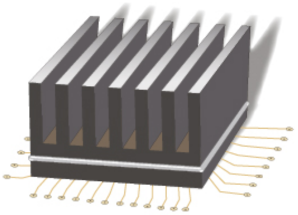
Understanding How to Choose an Appropriate Thermally Conductive Epoxy

WHAT

Understanding how to choose a thermally conductive epoxy

WHY

Knowing how to choose an appropriate thermally conductive epoxy will lead to the best thermal performance in a final device.



THERMAL INTERFACE MATERIAL (TIM)

Epoxies are traditionally considered to be thermally insulative with typical thermal conductivity values of 0.1-0.2 W/mK. To create a more thermally conductive adhesive, filler systems are added to allow heat to flow more quickly through the cured matrix. Depending on the type of filler system used, cured epoxy can have a resulting bulk thermal conductivity measured anywhere from 0.5 W/mK to upwards of 35 W/mK. Filler system choices can sometimes be limited due to application requirements.

How Does Thermal Conductivity Work in an Epoxy?

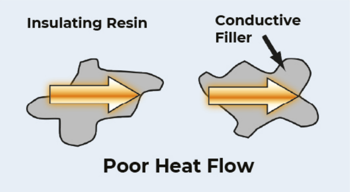
Regardless of filler type, the mechanism of conductivity is the same. Each filler particle needs to be in good contact with each other, to form a sufficiently conductive pathway. This is very similar to how electrical conductivity works with silver flakes. The particles (or flakes) are able to maintain good contact with each other through proper curing.

Hotter and faster cures will result in more shrinkage which pulls the filler particles closer together (yes, shrinkage can be a good thing). It is important not to go too high in cure temperature to avoid creating a large exotherm. Lower temperature cures will, subsequently, have less shrinkage and less particle contact. This leaves more non-conductive resin in between the filler particles, and slows down the flow of heat. Larger particle-sized fillers tend to achieve higher thermal conductivity due to this concept.

Impact of Cure Conditions on Thermal Conductivity

Uncured Adhesive

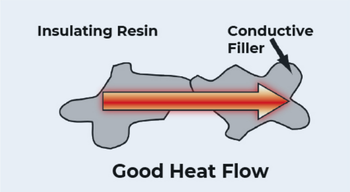
No Particle Overlap/Contact



High Resistance/
Low Thermal Conductivity

Properly Cured Adhesive

Optimal Shrinkage/Good Contact



Low Resistance/
High Thermal Conductivity

Important points to remember concerning cure temperatures:

Too low will result in a slow cure, low shrinkage and low thermal conductivity.

Too high can cause high exotherm that may introduce voids and cause the system to expand rather than shrink. Voids can cause low conductivity.

Proper cure conditions allows for optimal shrinkage with maximum thermal conductivity and particle overlap.

Levels of Thermal Performance

High Thermal Conductivity *and* Electrically Conductive

The majority of electrically conductive adhesives (ECAs) utilize silver fillers. This allows for high electrical conductivity and superior thermal conductivity, since silver has a much higher conductivity itself, over non-conductive fillers. These types of materials are able to achieve >10 W/mK. Applications that do not have a restriction to using electrically insulating material will benefit from this type of epoxy system. Since these products contain high levels of a precious metal, they are supplied at a higher cost.

High Thermal Conductivity *and* Electrically Insulating

In applications where electrical conductivity is not permitted, a user can still get improved thermal performance using thermally conductive epoxies only. These epoxies can achieve thermal conductivity ranging from 1-5 W/mK. The trade-off with using some of these materials over the standard thermally conductive line is that most, with some exceptions, tend to have very large filler particles. The large size of the filler particles are what help maintain conductivity by decreasing the amount of space between the particles. Unfortunately, this can also cause the material to have very high viscosity; making them hard to dispense and difficult to get the material into tight areas. That said, they are still a great choice for heat sinking or potting.

Standard Thermal Conductivity

Most thermally conductive adhesives have a thermal conductivity between 0.5 and 1 W/mK. While that may not be much higher than a thermally insulating epoxy, it can be enough to provide adequate cooling in many applications. Other advantages are that these materials tend to be very easy to work with due to their lower viscosities and can be easily dispensed or printed. They can be an excellent choice for anything from die attach to thermal potting.

Representative EPO-TEK® Thermally Conductive Epoxies

EPO-TEK® PRODUCT	CURE SCHEDULE	THERMAL CONDUCTIVITY (W/mK)
HIGH THERMAL CONDUCTIVITY, ELECTRICALLY CONDUCTIVE		
EK1000	150°C/ 1 hour	12.6
	150°C/ 1 hour + 200°C/ 1 hour	26.3
	125°C/ 2.5 hours + 150°C/ 36 min + 200°C/ 15 min	35.5
H20E	150°C/ 1 hour	2.5
H20E-HC	150°C/ 1 hour	10.9
	150°C/ 1 hour + 200°C/ 1 hour	23.0
HIGH THERMAL CONDUCTIVITY, ELECTRICALLY INSULATING		
930	150°C/ 1 hour	4.57
930-4	150°C/ 1 hour	1.67
T7109	150°C/ 1 hour	1.5
T7109-19	80°C/ 2 hours	1.3
T905BN-3	80°C/ 2 hours	2.02
STANDARD THERMAL CONDUCTIVITY, ELECTRICALLY INSULATING		
H70E	150°C/ 1 hour	0.9
H77	150°C/ 1 hour	0.66
T7110	80°C/ 2 hours	1.0

The recommended cure listed on the datasheet should be used to achieve maximum thermal conductivity. The datasheet may also detail where a change in cure condition can dramatically impact thermal conductivity.

REACH COMPLIANCE

RoHS COMPLIANT

MIL STD 883/5011 COMPLIANT

ISO 9001 COMPLIANT

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