Additive Manufacturing Capability Study for Semiconductor Test Components

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TestConX China

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Contents

Introduction to Additive Manufacturing

- Additive manufacturing refers to a wide variety of manufacturing methods where a finished part is created from material being solidified, bonded, or deposited through a series of additive steps.
  - 3D printing is a subset of additive manufacturing which deals more specifically with plastics and metals being formed in a 3D building space through computer automated machines.
- Recent improvements in 3D printing cost and quality have significantly increased the use of these machines in many markets but our semiconductor test market has been slow to adopt them.

Prior Studies from the BiTS Community

- "Using Alternate Manufacturing Methods for Rapid Prototyping of Test Sockets"
  - 2012 BiTS Workshop March 4 - 7, 2012, James Migliaccio RF Micro Devices
  - This project found some difficulty in printing the hole arrays needed for a socket and spring probes but it was acceptable for one time use application
- "3D Printed Space Transformers"
  - BiTS Workshop March 4 - 7, 2018, Don Thompson R&D Altanova
  - This project used some of the unique geometry available to 3D printers and is an excellent example of how the technology is shifting thoughts away from rectangular boxes and holes

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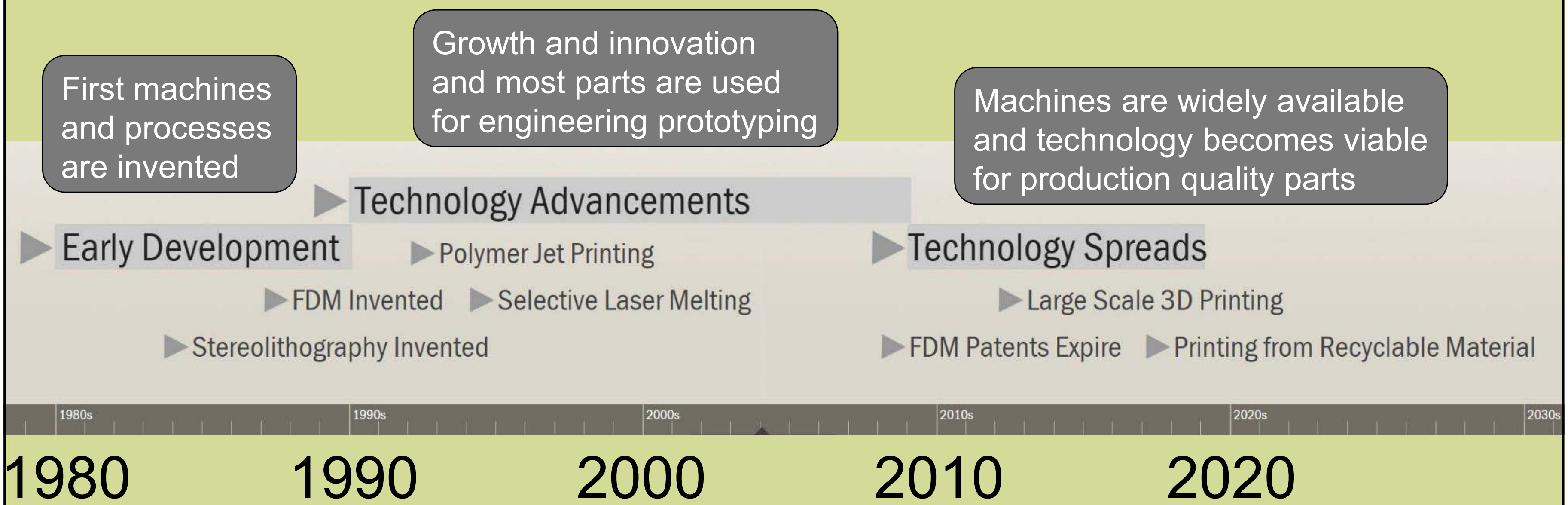
History of 3D Printing Technology



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3D Printing Manufacturing Processes

- FDM – Fused Deposition Modeling
  - Filament of material is extruded through a moving nozzle
  - Most common process, very low cost, low quality and low durability
  - Scalable to very large applications including automobiles, homes, etc.

