Modeling and Design of Materials Inkjet Printer LED Ultraviolet Curing Cartridges Using COMSOL Multiphysics for Printed Electronics Applications

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Purpose

- To eliminate the alignment problems associated with substrate removal during the curing process in a UV LED cartridge for a materials ink jet printer.
- To demonstrate an application of COMSOL Multiphysics for the simulation and design of UV cartridges.

Introduction

- Materials inkjet printers
  - Print functional materials
    - Print 2D electronic circuits and devices
      - Print conductive ink
- Printed Conductive Inks
  - In the form of dispersions
    - Require Heat Treating to evaporate carrier liquid
  - Curable polymer ink
    - Require UV exposure
      - 365nm – 405nm wavelengths
      - Dose of as much as $200\frac{mJ}{cm^2}$

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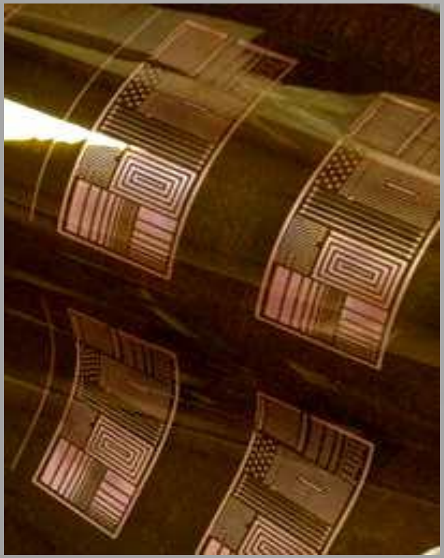
Introduction

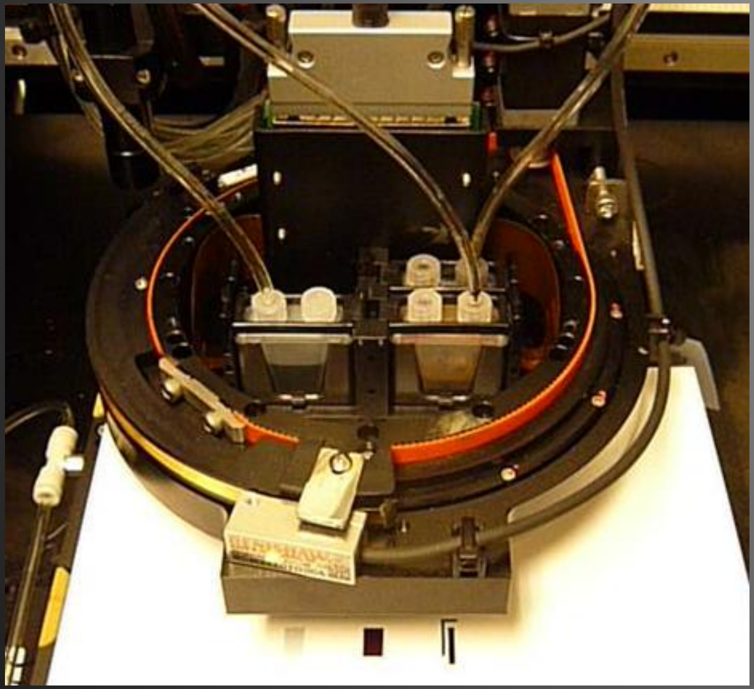
- Printed Electronic Circuits
  - Require Multiple Layers
    - Each of a different material
    - Substrate removal for UV exposure
- Substrate Removal
  - Time consuming
  - Misalignment
    - Few micrometers is unacceptable
- Goal – Avoid Removal



Alignment Solution

- Design a cartridge that will house a UV LED
  - In-situ curing of material ink
  - Must fit into printer head assembly
    - Replace ink cartridge
- Cure in a single pass
  - Speeds as low as $3\frac{cm}{s}$
- Requires High Powered LED

