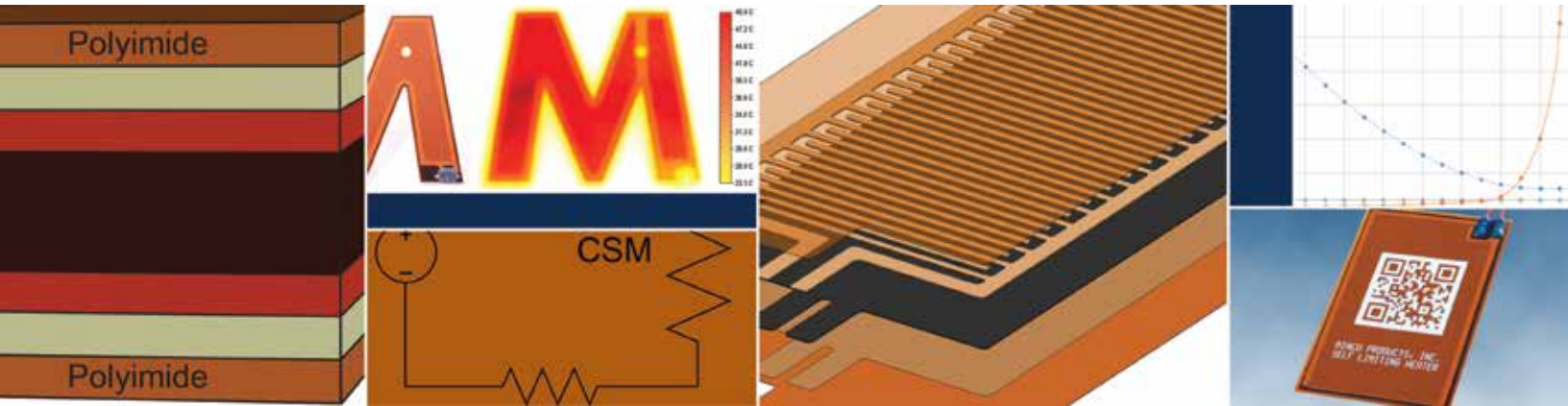


# SmartHeat SLT™ Thin-film Heaters



Thermostatic Control at the Molecular Level

**MINCO**

# SmartHeat SLT™: Temperature Control Was Never this Easy

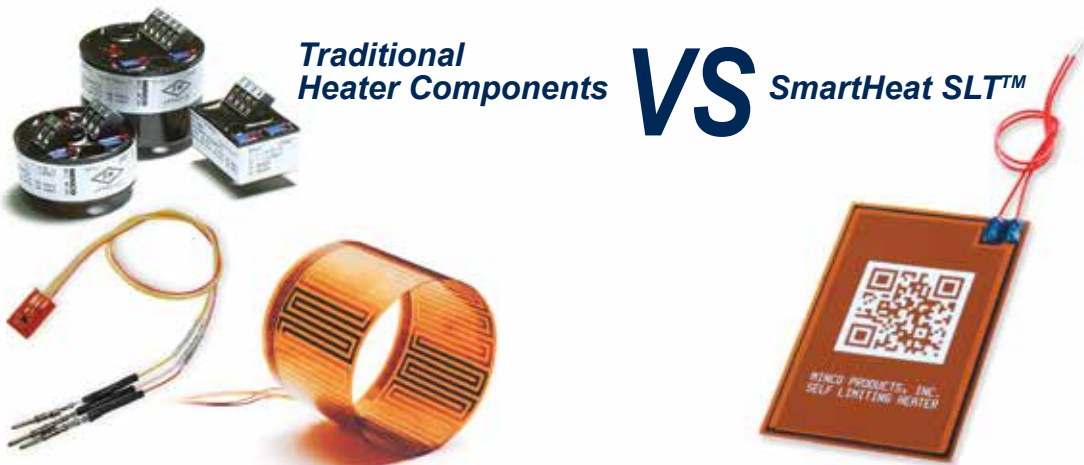
Temperature is critical to a variety of mechanical, chemical, and biological processes. From the cold of space to the halls of a modern hospital, developers build in heating to keep products and systems running properly. SmartHeat SLT™ uses a patented polymer compound to produce a thin film heater that controls temperature without external sensors or controllers.

## SmartHeat SLT: Simple, Stable and Safe

SmartHeat is the ideal solution for many of today's most demanding heating applications. It provides a plug-and-play heating solution requiring only a power source. Each heater operates to a specific temperature and power based on its unique design. The heating power is applied and modulated at infinite points across the entire heating surface based on the heat load. This allows the heater to provide the required power, up to but never exceeding the designed temperature and protecting both the heater and its heat sink.

