# Eliminate Pump-Out and Dry-Out Failures

*with High Temperature TIMs for Power Modules*

**Prashanth Subramanian**

As the manager of the New Product Development group at Graftech International, a world leader in graphite material science, Prashanth is responsible for the development and commercialization of solutions to the consumer electronics and Thermal Interface for high powered device markets. Prior to joining Graftech, Prashanth worked at SUMCO USA in the Development Engineering group providing solutions to the high-voltage device market.

Prashanth holds a degree in Electronics Engineering from Shivaji University (India) and a M.B.A. from The Ohio State University.

# Introduction

- **Overview**
  - The need for a highly reliable **thermal interface material (TIM)** for power electronic devices is driven by reliability for current devices and the increasing operating temperatures (>130˚C) and power densities to operate at the rated limits.

- **The Challenge**
  - Most available greases and phase-change materials **cannot provide reliable and sufficient thermal transfer** due to drying, pump-out and other physical limitations.

- **The Solution**
  - Highly-compressible, non-drying, **TIMs** that provide a long, failure-free lifetime

**Large surface areas in these devices provide significant challenges to non-compressible pad/foil solutions like metal & other graphite-based solutions**

# Failures in Power Electronics Devices

**What**

- > 50% of Power module failures are temperature related

**Why**

- Inadequate/improper thermal management is a key cause for high temperatures

**Why**

- Most Thermal Interface solutions do not maintain initial performance levels

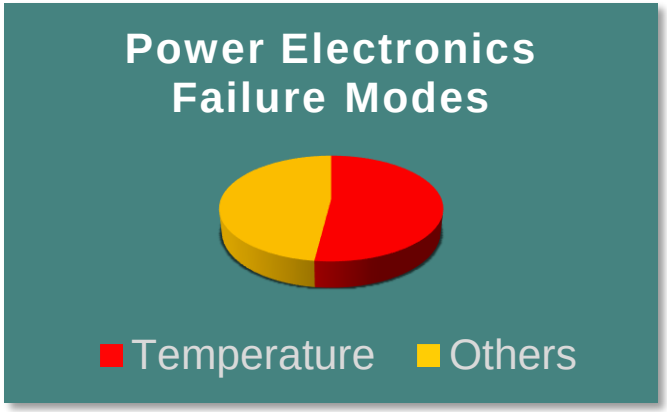
**Why**

- Pump-out, dry-out are some of the most common issues with non-foil based solutions

**Increase in junction temperature significantly affects performance in power modules**

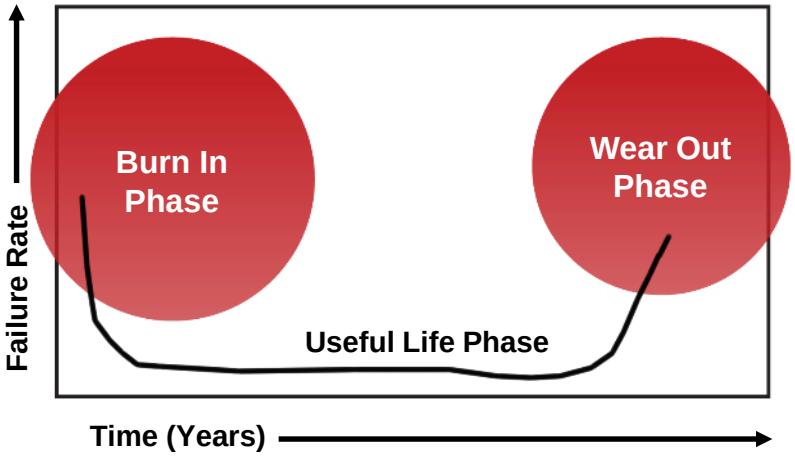
# Failures in Power Electronics Modules

- Temperature based failures are greater than all other modes combined
- Potential for failure significantly increases with junction temperature
- Paste like solutions do not exhibit uniform thickness profiles




**Burn In Phase**

- First cycle Turn ON
- Loss of contact/ material during "burn in"