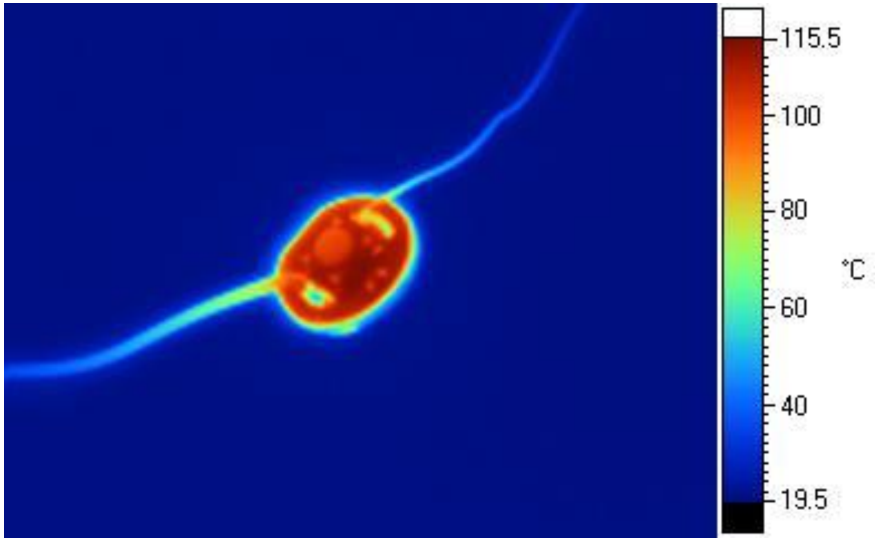
Printer Cartridge



LED with no Structure

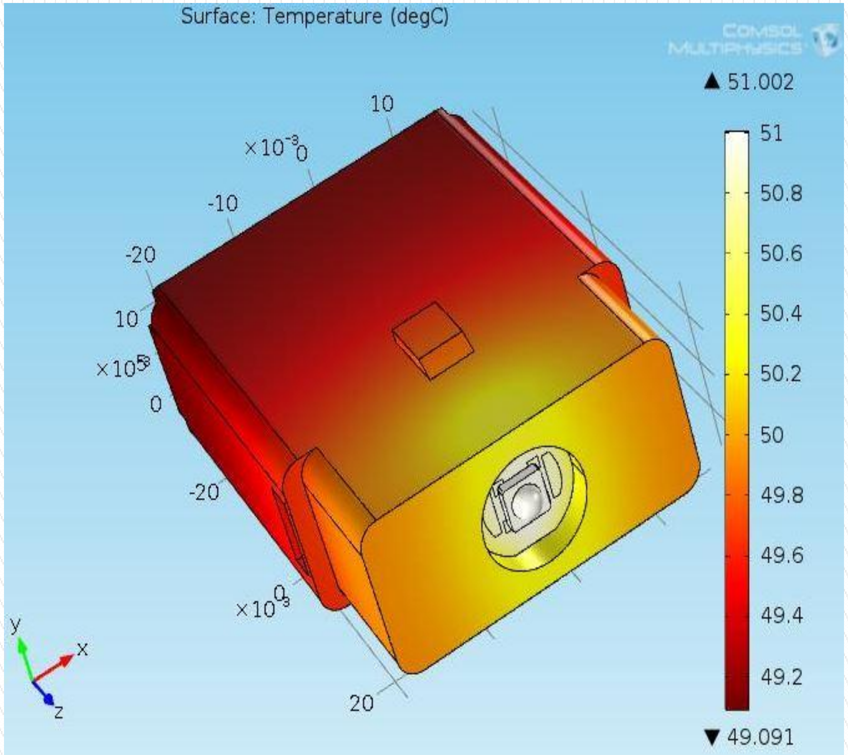
IR Camera

- LED powered
    - 400mA
    - 4volts

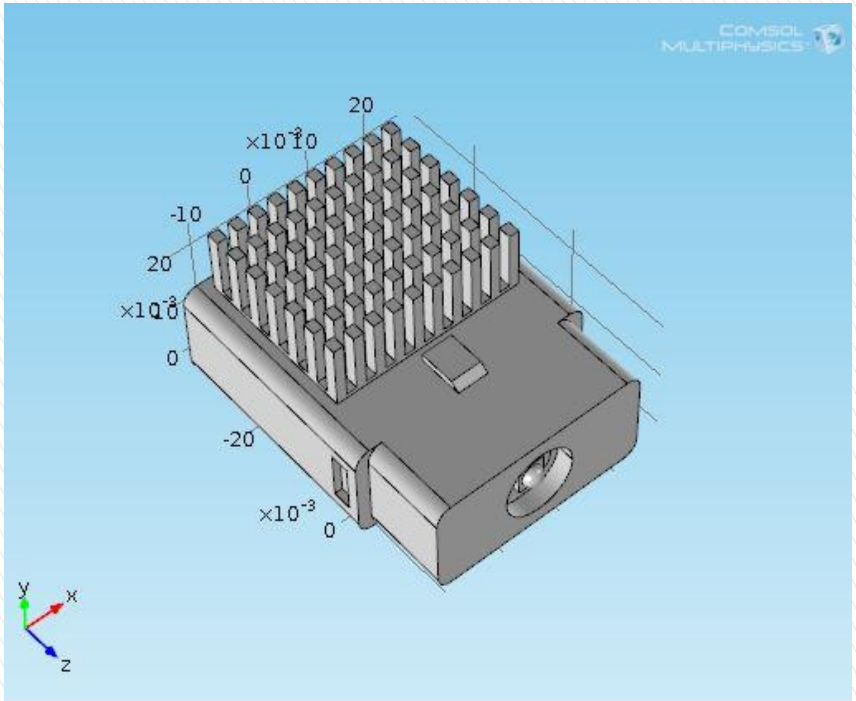


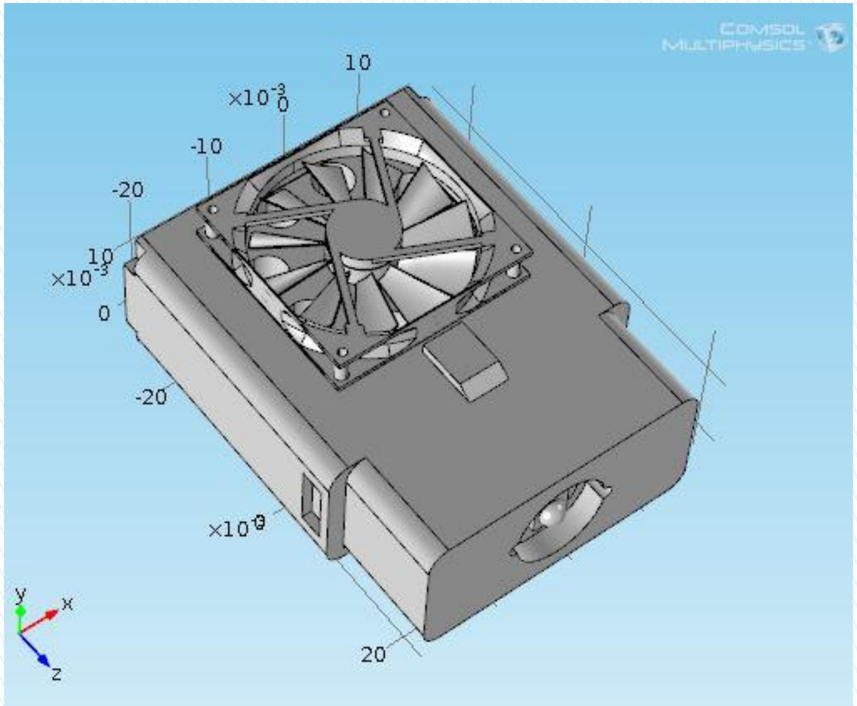
COMSOL Multiphysics Analysis – No cooling mechanism

- COMSOL analysis (5W)
  - Junction temperature of LED reaches 51°C
  - LED specs. 50°C
    - Heat Buildup
  - Degrades LED Longevity
  - Degrades LED optical output
    - 2% per 10°C
    - Heat dissipation crucial
  - Small temp. gradient
    - Suitable material (Al)
  - Cooling Mechanism to increase convection