## Simplicity

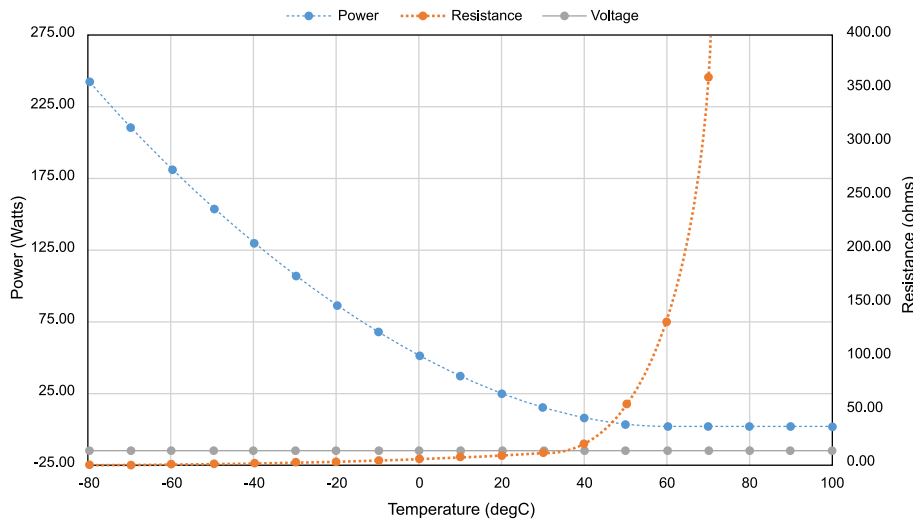
Each SmartHeat solution is designed and manufactured to achieve and maintain a specific temperature. Because of this, SmartHeat is unique in requiring no external sensor or controller. Every point on the heater's surface acts as heater, sensor, and controller. The resulting all-in-one design greatly simplifies your bill of materials and assembly of your final product. As a self-contained unit, SmartHeat is more reliable, combining the functions of a controller, a sensor, and a heater system in one component.



*SmartHeat is a simple self-contained solution, providing a more robust and compact design in comparison with traditional resistive heater and control systems.*

## Stability

From a cold start, SmartHeat initially provides maximum power to quickly reach its designated operating temperature. As it approaches the operating temperature it will sharply reduce power output and slow heating. When the operating temperature is reached, SmartHeat provides only the power required to maintain thermal equilibrium, eliminating any temperature overshoot. Once thermal equilibrium is achieved, SmartHeat responds to any changes in the environment to maintain the operating temperature across the entire device surface. The heater will adjust power output as necessary at each point across its surface to maintain uniform temperature. A traditional heater, where power output is typically controlled by a single sensor feedback loop, is unable to compensate for localized transient variations and can lead to non-uniform temperatures.



*Polymer resistance increases to reduce power draw as target temperature is reached.*

### Safety

SmartHeat is self-limiting, meaning it can never exceed the designed safety temperature. This is particularly important in applications in which overheating can damage equipment or impair the operation of the system. It prevents damage due to heater delamination or drastic changes in environmental heat loads. If a heater becomes delaminated, a traditional heater would over-temp and either create a hot spot or drive to failure. The SmartHeat material on the other hand will simply lower the power output to the delaminated area and maintain its set-point.

This is also true for drastic changes in environmental conditions, such as a sudden loss of liquid in a heated container. If a traditional heater encountered an empty or partially empty container or vessel the reduced heat loss from the heated surface may not be adequate, causing the traditional heater to overheat. This will not happen with the SmartHeat material. It will lower its power output and maintain its design set point.

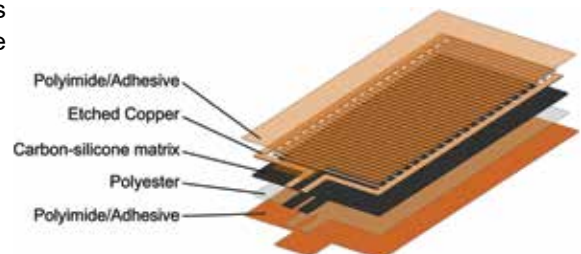
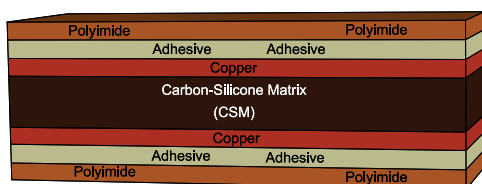
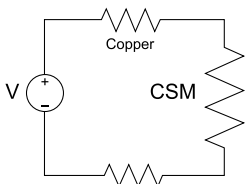
Loss of heating function can also be risky. Unlike a traditional heater, a damaged SmartHeat heater is unlikely to be completely shut down by physical damage. In most cases physical damage will only shut down the damaged area of the heater, allowing it to continue functioning at a reduced level. In some cases, the functioning area will draw increased power to compensate for the damaged area, which does not heat. Overall, SmartHeat is the better choice for applications in which both heater failure and overheating must be avoided.



