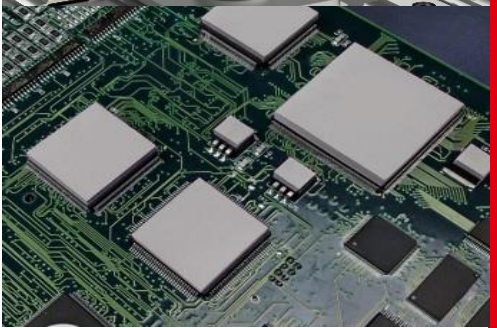


HIGH CONDUCTIVITY, SILICONE-FREE, THERMAL GAP PADS

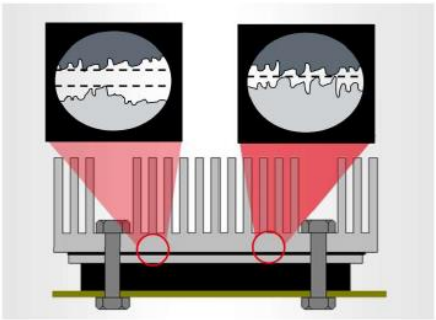
MARCH 2024

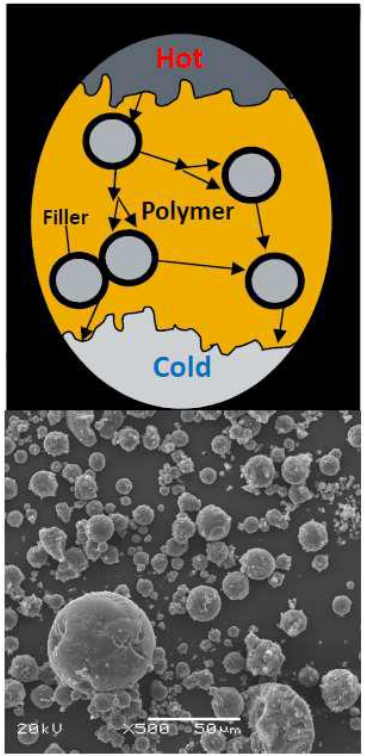
Henkel

THERMAL INTERFACE MATERIAL (TIM)

TIMs enable efficient heat transfer between solid surfaces

- Irregularities between solid surfaces:
  - macroscopic – warpage, out-of-flatness
  - microscopic – surface roughness
- Irregularities → air pockets → poor heat conductor
- Air is displaced by TIMs to improve heat transfer between the two surfaces





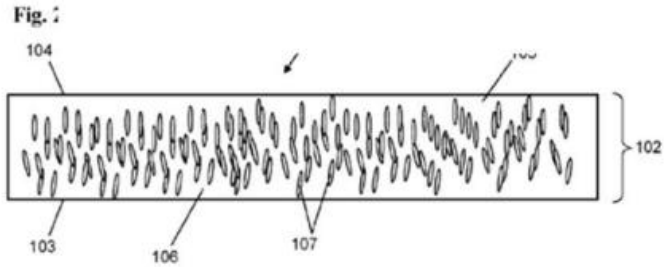
Polymer TIMs are formulated for optimal combination of thermal, mechanical, electrical, chemical properties, along with manufacturability, usability, cost

- Formulations comprise thermally conductive fillers (typically ceramic) mixed in a polymer matrix (typically silicone)
- In general, higher filler concentrations give better thermal properties with trade-off in mechanical properties, usability, and cost
- Proprietary formulations and processes are used to mitigate these trade-offs

NOVEL TECHNOLOGY FOR THERMAL INTERFACE MATERIALS

Patented Technology

- Thermally conductive fillers with **z-axis orientation** for efficient heat transfer from chip components to heat sink
- Oriented fillers enable high thermal conductivity without excess filler loadings => pad integrity, handling



Drawing from patent

Henkel high-performance, silicone-free Gap Pads

- Complementary to Henkel's thermal gap pad portfolio
  1. **TGP 40000SF**: **40 W/m.K**, not electrically insulating
  2. **TGP 18000SF**: **18 W/m.K**, electrically insulating
  3. **TGP 12000SF**: **12 W/m.K**, electrically insulating (in development)
- **Silicone-free** polymer binder – low bleed, low outgas
- **Elastomeric Pads –** reworkable, pick-and-place, no mess
- **Sustainability –** no-cure chemistry, no post-processing, ease of disassembly for rework and at end-of-life

PRODUCT INTRODUCTION

TGP 40000SF

- ~40 W/m.K
- <0.30 K-cm^2/W (0.045 K-in^2/W) for 0.5mm pads
- ~10% Compression @ 30-50psi (depending on strain rate)
- Carbon-based fillers in elastomer matrix
- Not electrically insulating

