Advanced Materials and Packaging

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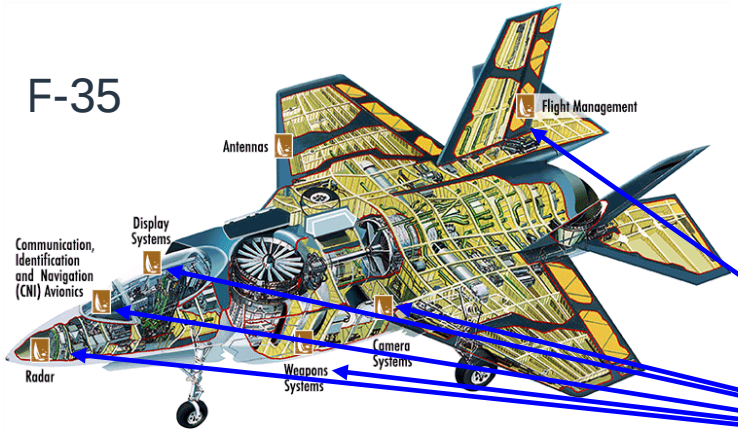
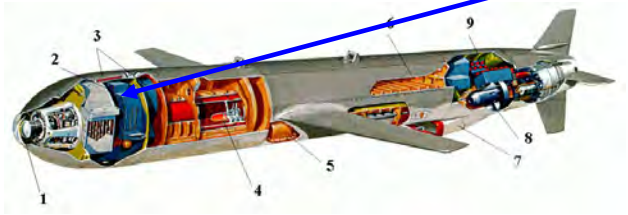
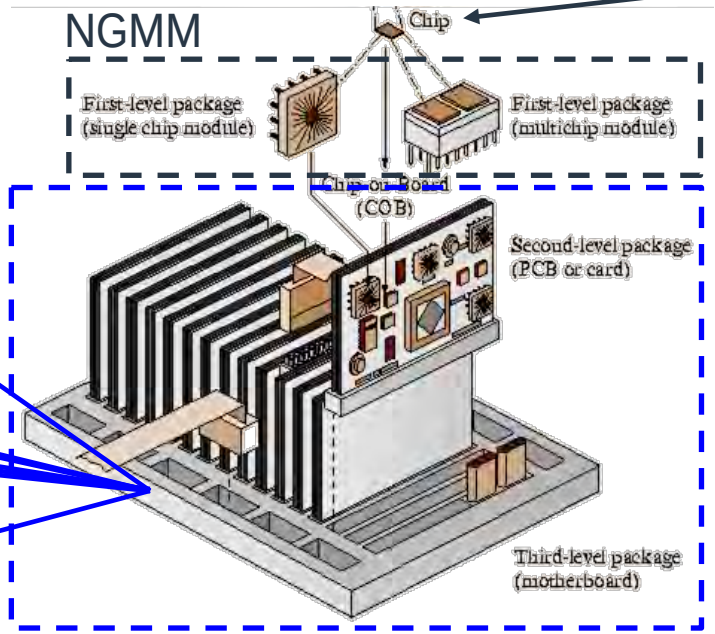
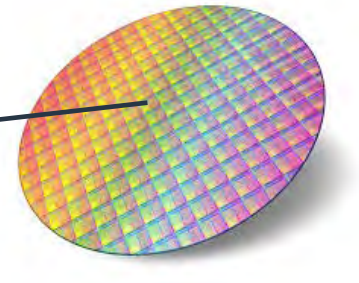
July 24, 2025

Microelectronics Advanced Packaging









Opportunity exists for improving:

