Cooling of LED Arrays

Light Emitting Diodes → Power efficient light source → Advantages compare to the conventional light source

Light Emitting Diodes → Require low junction temperature

90% of input power is dissipated as heat → Temperature increase → Decreases the life time of LED

LED for display application

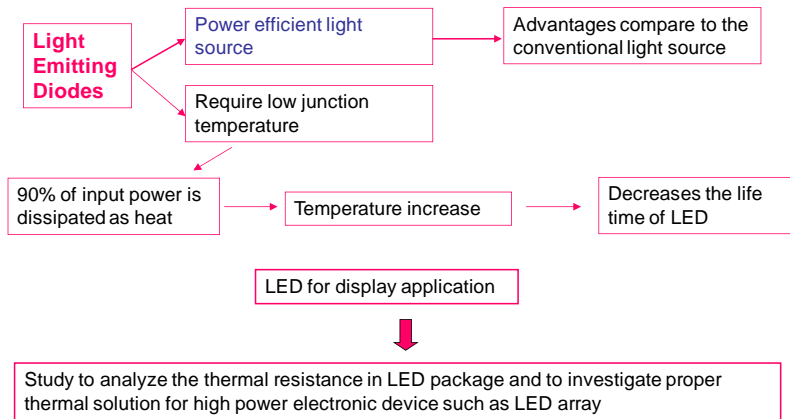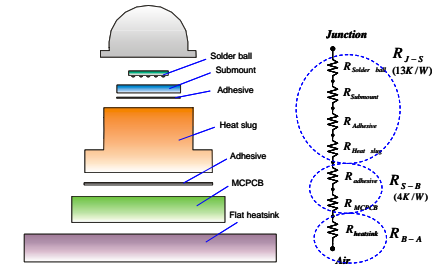Study to analyze the thermal resistance in LED package and to investigate proper thermal solution for high power electronic device such as LED array

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Two Phase Liquid Cooling --- WHY?

Application of High Power LED to Projection TV

➢ Advantages of LED for projection TV

- Operate at lower supply voltage
- Provide instant on-off (no warm-up period)
- Offer higher luminous efficacy
- Produce sharper and more vibrant colors
- Offer larger color gamut (up to 140% of NTSC gamut)
- Offer compact size
- Offer longer life time

Solder ball
Submount
Adhesive
Heat slug
Adhesive
MCPCB
Flat heatsink

Junction
R_{J-S} (13K/W)
$R_{Solder\ ball}$
$R_{Submount}$
$R_{Adhesive}$
$R_{Heat\ slug}$
$R_{adhesive}$
R_{S-B} (4K/W)
R_{MCPCB}
$R_{heatsink}$
R_{B-A}
Air.

Due to high thermal resistance, even liquid cooling cannot provides efficient cooling rate

LED array is needed for this kind of high optical output system

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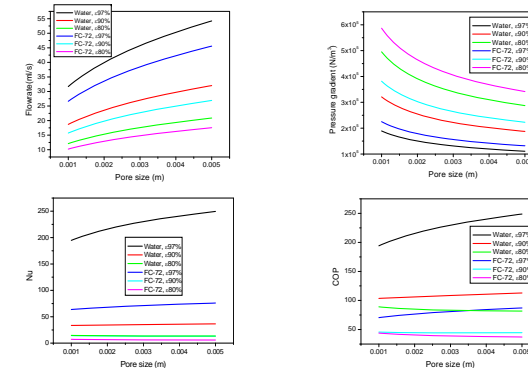## Permeability and Inertia effect Analysis of Porous Foam Material
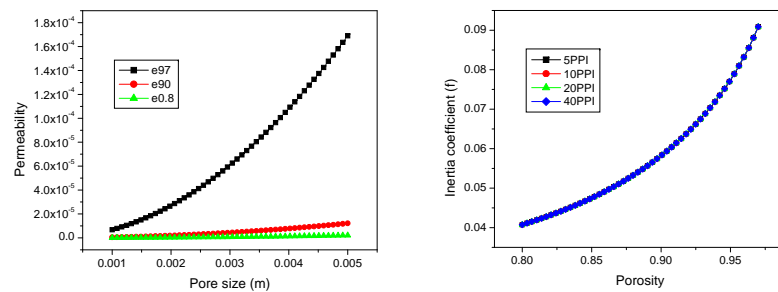
➢ **Permeability is affected by pore size and porosity, but porosity is main effect .**
➢ **Inertia coefficient affected by only porosity**

