tg is very important for High Rel applications in the military and automotive markets, as cycling multiple times across the Tg during the operation of the end-product can have serious repercussions on the lifetime of the part. Every time the Tg is crossed the adhesives softens or hardens slightly, which imparts stress into the adhesive.

Equally important is the CTE, as there are usually multiple CTE's in a typical assembly (FR4 or ceramic substrate, die attach adhesive, IC, wirebonds, and encapsulation adhesive). Therefore, having a CTE that is as close as possible to the CTE's of the constituent parts also helps minimise stress, due to the fact that the finished device contracts and expands with (sometimes severe) changes in temperature. The graphic below shows the range of CTE's possible in a typical application, and illustrates the issues of wire breakages:

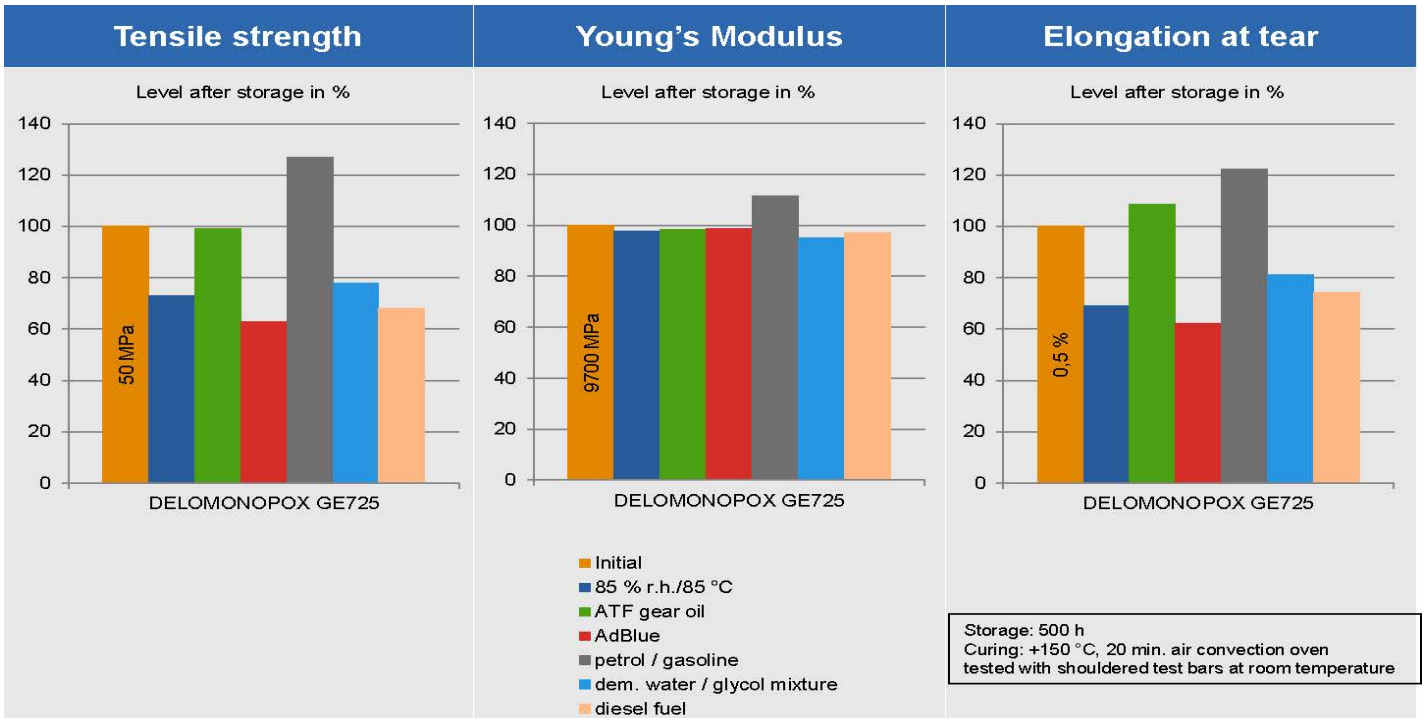
	Material	CTE [ppm/ K]
Encapsulant	epoxy resin	17 – 250
Bond wire	Au / Al	14 / 23
Chip	Si	4
Bond pad	Cu	16
PCB	FR4 / ceramic	10 – 20 / 1 – 3



Because the majority of these adhesives are used to protect bare semiconductors, it is important that any outgassing from the adhesive is kept to a bare minimum. All the encapsulation products in the Inseto range of materials meet this requirement, with measured ionic impurity levels of <10ppm.