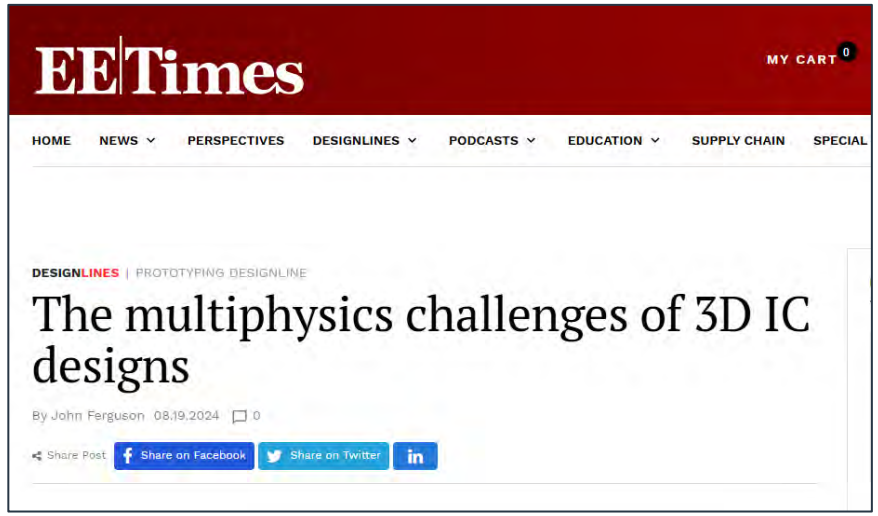
- Co-design of electrical, thermal, and mechanical
- Use of inverse design methodology
- Reduction of 3D volume / increased packing density
- Direct synthesis with multi-material additive manufacturing

References:

- *https://harbourind.com/resources/interactive-military-aircraft-f35*
- *https://en.missilery.info/missile/bgm109c-d/shema*
- *Halbo L, Ohlckers P (1995): Electronics Components, Packaging and Production. ISBN 82-992193-2-9. p. 1.3.*

Advanced Packaging Design Tool Limitations

- 3D CAD, multi-physics finite element modeling (thermal/structural/electromagnetic), EDA (electrical circuit functionality), and generative tools exist, but separately
- Current EDA tools neglect structural, thermal, and EM considerations when optimizing electrical layout – these factors must be considered for 3D since structural support and cooling are integrated in build



EE Times – The multiphysics challenges of 3D IC designs
August 19, 2024

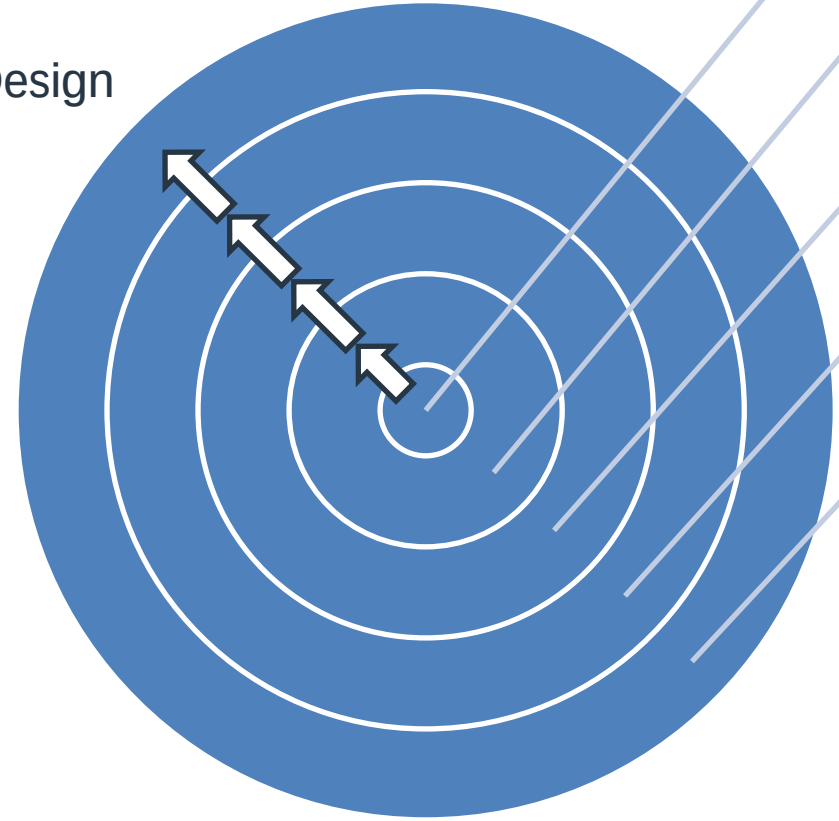
"However, the thermo-mechanical challenges associated with these designs calls for new multi-physics analysis solutions that work at the die-die and die-package level, are integrated into the design flow and are easy to use."