Permeability and Inertia effect Analysis of Porous Foam Material
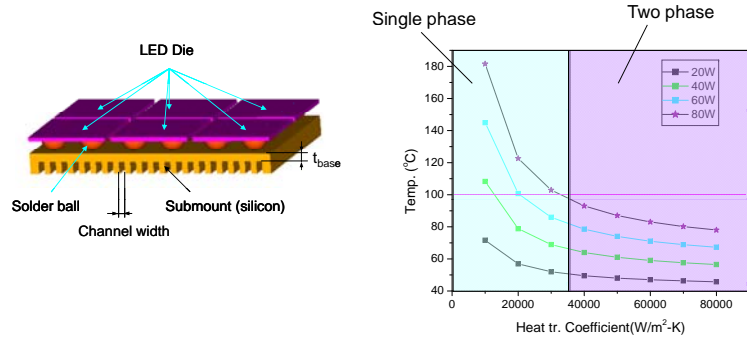
Constant Pumping Power Analysis (6W)

➢ **high porosity is desirable.**
➢ **Pore size effect on thermal performance is weak**

Submount Microchannel Cooling Performance

LED Die

Solder ball   **Submount (silicon)**

Channel width

t_{base}

Single phase

Two phase

- 20W
- 40W
- 60W
- 80W

Temp. (°C)

Heat tr. Coefficient(W/m²-K)

- **Possible to maintain the junction temperature under 100°C using water as coolant.**
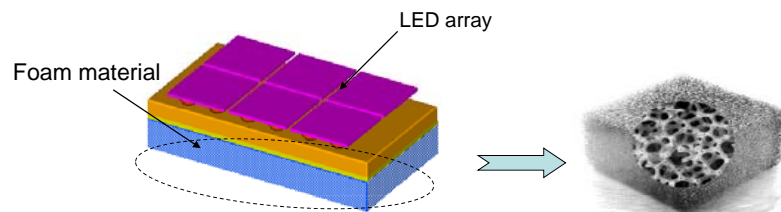- **Two-phase liquid cooling further reduces the junction temperature.**

Submount Microchannel Cooling

Use microchanneled submount to cool down the LED array package directly – decrease thermal resistance

LED array

Wire bond

MCPCB

Si submount   **Solder**

Porous foam

Submount microchannel
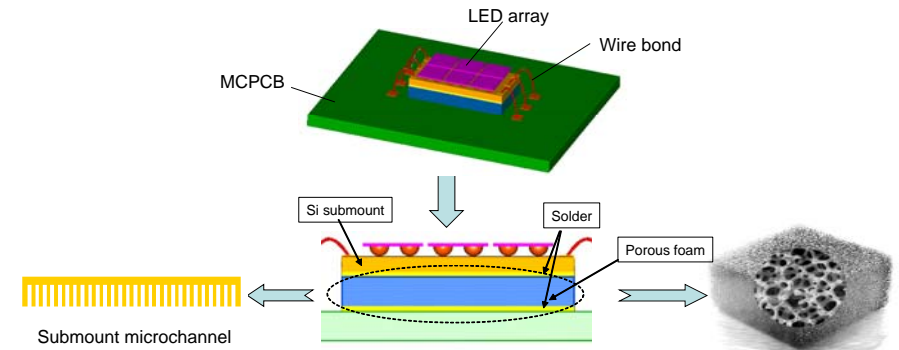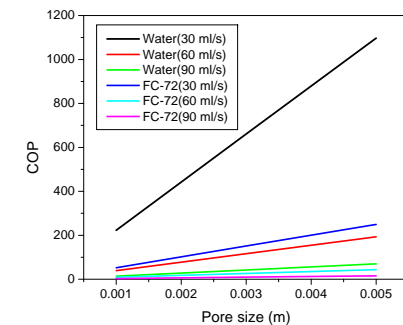

Micro-porous Submount Cooler

➢ **Use**
- Applied at the submount (or metal-core PCB level)
- Foam material "sandwich" soldered to the heat source

➢ **Advantages**
- Light weight
- Low modulus
- Low cost
- High contact area with fluid (much higher than micro-channel)

LED array

Foam material

Comparison of Water and FC-72

$$COP = \frac{q}{P}$$

P: pumping power

- Water(30 ml/s)
- Water(60 ml/s)
- Water(90 ml/s)
- FC-72(30 ml/s)
- FC-72(60 ml/s)
- FC-72(90 ml/s)

COP

Pore size (m)

For constant flow rates

Even though the dispersion effect can increase the efficiency of dielectric liquid, the overall performance is lower than water.