

Active cooling: a solution for low TCE, high thermal conductivity packages.

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Topic: SPACE-10-TEC-2018-2020
Type of action: RIA

Overview

- Motivation
- Principles of active cooling
- Implementation in packaging
 - 3D printed metal
 - Semiconductor materials

Motivation

- Thermal expansion coefficient of typical semiconductors [ppm/K]:

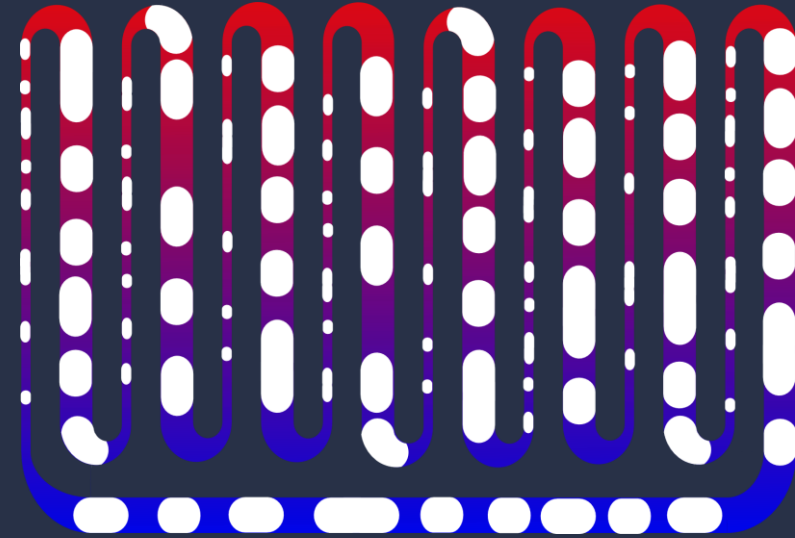
Silicon	Silicon carbide	Gallium nitride
2.6	4.0	3 - 4

- Thermal expansions coefficient and thermal conductivity of packaging materials:

Material	CTE [ppm / K]	Thermal conductivity [W/(m.K)]
Copper	16.7	385
Silver	19	429
Diamond	0.8	Up to 2000
Kovar	5 - 6	17
W90Cu10	6.5	180
W75Cu25	9	220
MoCu	6.8 – 10.3	195 -250

Principles of active cooling

- Mechanical pumping
- Heat pipes
- Oscillating heat pipe loops
 - With alternate diameters
 - Small loops



What it looks like



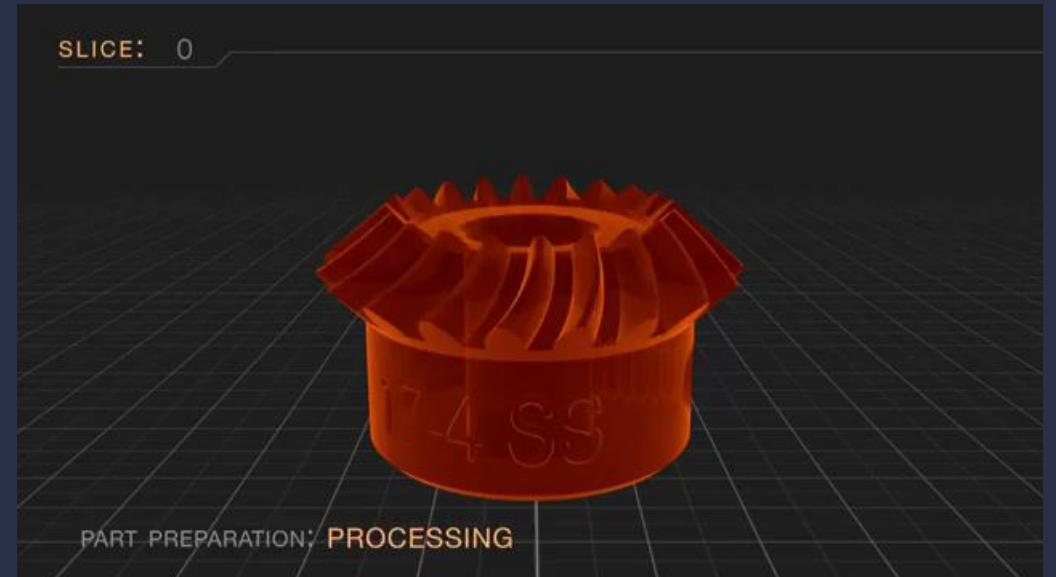
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Additive Manufacturing



