

## Thick Film Heaters on Ceramic Now Available Aluminum Nitride and Alumina

Watlow's thick film heaters on ceramic provide superior thermal characteristics, small heater profile, chemical compatibility and ultra-pure materials which are critical to successful wafer processing, testing, and packaging. Aluminum Nitride (AlN) and Alumina (Al<sub>2</sub>O<sub>3</sub>) are preferred heater materials for many semiconductor applications.

Watlow has developed specialized processes using hybrid thick film materials to manufacture precision heater circuits on Aluminum Nitride and Alumina substrates. Thick film heaters on ceramics can now be designed with multiple circuits and ramp rates of up to 40°C (104°F) per second depending on the substrate material and application details. Thick film on ceramic is capable of high operating reliability at temperatures of 300°C (572°F) for Aluminum Nitride and 500°C (932°F) for Alumina. Contact the factory for details of ongoing extensions to both of these capabilities.

Temperature uniformity, rapid response and thickness down to 1.27 mm (0.050 in.) for 300 mm pedestal heaters make Aluminum Nitride the preferred heater material for many semiconductor applications. Watlow thick film technology gives designers the capability of multi-zoning the heater for optimum temperature performance.

Alumina, a widely used semiconductor material due to availability, relatively low cost and stable physical properties is a well established material for use in demanding semiconductor applications. It is relatively easy to fabricate into a range of shapes while remaining strong at high temperatures. It is available in purity levels of 96 percent.

### Specifications

- Maximum operating temperatures of 300°C (572°F) for Aluminum Nitride and 500°C (932°F) for Alumina
- Voltages of up to 480V~(ac)
- Watt densities up to 23.25 W/cm<sup>2</sup> (150 W/in<sup>2</sup>) for Aluminum Nitride and 3.56 W/cm<sup>2</sup> (23 W/in<sup>2</sup>) for Alumina
- Ramping capabilities of up to 40°C (104°F) per second
- Flat shapes of up to 355.6 mm (14.0 in.) square
- Cylindrical shapes of up to 50.8 mm (2.0 in.) in diameter
- Thickness from 0.5 mm (0.025 in.) up to 12.5 mm (0.500 in.)



### Features and Benefits

#### Multiple circuit design capability and heater patterning

- Optimize heater performance for a specific application and precise temperature profile
- Multi-zone capability

#### High thermal conductivity materials

- Rapid thermal response in applications requiring fast heat up and cool down
- Promotes uniform surface temperature

#### Thin ceramic substrate

- Allows heater to be designed with a lower profile
- Reduces heater mass for faster thermal cycling

#### High dielectric material and thick film system

- Ideal for applications requiring high isolation resistance

#### Material compatibility

- Ideal for most ultra-pure semiconductor applications
- Ideal for use in demanding applications

### Applications

- Wafer pre-heat bake stations
- Photolithography track systems
- Annealing
- Wafer probers
- Chip bonding
- IC test
- Atmospheric rapid thermal processing



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## Case History

### Thick Film Heaters Provide High Temperature Ramping

**Application:** Atmospheric Rapid Thermal Processing (RTP) for Wafer Processing

A Semiconductor OEM was redesigning a single wafer-processing tool for improved performance. One key step in the process was the annealing of a copper ECD layer onto the wafer surface. This customer was attempting to:

- Minimize wafer processing cycle time in order to improve process reliability
- Maximize output while also achieving thermal uniformity on the wafer

The wafer needed to be loaded at a low temperature, quickly heated to 250°C (482°F) for approximately 30 seconds in a controlled environment, then cooled utilizing a thermal reactor capable of rapidly heating and cooling the wafer. Maximum temperature capability was specified at 450°C (842°F).

#### Solution:

Watlow's answer to this challenge was a low mass thick film heater printed on an aluminum nitride substrate. Aluminum nitride was a particularly good substrate choice because coefficient of thermal expansion closely matches that of silicon while the thermal conductivity is close to that of aluminum. Multiple thick film heater circuits were specially designed to provide optimal thermal uniformity during transient and steady state conditions.

#### Reasons for Success:

- Low profile product design minimized space requirements
- Very fast thermal response (higher watt density)
- Excellent thermal uniformity on the wafer
- Substrate and Watlow films were compatible with the customer's process.
- Greater operating efficiency
- High product reliability
- Innovative technology

## Ceramic Substrates Material Comparison Chart

|   | Aluminum Nitride (AlN)  | Alumina (Al <sub>2</sub> O <sub>3</sub> ) 96 Percent Purity                            | Type 430 Stainless Steel  |
|---|---|--|---|
| Description   | Good strength and thermal conductivity; excellent thermal stability and dielectric properties | High mechanical strength and temperature resistance; high chemical and wear resistance | Ferritic stainless steel; moderate cost; good thermal stability |
| Dielectric Constant   | 8.9   | 9.8  | N/A   |
| Dielectric Strength (V/in) @ 25°C   | 3.18E+05  | 2.39E+05   | N/A   |
| Electrical Resistivity (ohm ft) @ 25°C  | 3.28E+13  | 3.28E+13   | 1.96E-06  |
| Specific Heat (BTU/lb °F)   | 9.60  | 11.41  | 0.11  |
| Thermal Conductivity (BTU/ft hr °F)   | 98  | 17.91  | 15.08   |
| Coefficient of thermal expansion (ppm/°C for ceramics, cm/cm°C for stainless steel) | 4.3   | 10.2   | 5.8   |

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