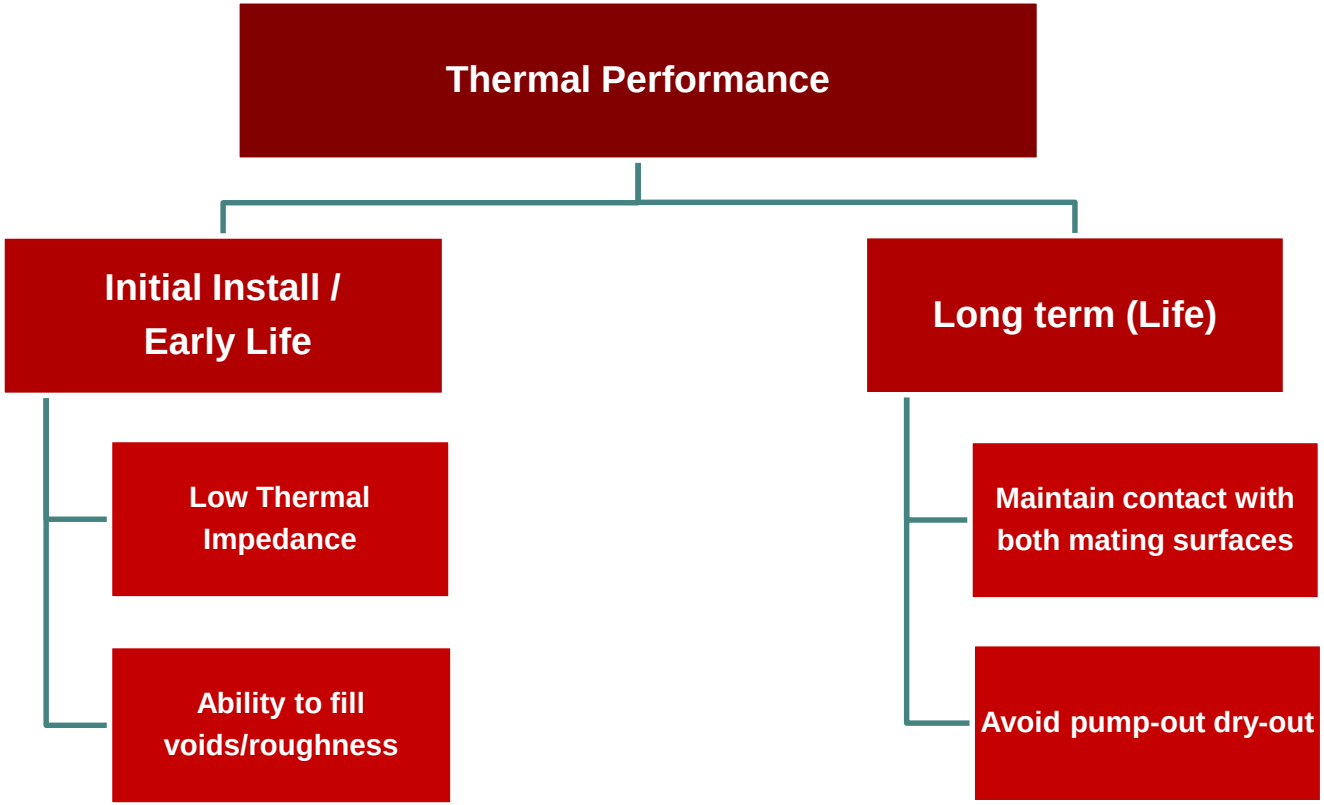



**Wear Out Phase**

- Dry-out, pump-out, micro-structural damage
- Increases effective thermal resistance

Source: http://www.irf.com/technical-info/whitepaper/tp-121015.pdf

# Thermal Performance Challenges




**Improper Thermal Interface solutions can cause significant thermal issues in the module**

# Initial Install / Early Life

**Contact**
- The roughness and flatness of the mating surfaces cause challenges in ensuring proper TIM contact

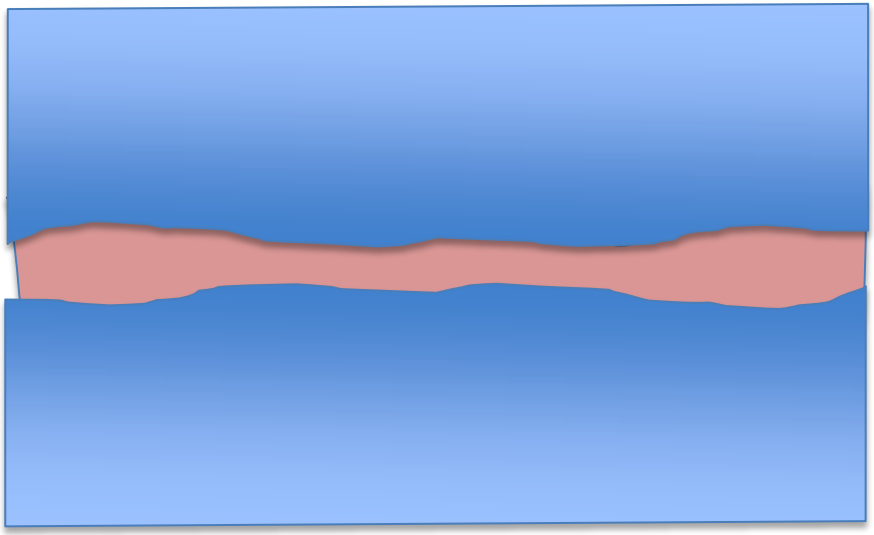
**Roughness / Flatness**
- Base plates can have ~50μ flatness on each metal surface
- Mating surfaces can have 50 - 100μ “gaps” to be filled by TIM

**Uniformity**
- Ability of TIM to maintain uniformity of thermal impedance over the surface area is key to avoiding hot spots

**Reliability**
- Reliable installation techniques are critical to ensure module to module uniformity and conformance
- TIM must be able to withstand high pressure during mount

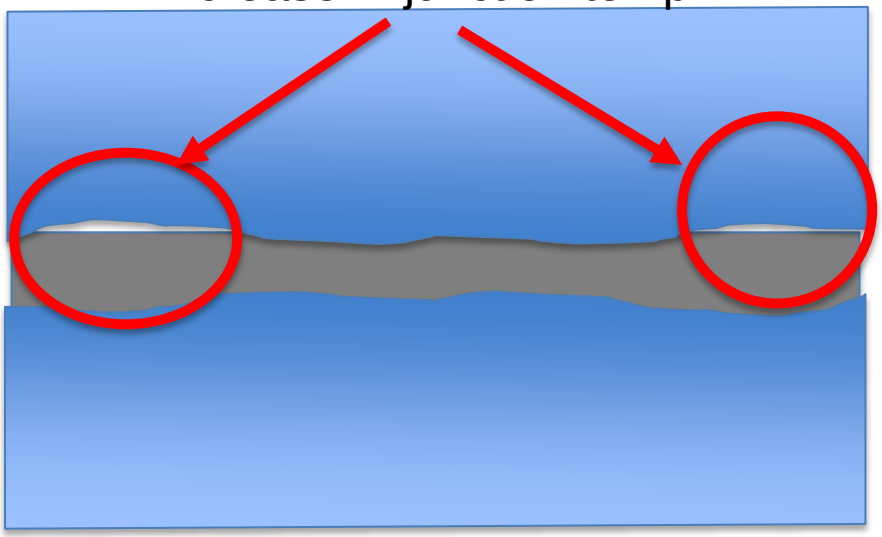
**Consistency in installation is critical to ensure module to module reliability**