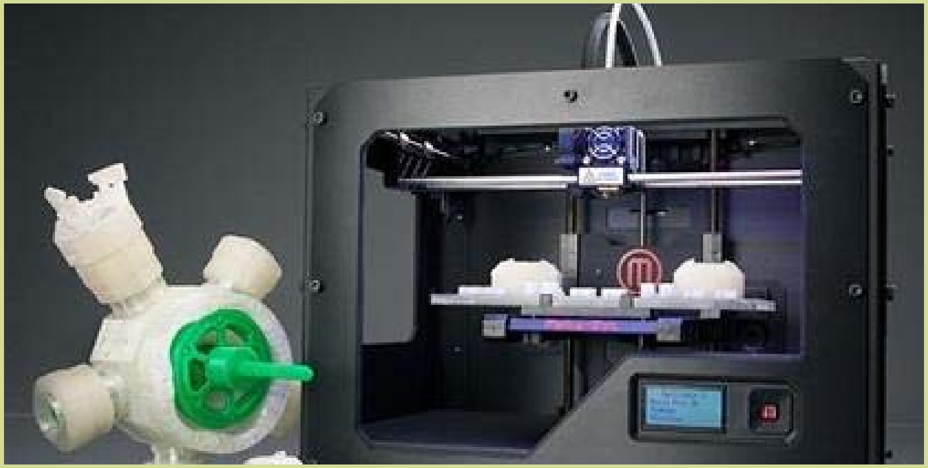

Image Source: www.makerbot.com

3D Printing Manufacturing Processes

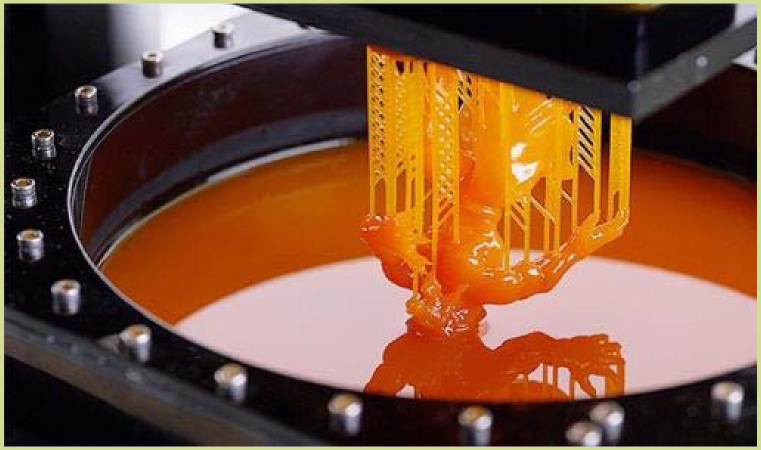

Image Source: www.3dnatives.com

- SLA, SLS – Stereolithography & Selective Laser Sintering
  - Laser scans the surface of the material to harden, melt, and/or cure it
  - Widest range of materials from durable polymers to metal alloys
  - High accuracy and moderate cost

3D Printing Manufacturing Processes

- MJP – Multi Jet Printing
  - Specialized print heads deposit droplets or particles of material similar to an inkjet printer which are then cured in place
  - Limited material choices with highest available accuracy and moderate cost, multi color printing available

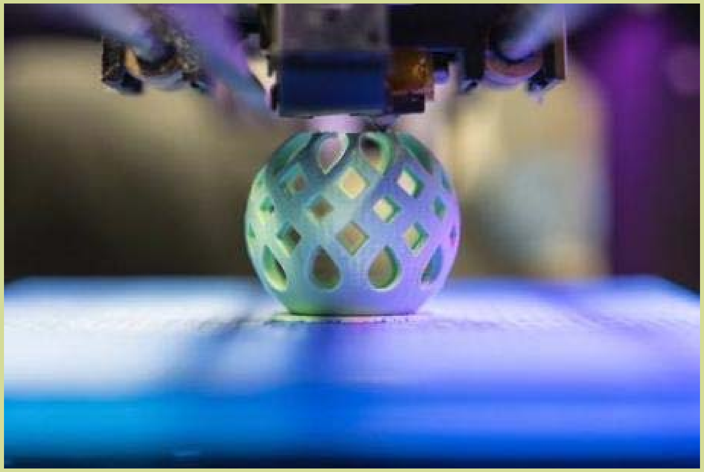

Image Source:
www.highlive.org

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3D Printing Material Comparison