Cooling Mechanisms





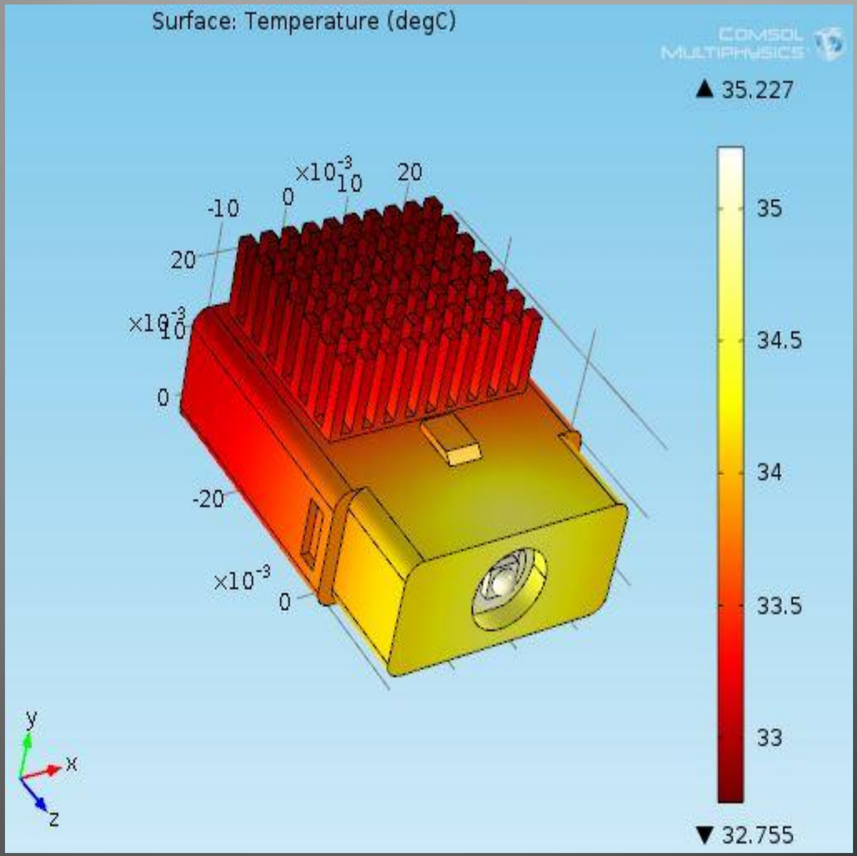
Passive – Fins

Active – Fan

Cooling Fins

COMSOL Multiphysics was used to determine the feasibility of adding fins

- Increase Convection HT
  - Doubled surface area
- Reduced Junction Temperature to 35°
- Feasible solution
  - Prevent burnout
  - Prevent optical output degradation