- Layer-by-layer addition of metal powder
- Local sintering of metal by laser

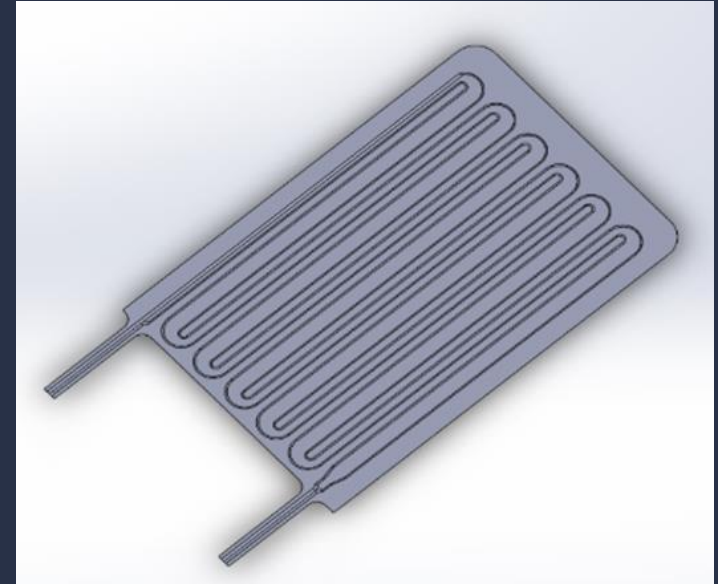


Source : Youtube



Additive Manufactured Metal Coolers

- Need to be made of two parts
 - Enables powder removal from channels
 - Requires welding / soldering of two parts
- Filling control by weighing ☹️
- Closing by pinching of channels ☹️



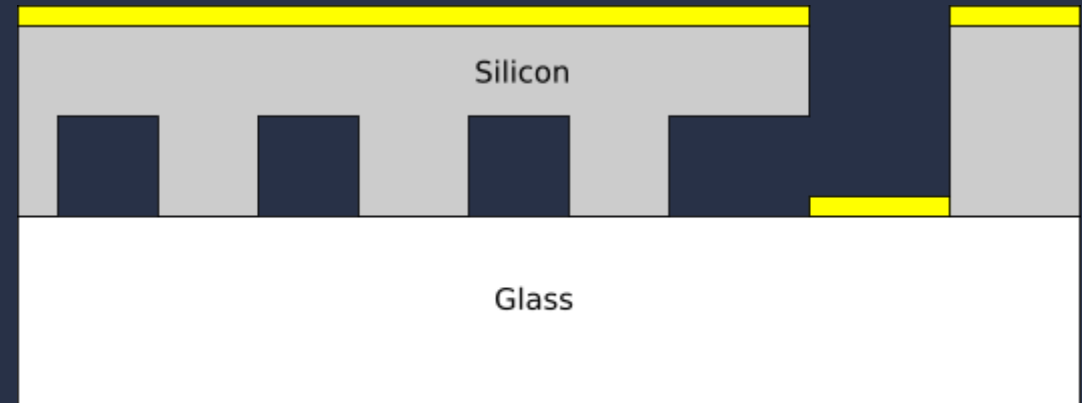
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Silicon (carbide) coolers



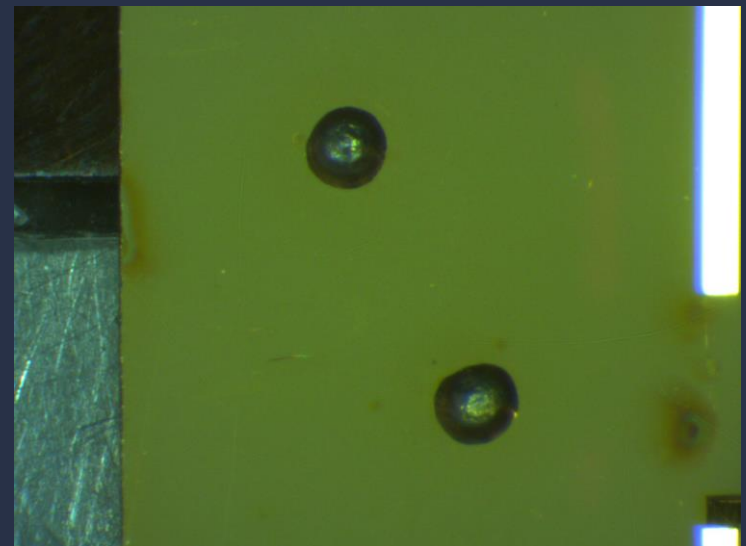
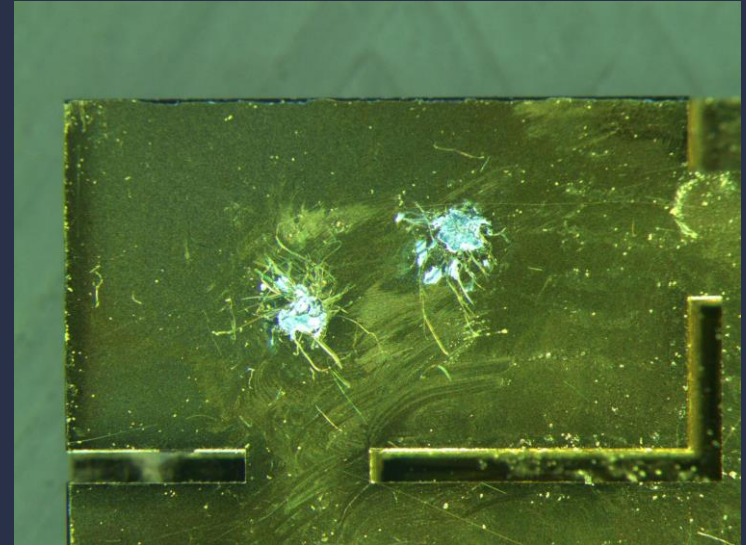
- Tests performed with silicon – glass stack
 - Easy to fabricate
 - Filling can be observed
- Challenge is in the plumbing
 - Materials are brittle: no threads
 - Need to metallize to solder
 - Closing in presence of liquid
 - Closing while maintaining low pressure