As well as protecting the IC and wirebonds from physical damage, encapsulant adhesives also must be able to withstand a wide range of chemicals, including water (one of the most difficult substances to protect against!). Inseto's encapsulants all meet the highest level of moisture resistance, JEDEC's MESL 1 standard. A phenomenon known as popcorning can happen and cause catastrophic device failure. If moisture gets into the encapsulant, it can expand during hot temperature cycling and cause the adhesive to bubble. If this gets too extreme, the bubbles "pop", just like popcorn!

Equally important is the adhesives resistance to a range of chemicals, e.g. those encountered in the automotive industry – oil, petrol, AdBlue, diesel, etc. The illustration below shows just how chemically resistant these adhesives are:



Light-Cured Encapsulation Adhesives

The overall purpose of light-cured encapsulants is the exact same as heat-cured encapsulants: to protect the IC and the wirebonds. The major difference is that the light-cured adhesives do not meet the highest reliability properties of the heat-cured adhesives, so they are used in less demanding applications such as Smart Card manufacture.

Inseto's heat-cured encapsulation adhesives are:

Globtop: DELO-KATIOBOND 4670
Dam: DELO-KATIOBOND DF698
Fill: DELO-KATIOBOND 4670 (4670 is suitable for both Dam & Fill and Globtop)

1. Properties of the uncured adhesives

The Dam is highly thixotropic and therefore must be dispensed from a large volume (800Gm) cartridge. Therefore a pressure tank plus a simple pinch valve must be used with this adhesive, using an X-Y table to manoeuvre the substrate. The Fill is available in 1,000ml bottles, so a pressure tank is required for this also. However, unlike the heat-cured encapsulants, the light-cured ones need only to be stored in cool conditions, at <10C. So significant savings can be made on transport (dry ice) and storage containers.

2. Curing method

These adhesives are cured by UVA light between 320nm to 400nm. High intensity LED lamps must be used, as sunlight will only harden the adhesives and will not provide any bond strength. Cure times are <20 seconds at an intensity of 160mW/cm^2. While there is extra investment required for the LED lamps (<£10K), the significant advantage of light-curing over heat-curing is process time. For medium to high volume applications, the added cost of

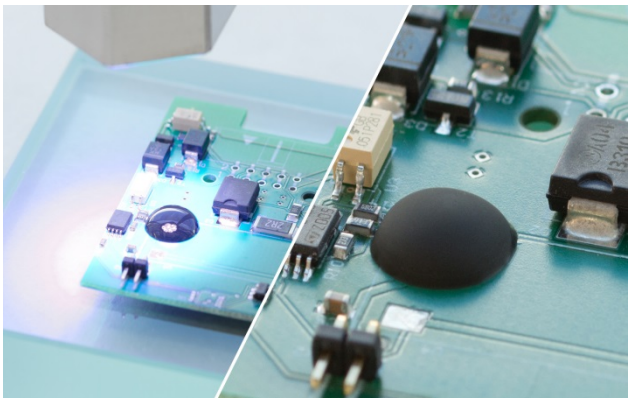
dispensing equipment and LED lamps is soon recouped, and process time and cost is significantly cheaper.

