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PACKAGING RESEARCH IN ELECTRONIC ENERGY SYSTEMS

ADDITIVE MANUFACTURING IN POWER ELECTRONICS PACKAGING

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Outline

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Additive Manufacturing & 3D Printing

- Defining AM & 3D
- Global Technology Players and Market Trends

Review and Quantification of the Latest 3D Printing Technologies

- Review of AM/3D Technologies
- Understanding Industrial, Commercial and Consumer Equipment

Identification of Metrics and Drivers for Evolving AM in PE

Evolving R,D&D Process of interest

- Identifying Applications to WBG devices
- Demonstration of key technology advances

Completion of a New University Research Resource

(YOLE agreed to leave slides in Sunday's Edu Course)



TODAY'S FACTORY

THE VISION Stratasys Education Open Curriculum Program

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TODAY'S SHIPPING

TOD

The boome

THE NEW FACTORY OF TODAY

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Parametric Design

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Parametric design – Designer writes the rules, and individuals customize within those rules

The designer is similar to a software programmer

The designer decides which attributes (e.g., materials, geometries, or size) are fixed or variable, and the relationship between these attributes?

Individuals design within the designer's rules to produce one of many possible outcomes.



Individuals can explore design options, design their own custom products without design expertise, and produce mass customization Stratasys Education Open Curriculum Program



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FROM THE FORD WEBSITE (2014):

Ford's 500,000th printed auto part is a prototype engine cover for the all-new Ford Mustang

The next steps in Ford's 3D printing strategy are auto industry firsts – mixed material applications, continuous 3D sand printing and direct metal printing

One day, millions of car parts could be printed as quickly as newspapers and as easily as pushing a button on the office copy machine, saving months of development time and millions of dollars.

...An engineer would create a computer model of an intake manifold – the most complicated engine part – and wait about four months for one prototype at a cost of \$500,000. With 3D printing, Ford can print the same part in four days, including multiple iterations and with no tooling limits – at a cost of \$3,000.



A Few Leading Companies

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3-D SYS CORP [DDD]



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EXONE CO [XONE]





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Brief Review of AM/3D Printing Technologies



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F2792 – 12a Standard **Terminology** for Additive Manufacturing Technologies

F2915 – 12 Standard Specification for Additive Manufacturing **File Format** (AMF) Version 1.1

F2921 – 11 Standard Terminology for Additive Manufacturing— Coordinate Systems and Test Methodologies

F2924 – 12a Standard Specification for Additive Manufacturing Titanium-6 Aluminum-4 Vanadium with **Powder Bed Fusion**

F3049 – 14 Standard Guide for **Characterizing Properties of Metal Powders** Used for Additive Manufacturing Processes



Additive Manufacturing Process Categories



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Binder Jetting — a liquid bonding agent is selectively deposited to join powder materials.

Directed Energy Deposition — focused thermal energy is used to fuse materials by melting as they are being deposited.

Material Extrusion — material is selectively dispensed through a nozzle or orifice.

Material Jetting — droplets of build material are selectively deposited.

Powder Bed Fusion — thermal energy selectively fuses regions of a powder bed.

Sheet Lamination — sheets of material are bonded to form an object.

Vat Photopolymerization — liquid photopolymer in a vat is selectively cured by light-activated polymerization.



Other Names for 3D Printing Technologies



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STEREOLITHOGRAPHY FUSED-DEPOSITION-MODELING (FDM) LASER MELTING (LM, SLM, SLS, DMLS) ELECTRON BEAM MELTING (EBM) BINDER JETTING (BJ)

MATERIAL JETTING (MJ, DOD) (Inkjet print heads are used to jet melted wax materials onto a build platform)

PHOTOPOLYMER JETTING (POLYJET)





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A few technology advances



Printed Copper Features

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The Hi Current Electro-Mechanical Interface



Source

Drair

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Progressing Toward Structured Metal (Cu, Al)

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- Fine vertical metal columns are used to provide electrical and thermal conduction with stress management.
- Development of direct printed metals are being developed.



"Packaging for power semiconductors based on the 3D printing technology Selective Laser Melting", EPE'14-ECCE Europe, 26-28 Aug. 2014, Conrad, M.; De Doncker, R.W.; Schniedenharn, M.; Diatlov, A. PACKAGING RESEARCH IN ELECTRONIC ENERGY SYSTEMS



Structured Copper Strain Buffer General Electric - US4385310 A Published: May 24, 1983, Priority: Mar 22, 1978



"Investigation of Rapid-Prototyping Methods for 3D Printed Power Electronic Module Development," H. Ke, A. Morgan, R. Aman, D. C. Hopkins, IMAPS'14, Oct. 13-16, 2014



Sintered Alumina Impeller

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- Ainsley C, Reis N, Derby B (2002) Freeform fabrication by controlled droplet deposition of powder filled melts.
- Example 3D Micromac part made from aluminum oxide powders (courtesy Laserinstitut Mittelsachsen e.V.)







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AM Materials for Power Module Housings





We're Getting Closer

A comparison of AM materials and traditional housing material is given based on the Heat Deflection Temperature (HDT) rating versus Tensile Strength.

Traditional power module housings are typically cast with materials such as:

- Thermoset allyls/epoxy
- Diallyl phthalate (DAP)
- Thermoplastic polyester
- Polybutylene terephthalates (PBT)





Present Advances Are In Use of Multi-Materials PREES

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Voxel8 Named Top 9 Innovation at CES'15



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NCSU-PREES Lab development

- Complete SiC Switch & Diode with top-side gate drive.
- Completed in two weeks





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An SiC-based Traction Inverter (ORNL)



- Optimized inverter heat sink, allowing heat transfer throughout the unit.
 - This allowed lower-temperature components closer to high-temperature devices to reduce electrical losses, volume and mass of the package.
- Also, incorporates several small capacitors in parallel with better cooling and lower cost compared to fewer, large and expensive "brick type" capacitors.
- First prototype is a liquid-cooled, allsilicon carbide, 30kW traction inverter, with 50% printed parts.
 - Initial evaluations confirmed an efficiency of nearly 99 percent and setting the stage for building an inverter using entirely additive manufacturing techniques.



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"New ORNL electric vehicle technology packs more punch in smaller package," M. Chinthavali, Oak Ridge, Tenn., 14 Oct 2014



Summary

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- The vision is strengthening for high volume (e.g. automotive) manufacturing in rapid prototyping and 'form/fit/-AND-function'.
- The technology in Additive Manufacturing (3D Printing) for power electronics is continuing to grow, though not necessarily providing growth in the financial sector.
- Primary movers in 3D for power electronics will use multiple materials for integrating control and drive into power stages.
- A large improvement in Thermal Management has been demonstrated in printed heat exchangers by Oak Ridge Labs.
- 3D printing of subassemblies and components is helping to define the boundaries for near term adoption.
- A new university-housed power electronics packaging resource is not complete.





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QUESTIONS???

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