https://www.eetimes.com/the-multiphysics-challenges-of-3d-ic-designs/

Opportunity to leverage new generative algorithms to assist in complex 3D multi-physics design space

Shift to Inverse Design Methodology

Conventional Design



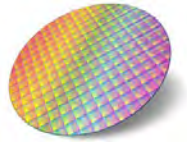
Core Technology

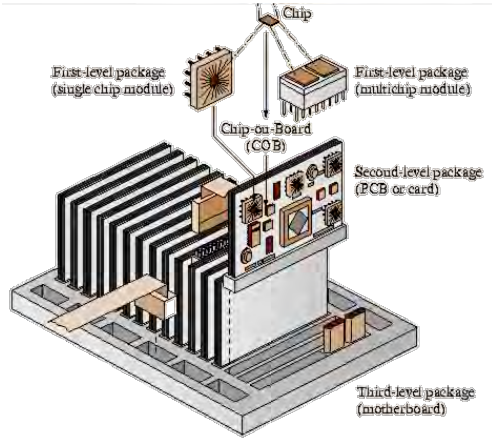
1st Level Packaging (Chip)

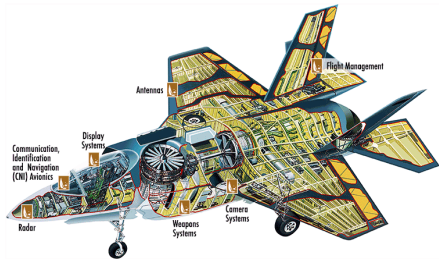
2nd Level Packaging (Board)

3rd Level Packaging (Assembly)

System Integration







References:
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Shift to Inverse Design Methodology

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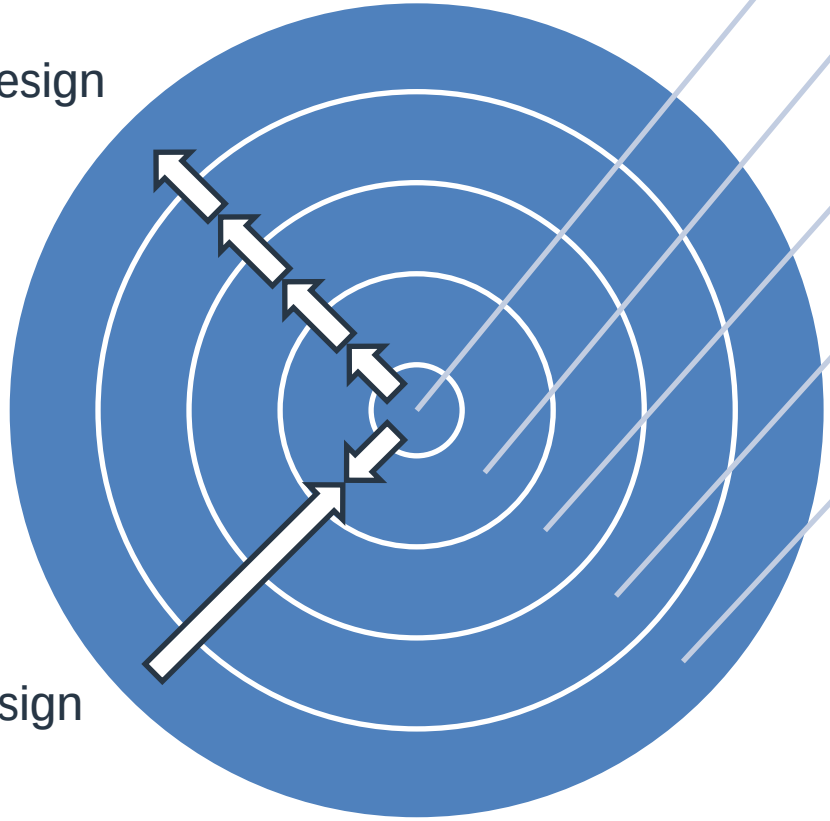