3. Properties of the cured adhesives

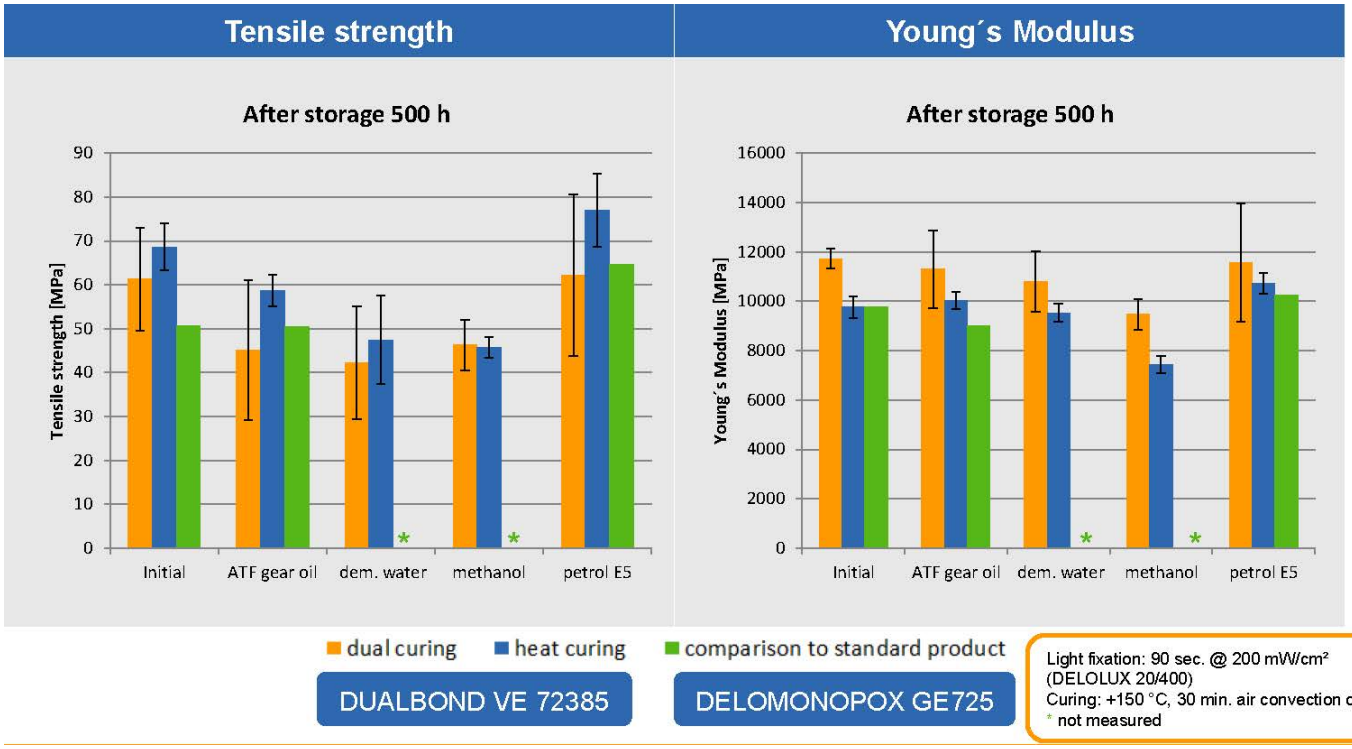
While light-cured encapsulation adhesives do not offer the same “highest reliability” that is achieved with the heat-cured adhesives, they are suitable for all other applications.

Light-Fixed, Heat-Cured Encapsulation Adhesives

In keeping with other very recent developments in the field of dual-curing adhesives, a light-fixing component has been added to the heat-cured matrix of the High Rel encapsulants to enable fixing in place of the encapsulation adhesive, followed by a subsequent (mandatory) heat cure of the adhesive. This prevents **ANY** movement of the encapsulant, whether it is Globtop or Dam & Fill, between the initial dispensing process and the hardening of the adhesive.



The curing process is a combination of the two already outlined: UV flash on the surface for 5 seconds at 200mW/cm^2, and then oven cure at 150C for 30 minutes. Comparisons against the existing GE725 Fill show no degradation in chemical resistance:



Conclusions

For optimum protection for bare semiconductors over extended periods of time in the most demanding applications, the best option is to use heat-cured encapsulation adhesives. They offer significant advantages over light-cured products, and are easier to process (if not as quick!). For less demanding applications, and where volumes are so high that very short cycle times are required, then light-curing the adhesives offers a significantly better choice.

New developments, both recent and in the near future, that combine the best of both worlds, should also be considered.