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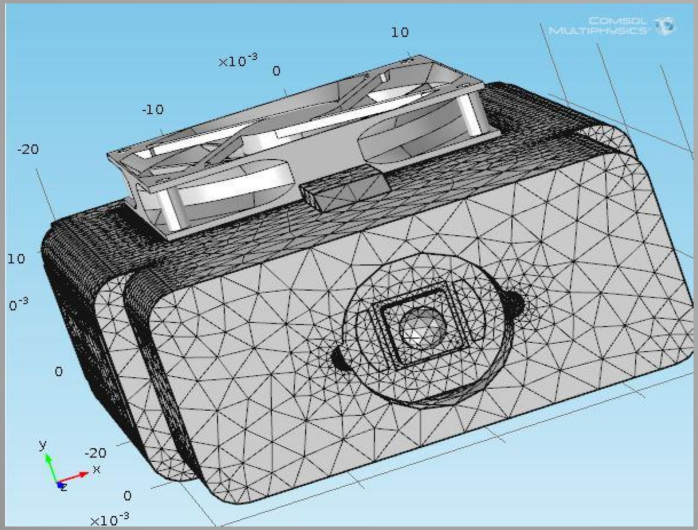
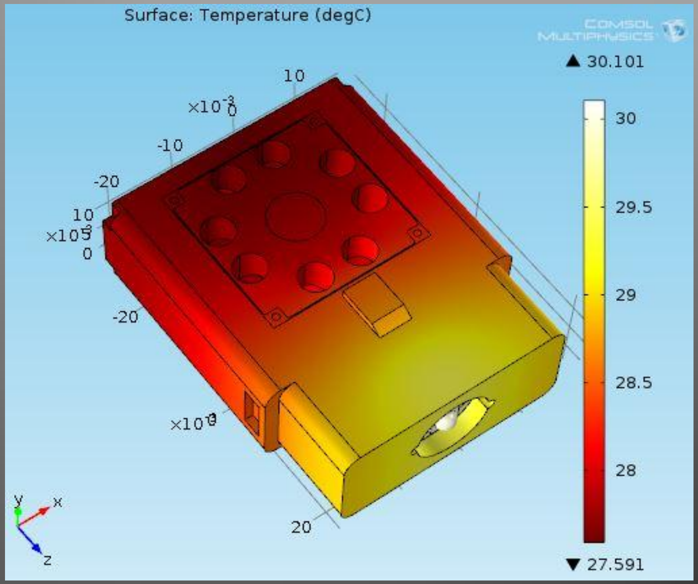
Cooling Fan

COMSOL Multiphysics was used to determine the feasibility of adding a fan

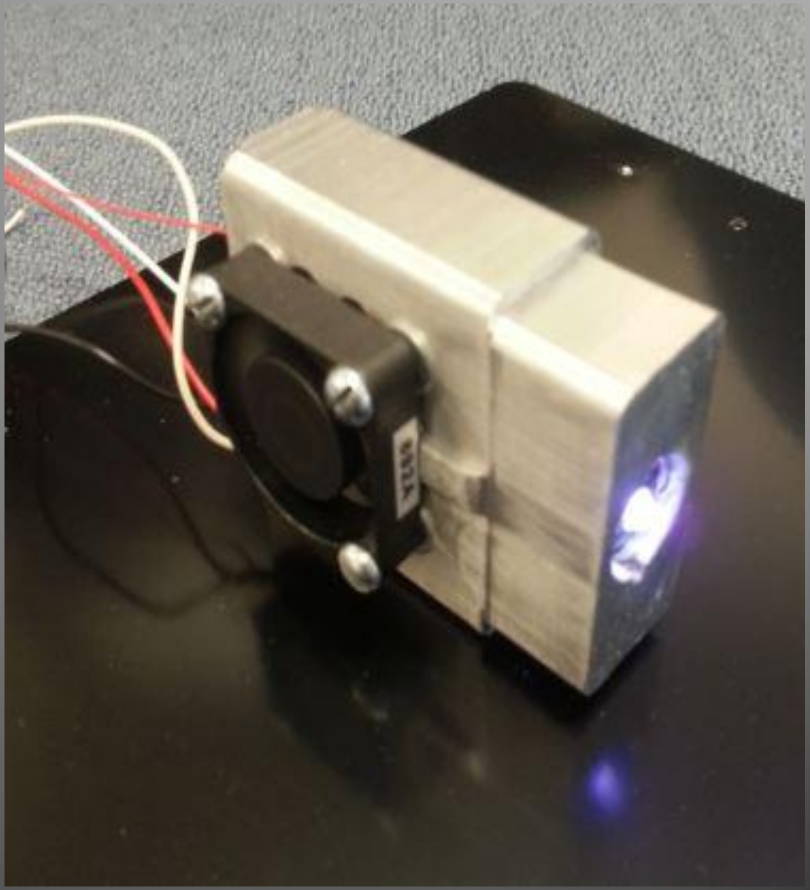
- Forced air through cartridge
  - Increased air flow
  - Increased surface area
- Reduced Junction Temperature to 30°C
- Optimal solution
  - Temperature reduced to 30°C
  - Increased optical efficiency