Inverse Design

Core Technology

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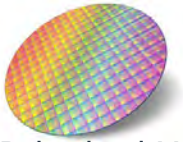
2nd Level Packaging (Board)

3rd Level Packaging (Assembly)

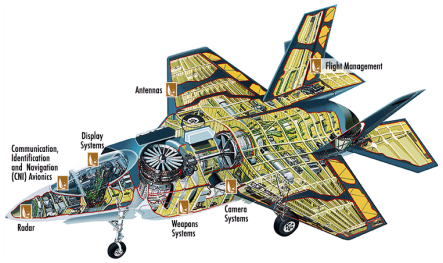
System Integration



Chip Behavioral Models

Generative & Optimization Algorithms for Electrical, Thermal, Structural Design Definition

Form/Functionality/Performance Goals



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2D Printed Circuit Board Assembly - Bill of Materials

[1]

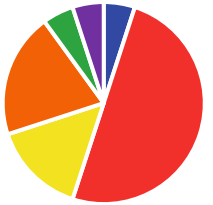
Materials used for PC board & components

Resistors	Capacitors	Inductors	Diodes	Traces / Connectors	PC Board
NiCr	SiO_2	Cu	Si (p & n-type)	Cu	Glass/PTFE
Carbon	Si_3N_4	Powdered Iron	Ge (p & n-type)	Au	Glass-ceramic
TaN	PET / PP	Ferrite	Al	Al	Cu
Ceramic	Mica	MPP	Mo	Ni-Au alloy	Al
Glass	Air	Air	Pt	Sn-Pb solder	Steel alloys
Plastic	Al		Cr	PBT	Au
	Ta		W	LCP	
	Nb			TPE	