# Conformity to Roughness & Flatness



Paste-like solutions fill gaps well, making for good contact initially

Air gaps can cause hot spots leading to increase in junction temp



Solid – uncompressible TIMs do not fill the gaps well

**Ability to fill the gaps due to roughness and flatness is key for reliable performance**

# Long Term (Life)

**Contact**
- The roughness and flatness of the mating surfaces cause challenges in ensuring continued proper TIM contact

**Roughness / Flatness**
- As the TIM “ages”, especially the dispensed kinds, they tend to dry-out or pump-out causing disjoined contacts

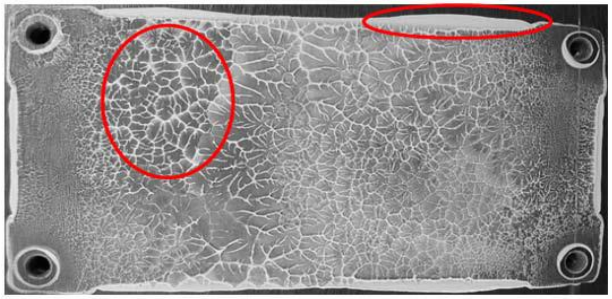
**Uniformity**
- Micro-structural damage causes reduction in uniformity, this is most common for TIMs that can dry

**Reliability**
- Temperature cycles can cause the TIM to disperse, dry or change conditions that is vastly different from when installed

**Consistent performance over time is a key factor in maintaining proper module operation**

# Improved reliability

- Grease and phase-change materials degrade over time, due to pump-out and drying



Degradation results in thermal failures and maintenance events

Image source: Infineon Application Note AN-2006-02

- Failure Free options must be no “drying” agents, no flow (e.g. graphite)

*No change in graphite properties or performance*

# Pros

| Paste-Like TIM | Solid TIM (Metal, some Graphite) | HITHERM™ HT-C3200 TIM |
|---|---|---|
| Low thermal impedance | Low thermal impedance (if proper contact is ensured) | Low Thermal Impedance, conforms well to roughness and flatness |
| Low bond line thickness | Low bond line thickness | Low bond line thickness |
| Ability to fill gaps due to roughness of plates | Long life | Long life (Will outlast device in most instances) |
| - | Pressure agnostic | Thermal impedance reduces with pressure |
| - | Easy to install | Easy to install and replace |
| - | First cycle turn ON | First cycle turn ON and no degradation during life of solution |

**Consistent performance over time is a key factor in maintaining proper module operation**

# Cons

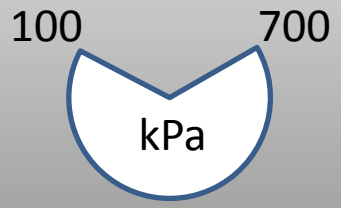
| Paste-like TIM | Solid TIM (Metal, some Graphite) |
|---|---|
| Pump-out, Dry-out with thermal cycling | Non-compressibility inhibits proper contact |
| Messy to install and maintain | Roughness and flatness can cause thermal issues |
| Operates <130 C for most instances | Cannot be used reliably in large surface areas |
| Thickness variation of TIM causes thermal hot spots | - |
| Some require bake out process: No First cycle turn on | - |

**Both initial installation and lifetime are critical for longevity of the module**

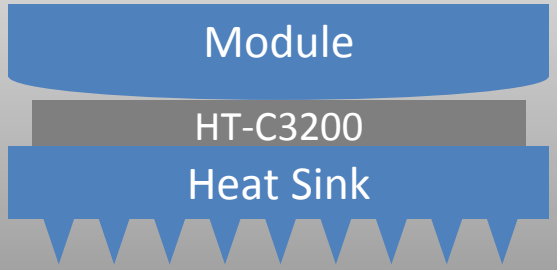
# Low Thermal Resistance

## Compressibility key to Performance

### Clamping Force

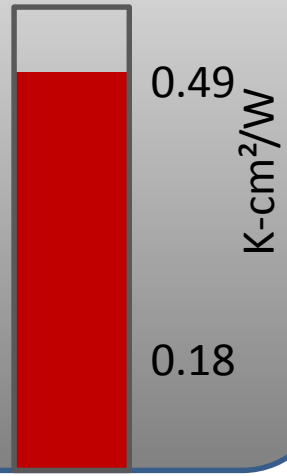



### Surface Compliance




Up to 70% compression
50 micron bond line thickness
>2x thermal spreading of copper

