Controlled Viscosity Molding (CVM) is a Game Changer for Thermal Management in Electronic Systems

INTRODUCTION

All electronics generate heat, and over time, heat builds up, creating the potential for premature failures. That's why thermal management is crucial for the long-term reliability of electronic systems.

The evolution of electronics has been astounding, from early electronic circuit boards of the 1960s to today's highly integrated microcircuits, the trend toward smaller, more functional devices has created a surge in power densities and heat. As electronics expand into nearly every facet of society making life easier, more convenient, and safer, the increasing demand for cost-effective and energy-efficient thermal management solutions requires urgent attention.

The pursuit of practical solutions to the complex thermal challenges of today's electronics has led to a lot of scientific research and a number of innovations. For example, the development of ultra-high performance thermally conductive polymer composites is of significant importance to the electronics industry. However, by incorporating thermally conductive fillers, such as ceramic or metal particles, into polymers, the viscosity of polymer materials changes in ways that make them difficult to mold using conventional injection molding equipment. This has limited the shape, form, and application methods that can be used, until now.

An innovative Controlled Viscosity Molding (CVM) technology, developed by X2F, is delivering impressive results, enabling molding of ultra high-performance thermally conductive polymer composites, previously thought to be impossible to mold. CVM technology is providing a game changing, cost-effective and time-efficient over-molding solution that not only dissipates heat, but also protects electronic components from environmental contamination and mechanical stresses such as shock and vibration.

Figure-1: Overmolded automotive component with thermally conductive polymer

TRADITIONAL COOLING METHODS

Electronics are cooled in many ways and the method used can be classified as either "active" or "passive." Active cooling requires energy to operate and includes equipment such as pumps or fans to circulate liquid or air. On the other hand, passive cooling doesn't need a power source, dissipating heat naturally using heat sinks, heat spreaders, heat pipes and thermal interface materials (TIMs).

Installing a fan inside a system to move air over electronics is an active cooling technique. In this scenario, heat is dissipated by forced air convection. Although fans are effective, they tend to be large, and their use is restricted as the electronic industry moves toward smaller form factors. Additionally, fans inadvertently introduce vibration into the system, which can lead to undesirable fatigue-stress cracks, fractures, and failures.

Mounting a metal heat sink to the outer casing of a heat-generating component is a passive cooling technique. TIMs such as thermally conductive pads or adhesives are needed at the interface between the heat sink and the component to fill microscopic air gaps and improve thermal conductivity. Designed with fins or other protrusions, heat sinks increase the surface area of the component to be cooled, transferring heat by conduction from the component through the TIM to the heat sink. Then natural air convection through the metallic fins further dissipates heat from the system. Although this method is widely used it involves multiple manufacturing steps, materials, and parts that increase manufacturing complexity, assembly time and cost.

CONTROLLED VISCOSITY MOLDING (CVM) TECHNOLOGY BY X2F

CVM technology is revolutionizing traditional thermal management strategies by enabling over-molding of electronics with ultra high-performance thermally conductive polymers that were previously thought to be impossible to mold.

The X2F CVM approach to overmolding electronics combines patented hardware, sensors, and software to control the viscosity of ultra-high-performance materials and optimize mold pressure. Heat is generated electrically for continuous temperature control, and a multi-step "pulse-pack" extrusion process is used to fill the mold. By continuously sensing mold cavity pressure and deploying its low pressure "pack-hold-and-repack" process, X2F builds to the optimal mold pressure for the application. As a result, X2F can wrap the complex contours of components and printed circuit boards (PCBs) with highly filled ultra high-performance thermally conductive polymers without damaging sensitive components.

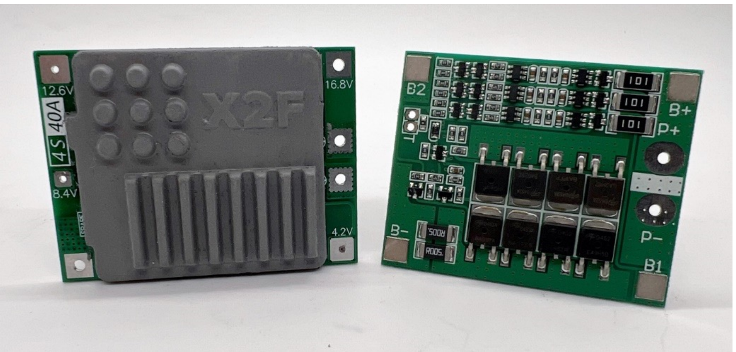


Figure-2: PCB with X2F's CVM overmolding (left) ; PCB without overmolding (right)

CVM BENEFITS

Implementing a CVM thermal management strategy not only protects sensitive electronics from thermal stresses, but also creates a barrier that protects electronics against environmental contamination, vibration, shock, and electrostatic discharge (ESD). Consequently, CVM replaces multiple protective materials and processes, including conformal coating, potting, encapsulation, gap fillers, gap pads, and structural adhesives, significantly reducing manufacturing time, complexity, and cost.