Material Classes

- Magnetics
- Polymers
- Ceramics
- Metals
- Semiconductor
- Composites

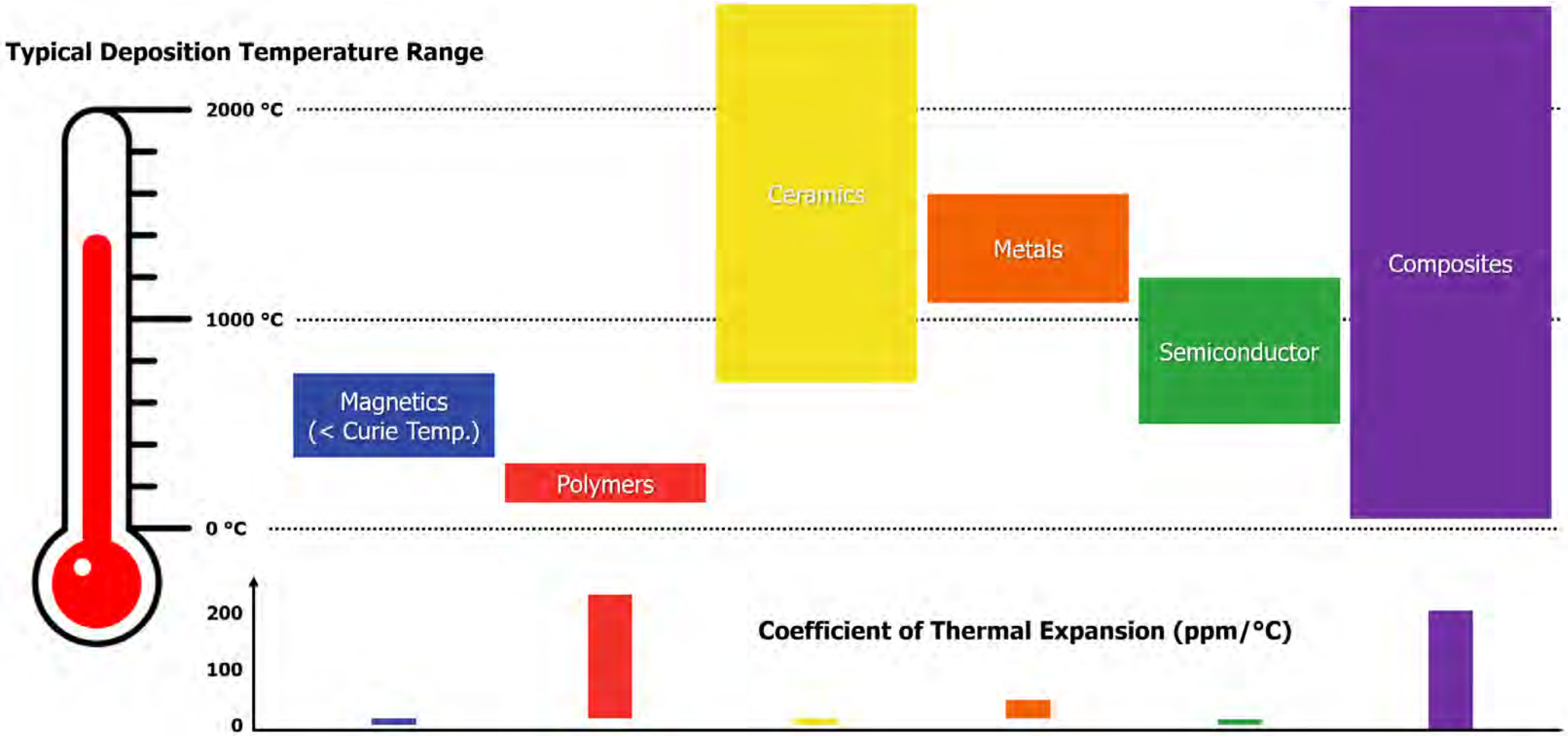
Typical PCB Composition



PCBs typically utilize six classses of material with 40+ commonly-used individual material options

PCB: Printed Circuit Board
MPP: Molypermalloy Powder
PTFE: Polytetrafluoroethylene
[1] Midea Microwave Control PCB Board Assembly PCBA

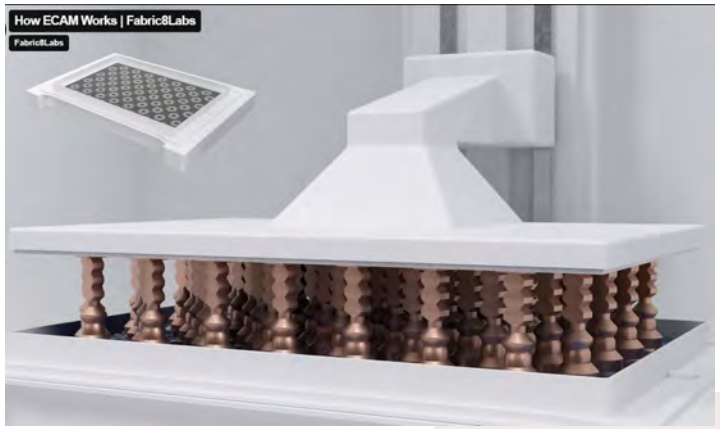
Multi-Material-Class Integration Challenges: Temperature

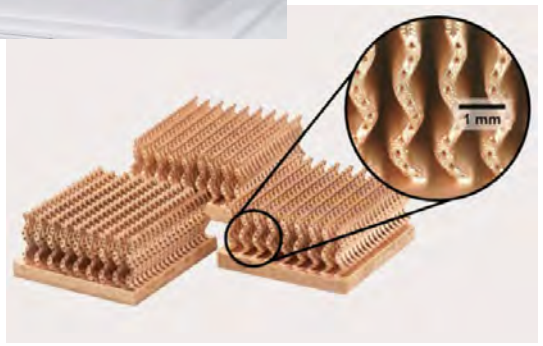


Opportunity to find novel ways to additively integrate material classes

Parallelization of Additive Manufacturing (AM)