### Impedance

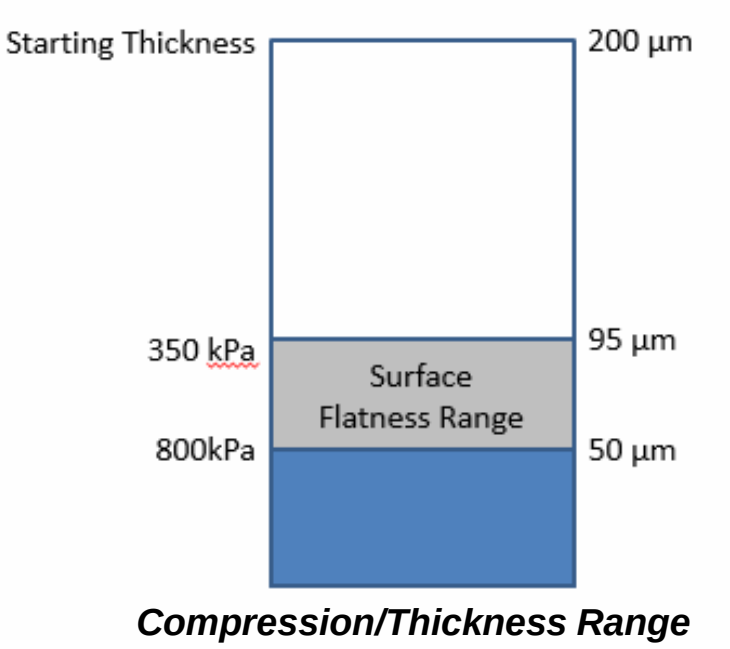



- Best performing graphite TIM offered on market
- Similar resistance to phase change materials
- Highly compressible: up to 70%
- Reduces Thermal gradient in the X-Y plane
  - due to high Thermal Conductivity

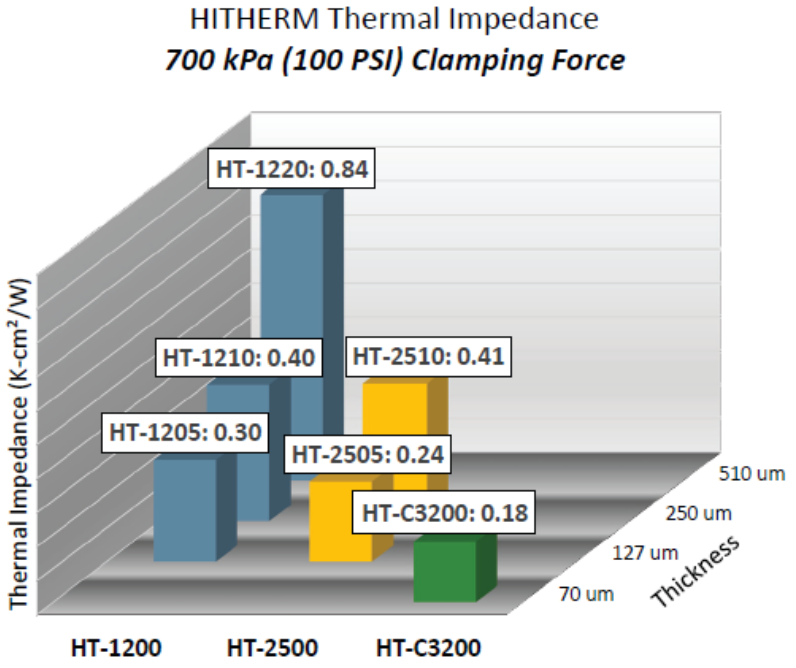
# Low Thermal Resistance

## *Compressibility: Key to Performance*

- Best performing graphite TIM offered on market
- Similar resistance to phase change materials
- Highly compressible: up to 70%




***Compression/Thickness Range***




**High level of compressibility compensates for flatness non-uniformity of base plates**

# Mess-Free Installation

***Simplicity of Sheet TIMs***

- Simple application process
- Module specific parts
- Install at same time as module
- Module bolts hold assembly in-place