Silicon (carbide) coolers closing



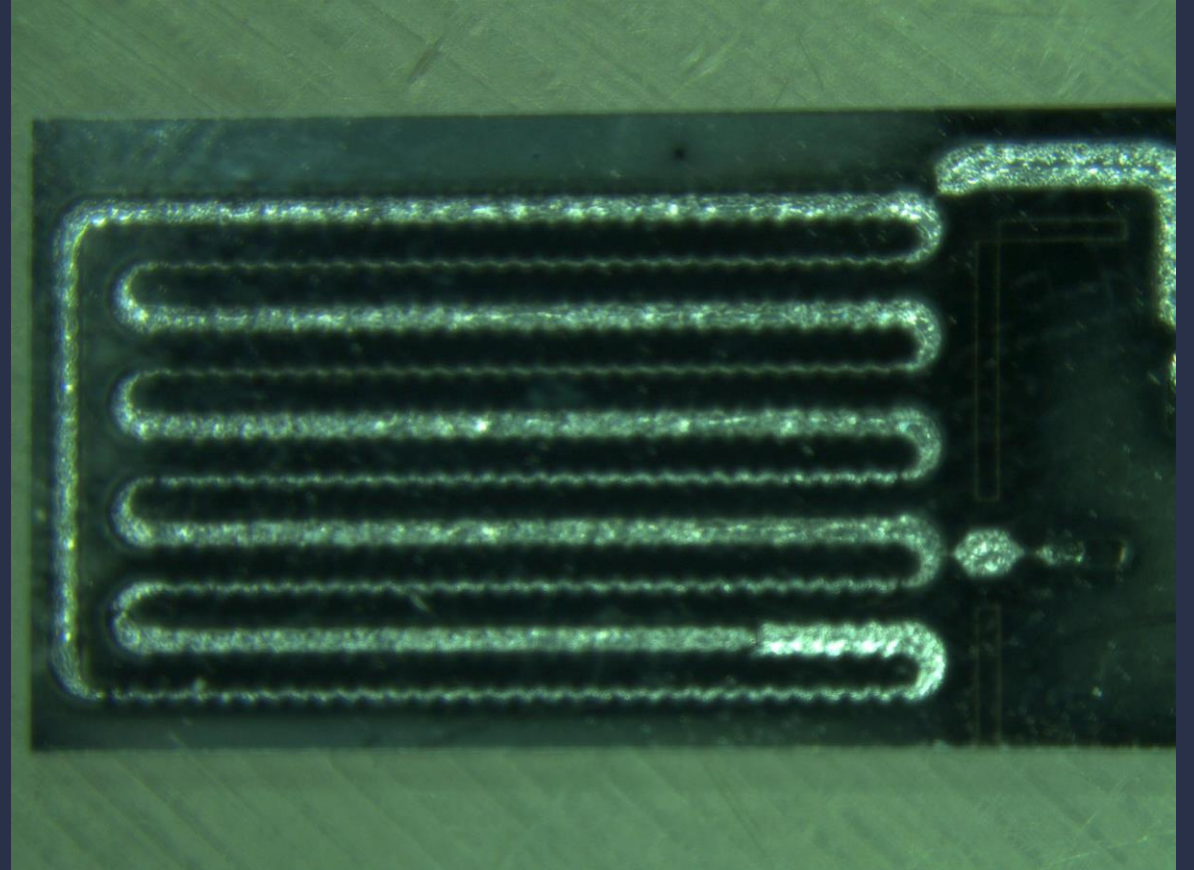
- Two promising approaches:
 - Indium cold welding
 - Laser solder ball soldering



Current status



- Difficulty in getting system under vacuum with Indium cold welding
- Laser soldering has yielded first system under vacuum
 - Currently replacing parts in filling and closing system



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