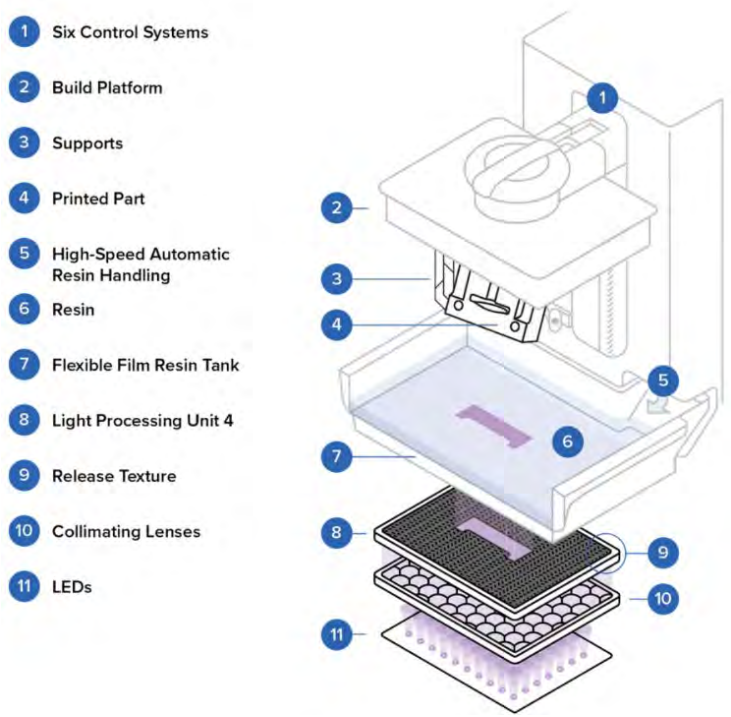
Electro-chemical Additive Manufacturing (ECAM)

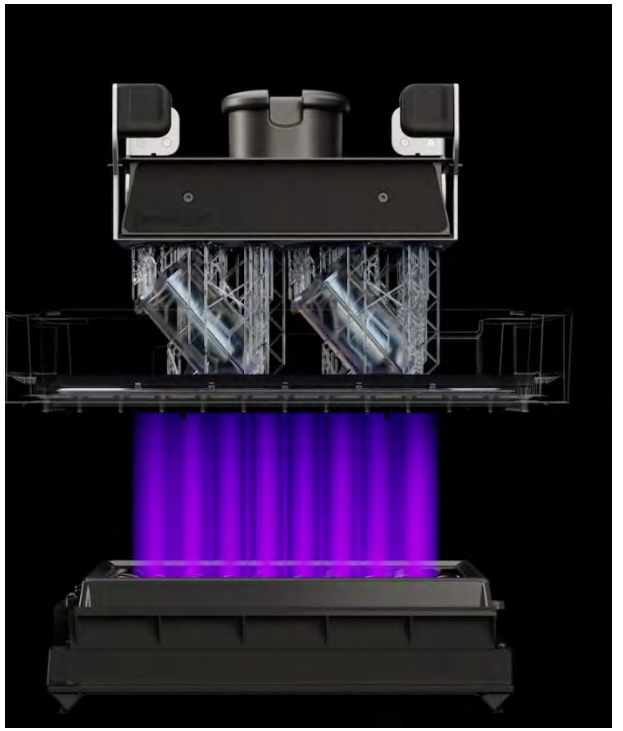




Reference: Fabric8 Labs, Inc.
https://www.fabric8labs.com/technology/

Inverted Stereolithography (SLA)





Reference: Formlabs
https://formlabs.com/blog/ultimate-guide-to-stereolithography-sla-3d-printing/

While AM tooling is increasing throughput via parallelization, multi-material-class integration still needs development

www.darpa.mil