**Easy installation reduces steps and ensures reliability from module to module**

# Mess-Free Installation

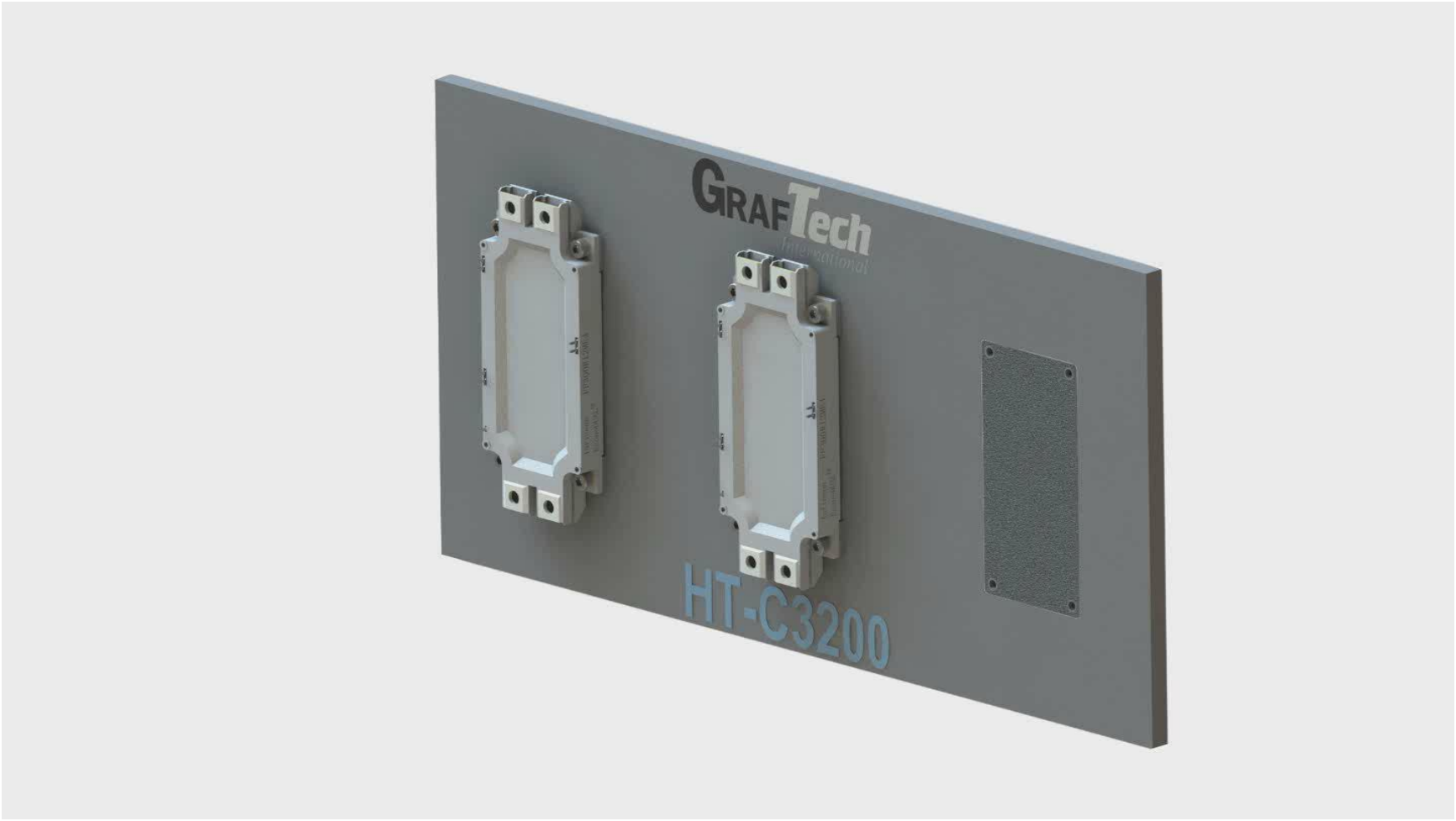
## Step 1



**Position compressible graphite part on heat sink, aligning to mounting holes**

# Mess-Free Installation

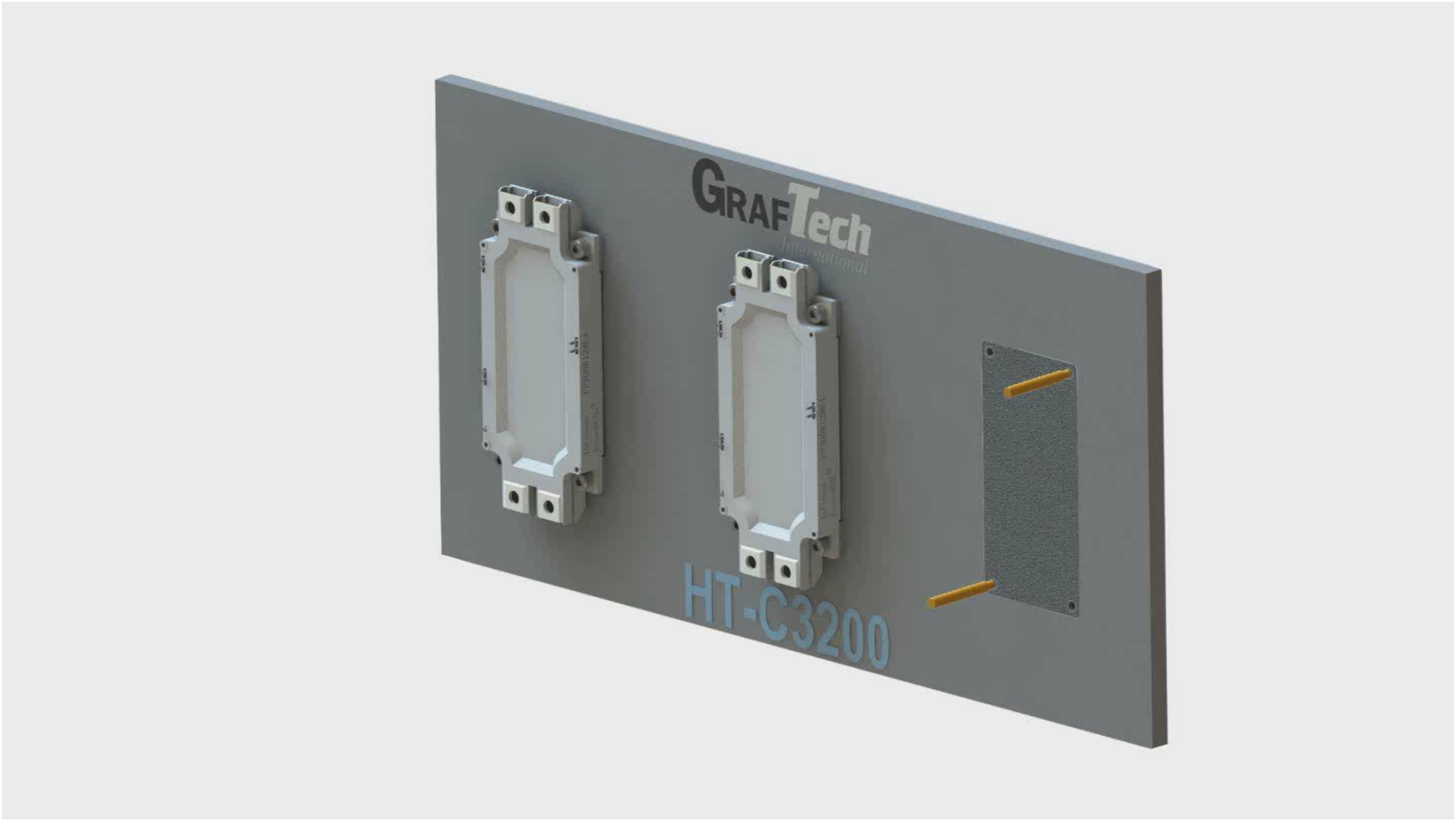
## Step 2




**Insert alignment pins to keep compressible graphite part in place**

# Mess-Free Installation

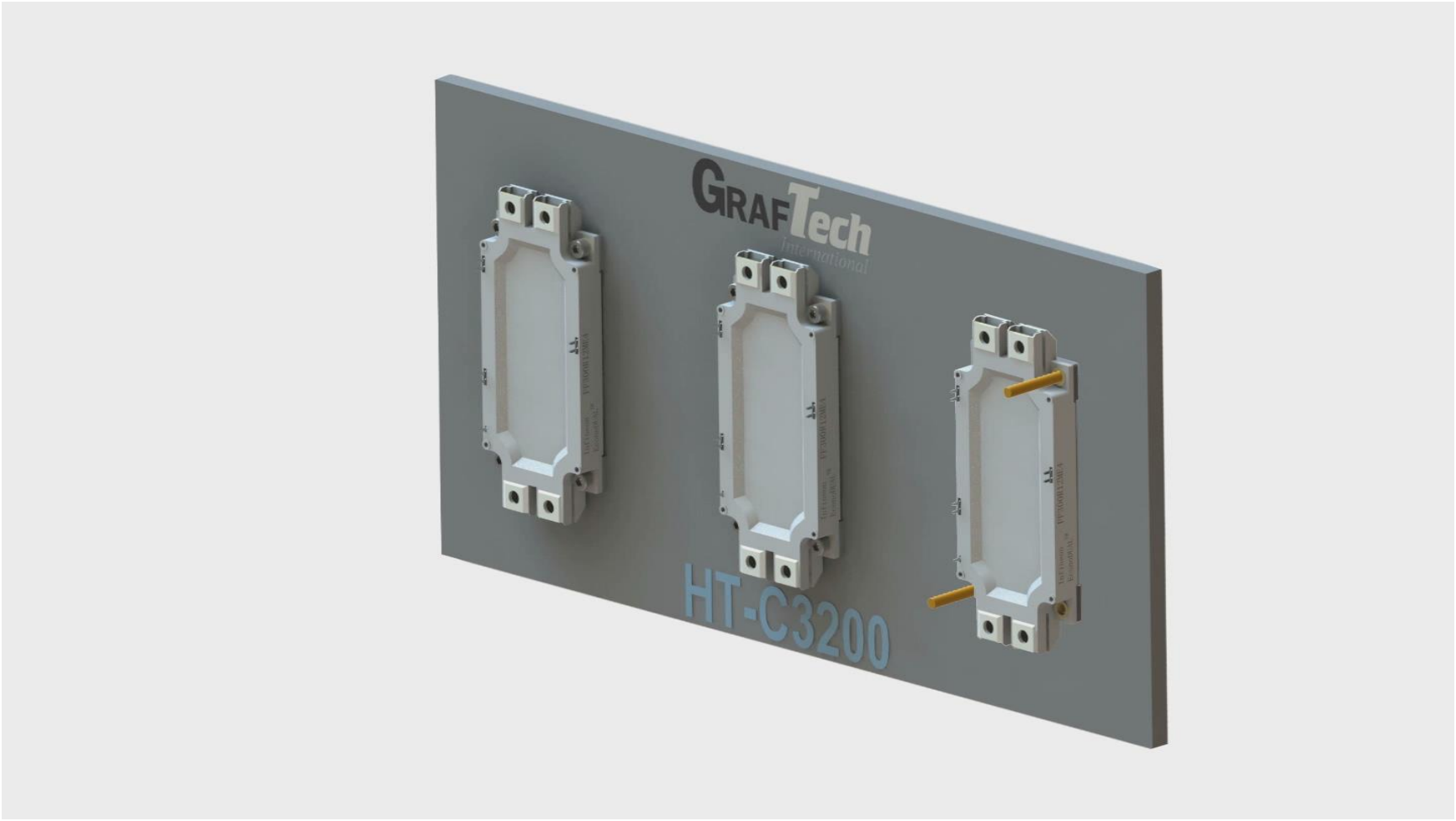