*SmartHeat SLT heater intentionally damaged by a hole punch (left, visual image). Heater is shown to continue operating in areas surrounding the damage (right, thermal image).*

### SmartHeat Construction

The multilayer construction of SmartHeat allows power to be delivered to the entire surface of the carbon-silicone matrix (CSM). The CSM layer determines the power draw at each point to equalize heating across the entire surface. If a higher heat load is seen at one section of the heater, the CSM will lower local resistance, allowing more power to flow to that section, bringing temperature of the area back up to its set point. The CSM and copper material (SLT foil) are encased in the same polyimide material Minco's traditional heaters are made of to provide a protective electrical insulative layer.



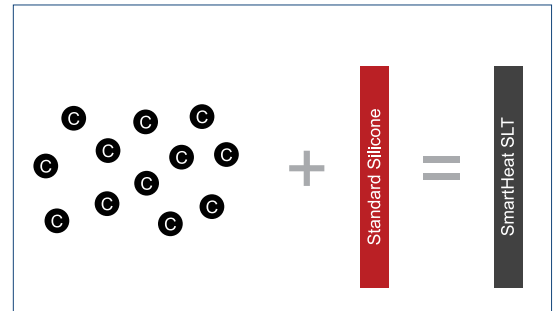
*SmartHeat incorporates the functions of sensor, controller, and heater into a compact, thin-film form factor.*

## How it Works

SmartHeat SLT consists of a thin silicone matrix loaded with conductive carbon particles. Electrical current moves between the carbon particles via quantum tunneling of electrons through the non-conductive silicone material. The electrical resistance of the material and the current it can carry at any point is determined by the spacing between the carbon particles, and that the spacing changes with temperature.

As the silicone warms, thermal expansion drives the carbon particles farther apart and increases resistance point-by-point over the surface of the heater. At the designed set-point temperature the heater effectively becomes an electrical isolator, drawing negligible current, and no longer producing heat. Conversely, if the silicone cools via environmental or load variations, the carbon particles pull closer together reducing resistance. This allows localized increased current flow and the heater to produce more heat at that location as needed to maintain thermal equilibrium.

These effects drive the self-limiting nature of this technology without the need for external instrumentation and control systems. By controlling the composition of the carbon-silicone matrix in production, the heater is designed to approach, but not exceed, a specific temperature set point. When the heater is powered, it warms to its designed temperature set point and maintains that temperature within a narrow band.



*Carbon particles diffused through a silicone matrix move apart due to thermal expansion of the matrix, increasing electrical resistance and reducing power flow.*

## Applications

Many applications can benefit from the simplicity and reliability of SmartHeat. Some examples include:

- ▼ Keeping batteries warm and condensation-free for maximum output
- ▼ Humidifying respiratory equipment for patient safety and comfort
- ▼ Safe storage of reagents for accurate analysis
- ▼ Defrosting of displays for clarity and readability
- ▼ Defrosting LEDs for safe, clear lighting
- ▼ Deicing infrared lenses for reliable signaling
- ▼ Sensor anti-icing for effective function
- ▼ Valve warming to maintain liquid flow
- ▼ Low-weight deicing of aircraft wings for safe, reliable operation

## The SmartHeat Advantage

SmartHeat may be the perfect heater for your application.

- ▼ Custom designed to maintain a set-point temperature with no programming required
- ▼ Compact design for simplified manufacturing and use in today's miniaturized devices
- ▼ Point-sensitive control for even heating and fast response to environmental change
- ▼ All-in-one design for reduced purchase and assembly cost
- ▼ High reliability for reduced maintenance and repair cost

## Limitations of Traditional Heating Components

Traditional heating components can be very effective at maintaining heat, but they have limitations.

- ▼ Even if the heaters themselves are compact, they require external sensors and controllers, which increase cost, add weight, take up space, and increase system complexity.
- ▼ Connections to sensors and controllers complicate product assembly and become potential points of failure requiring costly maintenance and repair.
- ▼ They are either on or off and don't respond to local changes in temperature unless designed with multiple, separate zones.
- ▼ A variety of faults such as delamination or drastic changes in heat losses can lead to dangerous overheating.

Simple. Stable. Safe. SmartHeat SLT™

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