3D Printing Material	Flexural Modulus (MPa)	Flexural Strength (MPa)	Tensile Modulus (MPa)	Tensile Strength (MPa)	Elongation at Break	Impact Strength, Notched (J/m)	Heat Deflection Temp (°C)
High Temp SLA	8300-9800	124-154	7600-11700	66-68	1.4-2.4%	13-17	@ 66 PSI - 267-284
High Res SLA	2690-3240	88-110	3200-3380	63-68	5-8%	12-22	@ 66 PSI - 55-58
High Strength SLS	4400-4550	83-89	5475-5725	48-51	4.5%	37.4	@ 66 PSI - 184
High Strength MJP	2168	65	2168	49	8.3%		@ 66 PSI - 88
Standard Materials							
Ceramic PEEK	5500	170	5500	102	5%	35	@ 264 PSI - 316
MDS 100	9790	141	10300	101	1.5%	21	@ 264 PSI - 210

Sources: www.3dsystems.com
www.matweb.com

- Polymer materials for SLA and SLS can reach comparable performance to currently used standard materials for contactors and lids
- High temperature material performance is still limited

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3D Printing Process Strengths and Weaknesses

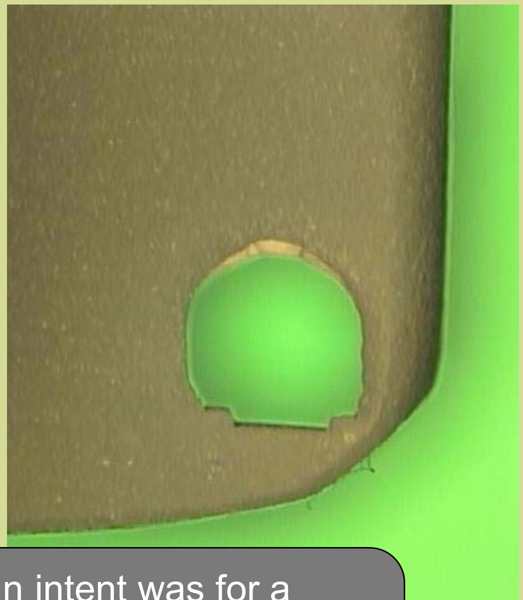
- FDM
  - Fast, low-cost parts, suitable for prototype checks
  - Low accuracy, weakest selection of material properties
- SLA, SLS
  - Moderate cost, high accuracy with widest available material selection, suitable for prototype or production quality parts depending on application
  - Not capable of finest detail
- MJP
  - Moderate cost, high speed, highest accuracy parts
  - Moderate strength and low temp applications only

3D Printing Strengths

- 3D printing can create nearly any geometry that a designer can imagine and model in CAD
  - Shapes and features that are forbidden in traditional subtractive machining processes are OK for 3D printing:
    - Undercuts and internal grooves, square or hexagonal holes, sharp interior corners
    - Angled and curved surfaces, lattices and meshes, air and fluid channels,
    - Negative images of final parts for filling or secondary processing, Etc. to the limits of your imagination
- Reduced number of steps from design to finished part reduces lead times

Image Source: www.3dprintingprogress.com

3D Printing Weaknesses

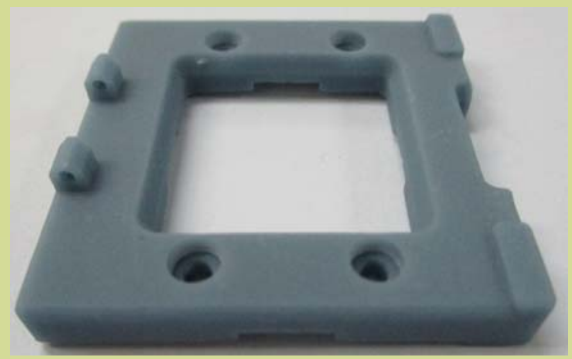


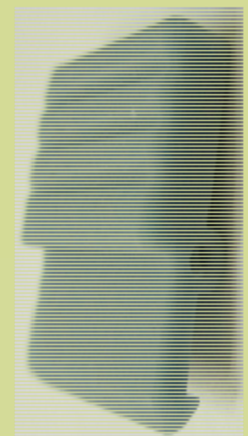
Design intent was for a 1.5mm circular hole near a chamfered 90 degree corner, Z axis steps visible