## Step 3




**With pins in place, slide module into position**

# Mess-Free Installation

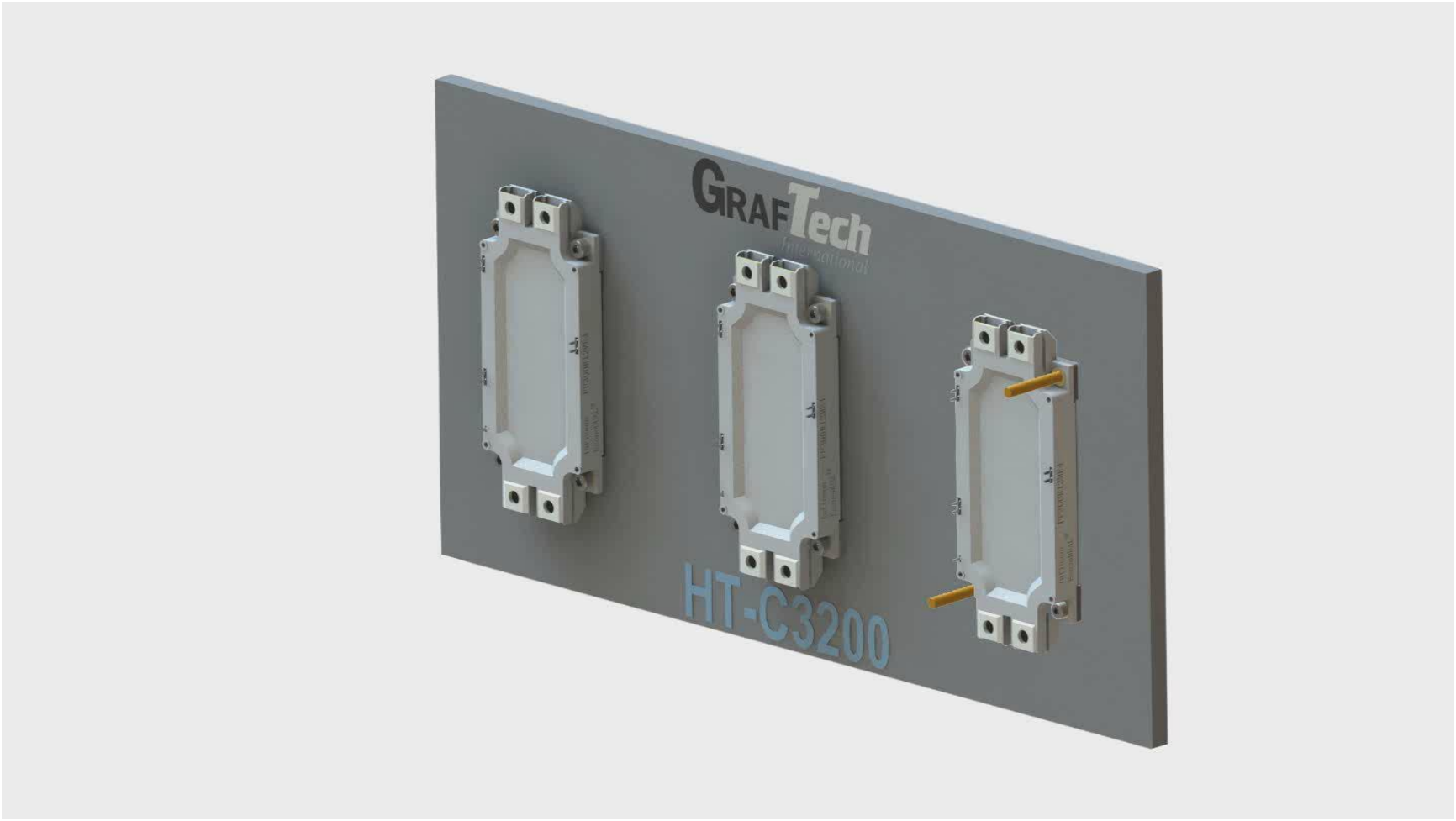
## Step 4




**Loosely screw in first two bolts**

# Mess-Free Installation

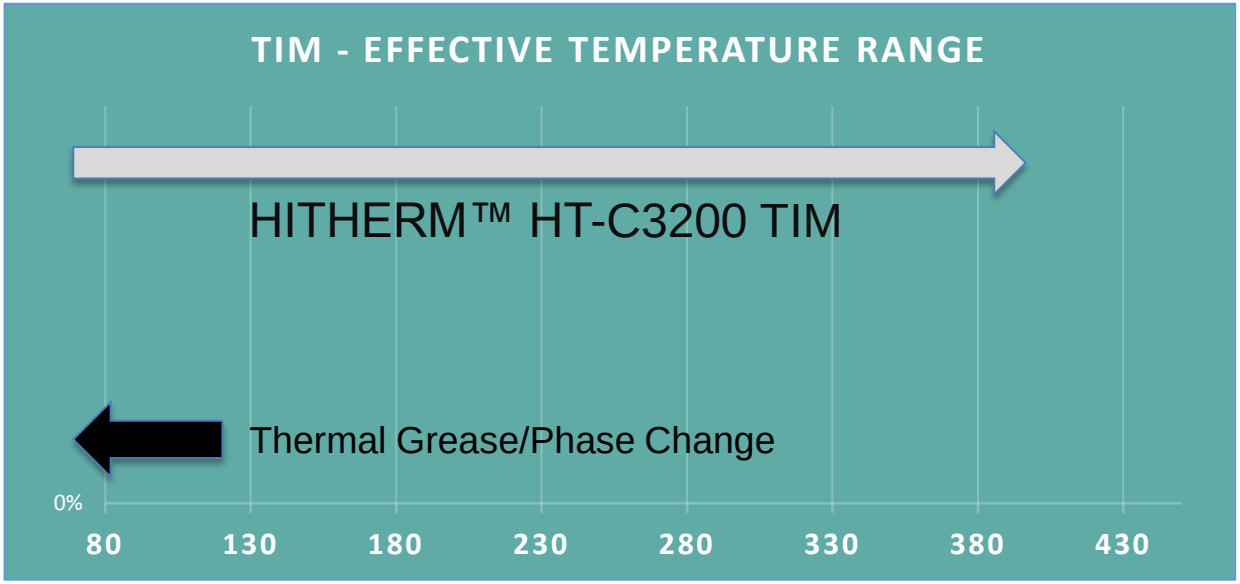
## Step 5




**Remove alignment pins, screw in remaining bolts, and torque per application notes**

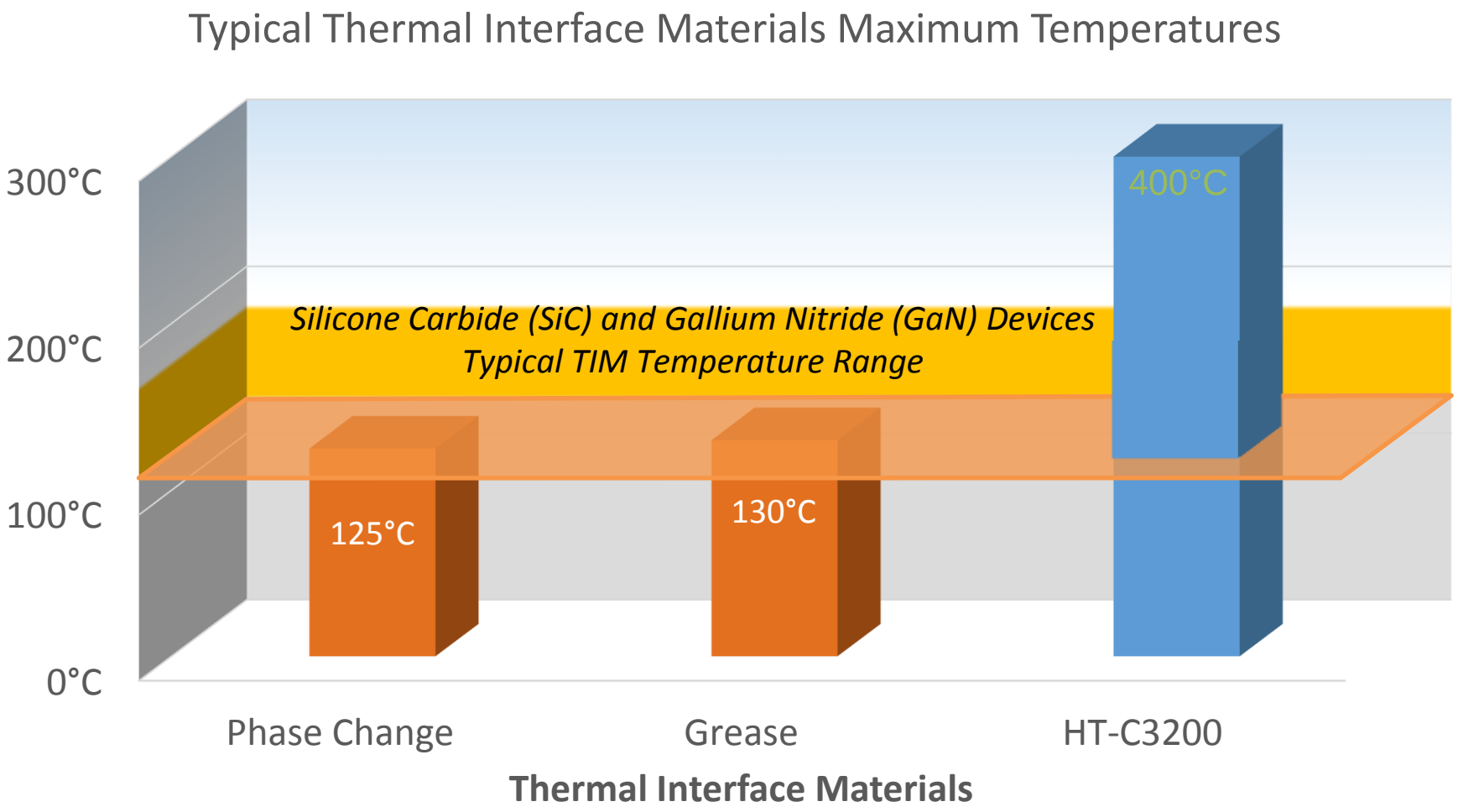
# Temperature Challenges

- New age power devices can operate in temperatures upwards of 180˚C (WBG)