Utilizing CVM technology enhances design flexibility. It supports compact and integrated circuit designs and can mold intricate shapes and features such as heat sink fins and thermal vias directly into the over-mold. Integration of cooling features directly into the over-molding enhances the overall thermal performance of the device while eliminating the need for additional assembly steps and reducing the weight of the final assembly.

TESTING CVM TECHNOLOGY WITH DIFFERENT POLYMERS

To demonstrate the effectiveness of using CVM overmolding technology to over-mold thermally conductive polymers for enhancing thermal performance, X2F conducted a study that measured temperatures on four printed circuit boards (PCBs).

CVM TEST SETUP

PCBs were setup as follows:

- PCB 1: This “baseline” board had no overmolding material and no thermal management solution applied.
- PCB 2: This board was over-molded using CVM technology and a standard low-pressure molding material without fillers and with a thermal conductivity (TC) of 0.2 W/mK.
- PCB 3: This board was over-molded with a thermally conductive polymer composite with fillers and a TC of 0.8 W/mK.
- PCB 4: This board was over-molded with a highly filled ultra high-performance thermally conductive polymer composite with a TC of 2.0 W/mK.

Type J thermocouples were soldered to the back of each board, on the bottom-middle pad, and plugged into a thermometer.
A power supply was attached to each board to control current.

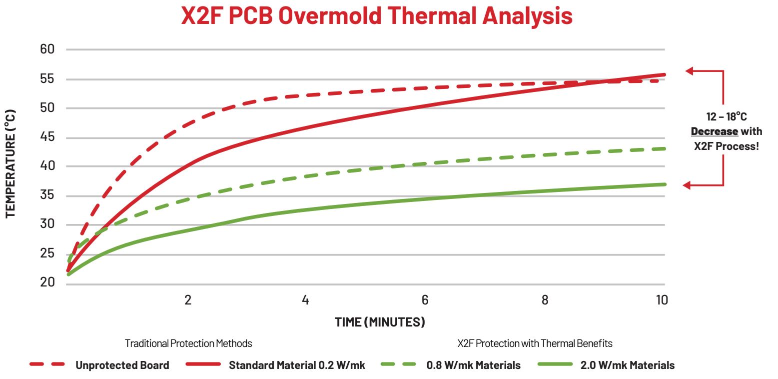
CVM TEST PROCEDURE

270mA of current was applied to each board for 10 minutes. Temperature readings were taken every 10 seconds over the 10-minute period. Temperature readings were plotted graphically for each PCB tested.

CVM TEST RESULTS

The test results shown in Graph 1 clearly demonstrate improved thermal performance for PCBs over-molded with polymers that contain thermally conductive fillers.

- CVM overmolding with highly filled thermally conductive polymer composite material (TC of 2.0 W/mK) excelled in this study, reducing PCB temperature to 45°C compared to the PCB temperature with no thermal management solutions (90°C).
- CVM overmolding with moderately filled thermally conductive polymer composite material (TC of 0.8 W/mK) reduced PCB temperature to 62°C compared to the PCB temperature with no thermal management solution (90°C).
- In contrast, the PCB over-molded with the standard polymer, without fillers, worsened the PCB thermal performance, increasing PCB temperature to 93°C compared to the PCB with no thermal management solutions (90oC), effectively impeding thermal conductivity in the system.


X2F PCB Overmold Thermal Analysis

CONCLUSION

CVM technology is revolutionizing thermal management by enabling overmolding of electronics with ultra high-performance thermally conductive polymers that were previously thought to be unmoldable.

CONCLUSION – CONTINUED

Manufacturers from a wide variety of industries now have the opportunity to realize several high-value benefits of CVM overmolding technology. From superior heat dissipation and the ability to mold complex shapes and features, to enhanced protection from dust, moisture, contaminants, vibration, shock, and ESD, CVM is creating lighter, stronger, more reliable, and affordable electronics while reducing overall production time and manufacturing costs.

Overmolding electronics with thermally conductive polymer composite materials is particularly beneficial for high power applications such as LED lighting, power electronics, automotive electronics, high-speed computing, data centers and 5G telecommunications, where compact, effective, and efficient thermal management solutions are crucial to meeting high reliability requirements.

X2F.com

ABOUT X2F:

X2F, based in Loveland, CO., is commercializing a new category of molding technology that leverages controlled viscosity and a patented pulse-packing approach to create high-value components for a variety of industries. X2F's process uses advanced materials previously thought impossible to mold and achieves complex product geometries with improved operational efficiencies. The technology creates entirely new paradigms in product design, tooling, and material science for molded parts.

Initial target applications include over molding of delicate electronics and circuitry, highly filled engineering resins, and polymer-based optics with improved properties. The company has financial backing from Atlas Innovate with senior advisors that include the former CEOs of General Motors and Dow Chemical. For more information, visit www.x2f.com.

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