- Limited resolution in high performance material, Z axis less accurate than XY
- Material properties are non isotropic and can change depending on part orientation
- Rough surface finishes require some post processing which can affect tolerance control
- Design methods need to be adapted to a different set of DFM (design for manufacturing) rules

Sample Part Analysis: Hand Socket Lid

With knowledge of the difficulty in creating the pin arrays for a Test Socket we decided to focus on Hand Socket Lid components for this study





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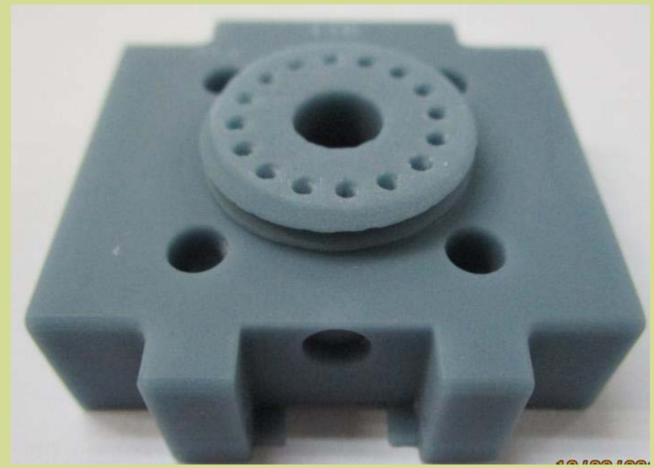
Sample Part Highlights

Edge features are better for alignment than dowel pins due to hole tolerance

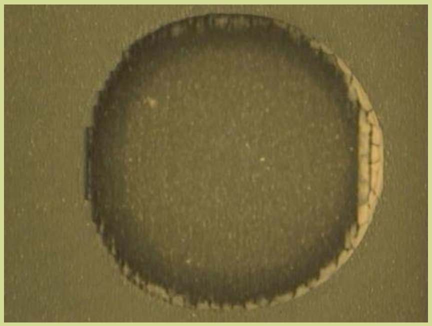
Crossed air flow holes on CNC would require 3 setups to drill on 3 orthogonal planes

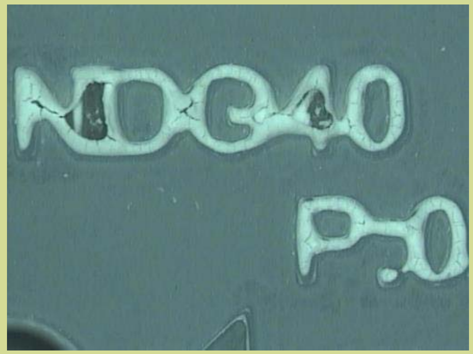
Fully functional male/female threaded knob, overall clean parts and assembly



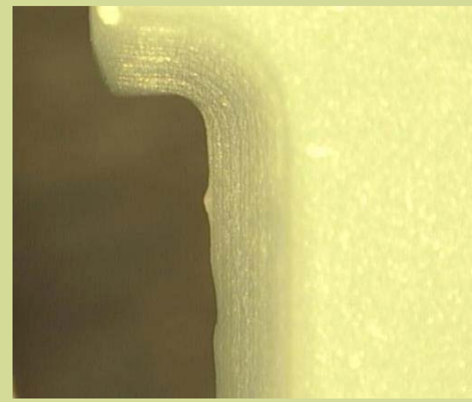
Sample Part Lowlights

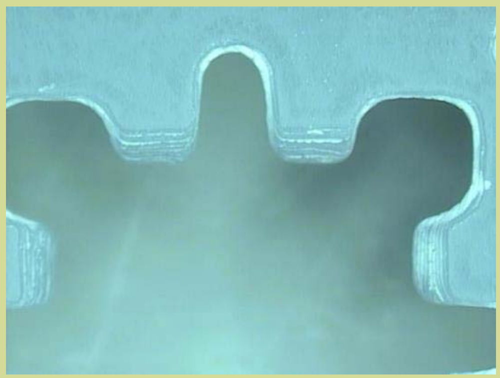
Sanding and material removal in blind holes is difficult





Lettering groove smaller than min feature size





Excessive stepping on draft edges

Rough line where chamfer comes to a sharp edge (thickness < min feature size)