- Most grease and Phase-change material have operating temperatures of <120˚C
- HT-C3200 works effectively in temperatures >400˚C



# Temperature Invariant Performance

**Compatible with current and next generation devices**




- **HT-C3200 graphite compressible TIM enables roadmap for wide-bandgap devices**

# Ideal TIM Solution for Power Electronic Modules

- Low Thermal impedance
- Excellent contact between mating surfaces
- First cycle Turn-On reliability
- No degradation over the life of the solution
- Last as long or more than the device
- Easy to install and repeatable
- Easy scale up from a few to 1000s of devices
- No capital investment

**Solutions that address both initial install and the lifetime reliability and performance**

# Questions?

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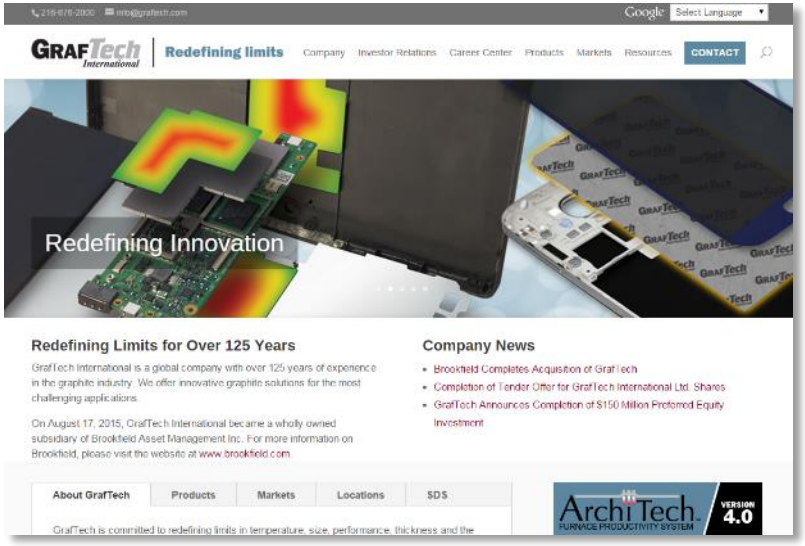


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