TGP 18000SF

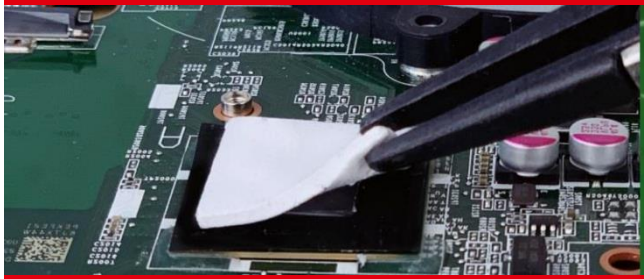
- ~18 W/m.K
- <0.50 K-cm^2/W (0.08 K-in^2/W) for 0.5mm pads
- ~10% Compression @ 30-50psi (depending on strain rate)
- Ceramic fillers in elastomer matrix
- Electrically insulating ~7 kV/mm (170V/mil)

TGP 12000SF – in development

- ~12 W/m.K
- Softer formulation, ceramic fillers, electrically insulating

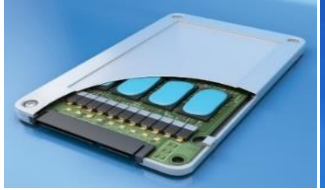
TGP 40000SF

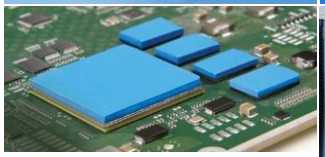
TGP 18000SF



VALUE PROPOSITION

- Industry-leading **Thermal Performance** gap pads for high power chips
  - **40 W/m.K, 18 W/m.K, 12 W/m.K**
- High z-axis thermal conductivity at lower-filler/higher-polymer loading than typical TIMs – enabled by **novel oriented filler technology**
  - Allows easier **handling** and retains elastomeric behavior in application
  - **Lightweight** – lower density, 1.7 gm/cc
- **Non-silicone**, non-reactive, no-cure chemistry
  - **Low liquid phase migration** (bleed-out) under temperature and pressure
  - **Low out-gassing** under temperature/vacuum – pass NASA test (ASTM E595)
- High **temperature reliability** for non-silicone – long-term 125–150˚C
- **Sustainability** – no post-process, allows disassembly: repair, end-of-life
- **Usability** – broad **range of thickness**, 0.5–3.2mm (20–125mils)
  - Readily cut to **custom sizes and shapes**
  - Optional one-sided tackiness to facilitate **pick-and-place assembly process**
  - **Reworkable**, no messy clean-up






Product Format

- 2” (5cm) size - pilot line
- 6” (15cm) size – Q2 2024 limited prod
- 10" (25cm) size – Q4 2024 full prod
- Thickness: 20, 40, 60, 80, 100, 125 mils (0.5, 1.0, 1.5, 2.0, 2.5, 3.2 mm)
  In development – 12mils (0.3mm)

APPLICATIONS ACROSS SEVERAL MARKET SEGMENTS

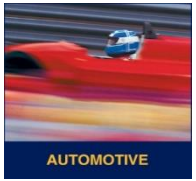
1. **5G Telecom and Datacom**
   - 5G Networks, Datacenters, Routers, Optical Transceivers

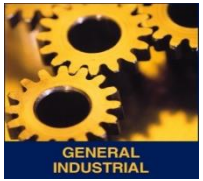
2. **Automotive ADAS**
   - Vehicle Control Units, Power Modules, Radar/LiDAR Sensors

3. **High Performance Computing**
   - CPUs, GPUs, ASICs in Servers for AI, Crypto, Gaming

4. **Industrial**
   - Power Modules, AC-DC, DC-DC Converters, Motor Controls, Lasers

5. **Aerospace, Defense**
   - Embedded Processors, Power and Control Modules, Satellite Payloads





EXAMPLES OF APPLICATIONS

ACROSS MARKET SEGMENTS – DATACENTERS, ADAS, HPC, POWER MODULES, AEROSPACE

- Applications requiring **high thermal performance** (low thermal impedance)
  - High power density, high heat dissipation, high ambient temperatures => need to limit chip / junction temperature
- Applications that specify **silicone-free** – e.g. optical transceivers, lasers, satellite payloads
- Applications that specify **low bleed, low out-gassing** for reliability
- Applications with **thicker bondlines** to fill chip-to-heatsink gap, current≥0.5mm (developing 0.3mm)
  - Key metric: % compression at maximum allowable pressure that accommodates gap tolerances
- Applications that prefer gap pad TIMs for ease of **handling** and **reworkability**
  - Ease of disassembly during test, in-use and end-of-life without damage to devices and with minimal clean-up
- Applications that prefer **no post-processing** – no cure (vs. gap filler) and no reflow (vs. PCM, solder)
  - No additional process step required and avoids any reliability concerns related to high reflow temperatures
- **Immersion cooling** applications in Datacenters – promising initial results with dielectric fluids
  - On-going customer testing and Henkel internal testing

THANK YOU

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