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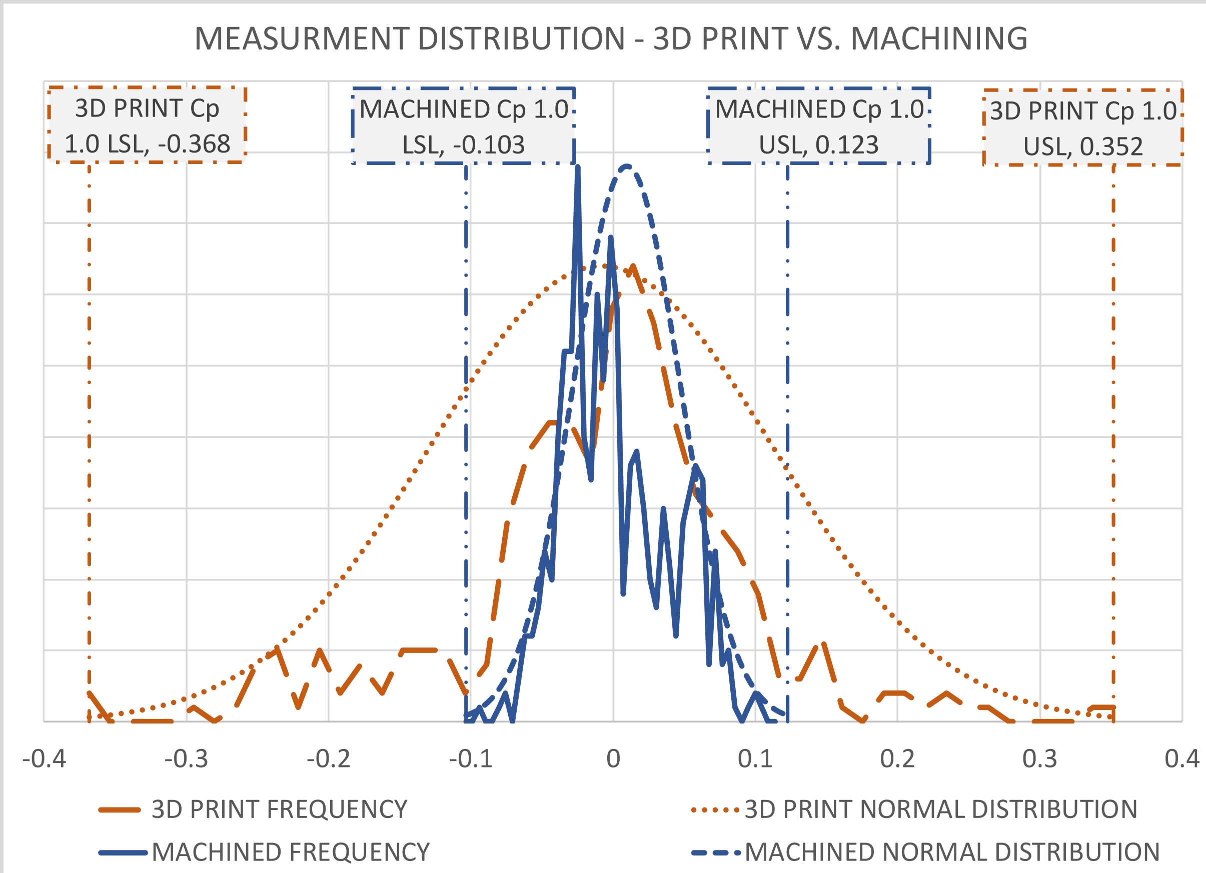

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Component Tolerance Analysis

- 3D printed parts had a linear tolerance band approximately 3x greater than the machined components
  - 3D print data was clustered close to the machining data but had more outliers spreading the distribution
  - Outliers are mostly contributed by areas of the part that fell outside DFM guidelines for 3D printing such as corner relief radii, thin edges on chamfers, etc.
- Tolerance deviations did not have a negative affect on the overall form, fit and function of the assembly indicating that lid most components can generally allow for extra linear tolerance

Lessons Learned

- 3D printing requires a new dedicated set of design rules to maximize the benefits of the unique geometry available while minimizing deviations from minimum feature size restrictions
  - Many design requirements that are needed for machining can be removed or simplified with 3D printed parts, speeding the design process and allowing for more robust designs
- We will continue to study the functionality and longevity of 3D printed parts to find knew ways to use them in other assemblies
- With proof of concept complete the door is open for novel new designs and test technology using this emerging manufacturing method that will continue to advance in coming years