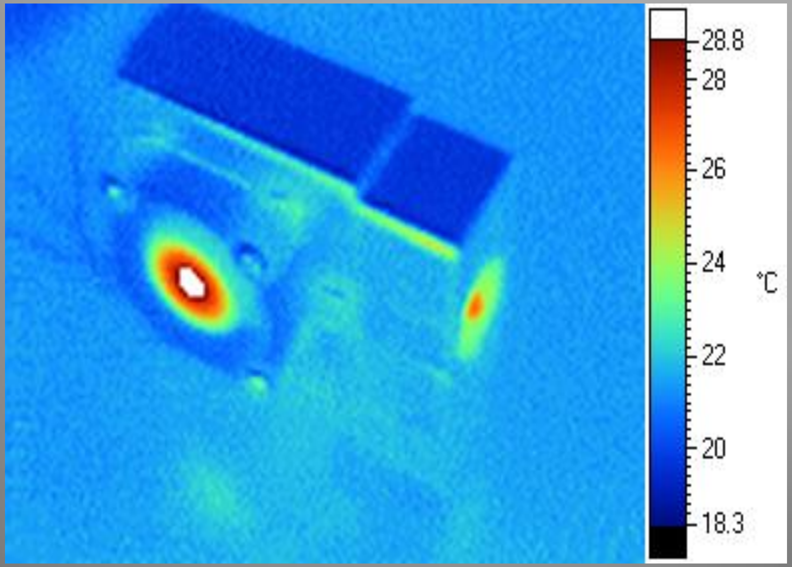
Constructed Cartridge

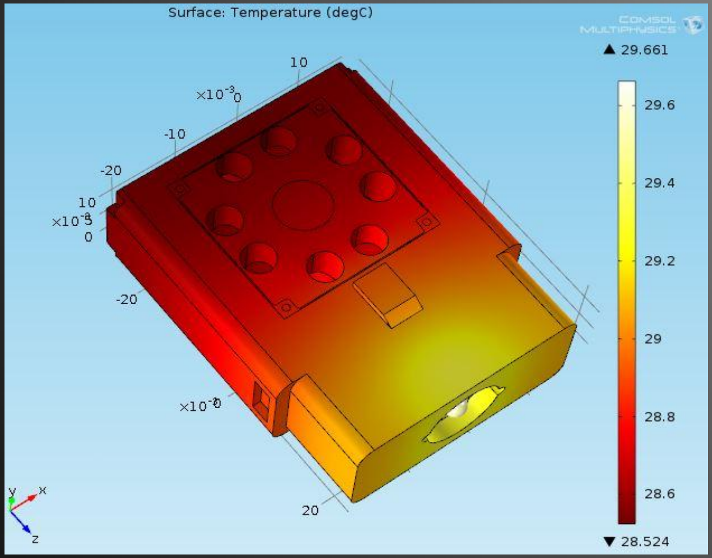
- Material
  - Aluminum
    - Suitable conductivity
    - Easily machined
- Fan
  - Provides optimal cooling
    - Additional 5°C
    - Optical efficiency loss 1%
    - LED Longevity
- LED
  - 365nm
    - Experimentally determined to be most effective
  - Thermal paste
    - Ensure conduction to Al



Thermal Testing Comparison

- Heat testing
  - 400mA, 5V
  - Fan powered





- Similar Results
  - COMSOL
    - Ignoring power converted to optical

Exposure Testing

- Tested samples uniformly coated with ink
- Samples were prepared by dabbing and spreading ink
  - Thickness greater than 60μm
- Samples were placed in printer
  - Printer speed $3\frac{cm}{s}$
- Samples cured in a single pass
  - Dose of 25 $\frac{mJ}{cm^2}$ for the tested ink
  - LED powered at 50% rated

Conclusion

- COMSOL Multiphysics Heat Transfer in Solids was employed to
  - enable rapid design verification
  - determine a feasible cooling mechanism
- Determination that in-situ curing of UV curable inks was feasible
- Opens up the possibility of drying/baking /annealing of non-UV inks by heating
  - Exposure to visible or infrared radiation
    - Much high power levels

THANK YOU

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