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# Additive Manufacturing Capability Study for Semiconductor Test Components

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## Contents

- Introduction to Additive Manufacturing
- History of 3D Printing Technology
- 3D Printing Manufacturing Processes
- 3D Printing Material Comparison
- Strengths and Weaknesses
- Sample Part Analysis: Hand Socket Lid
- Component Tolerance Analysis
- Lessons Learned

## 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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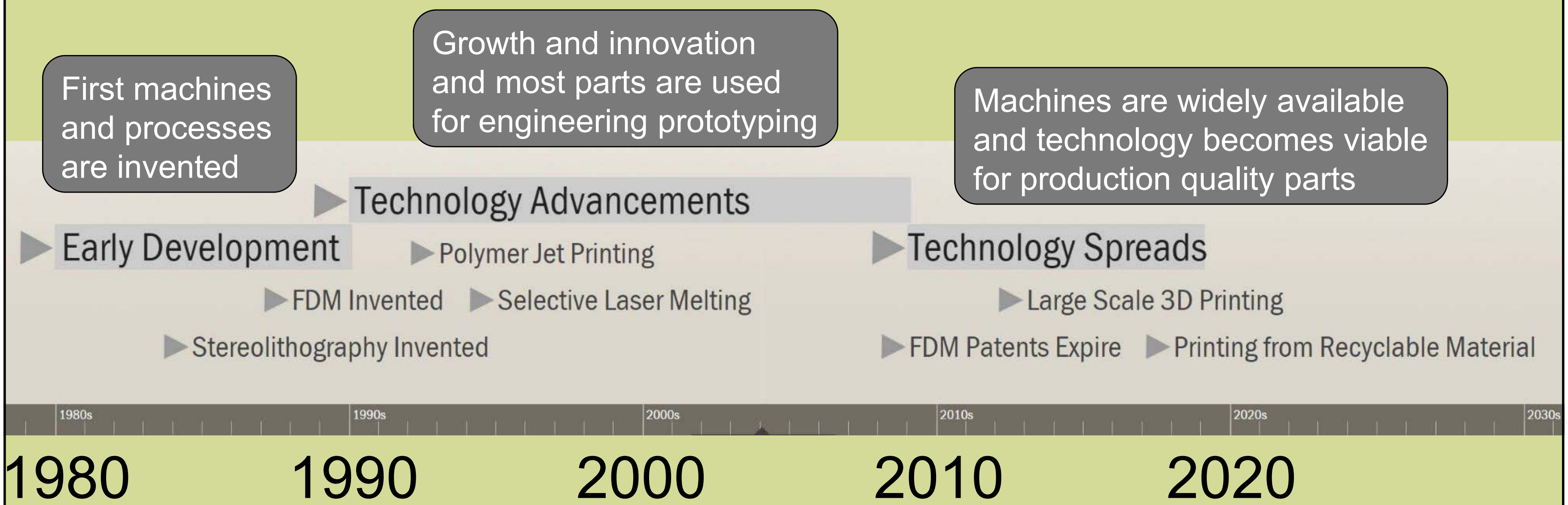
## History of 3D Printing Technology

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2018

5

# 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.

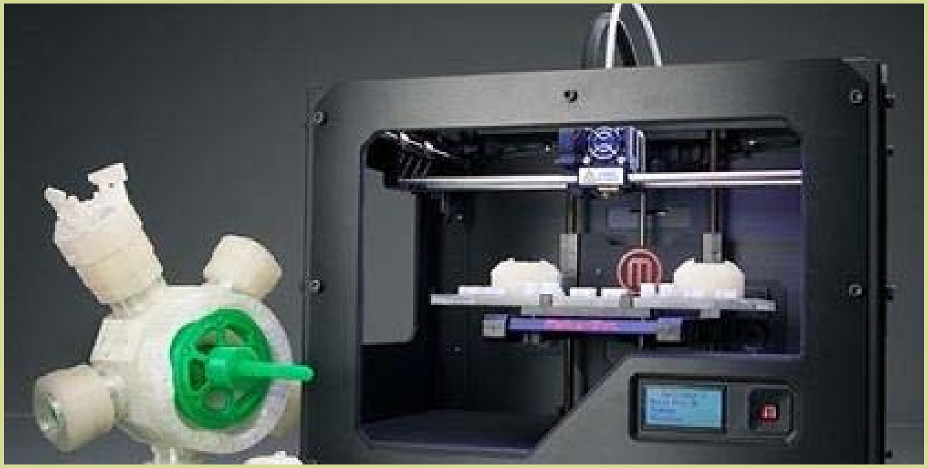

Image Source: www.makerbot.com

## 3D Printing Manufacturing Processes

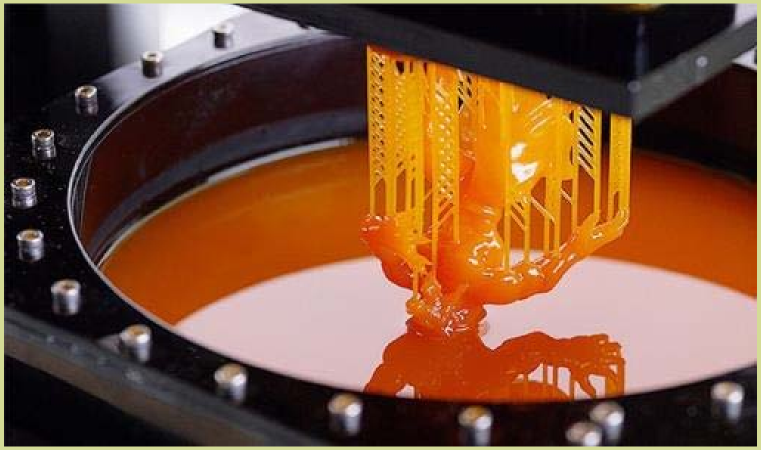

Image Source: www.3dnatives.com

- 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

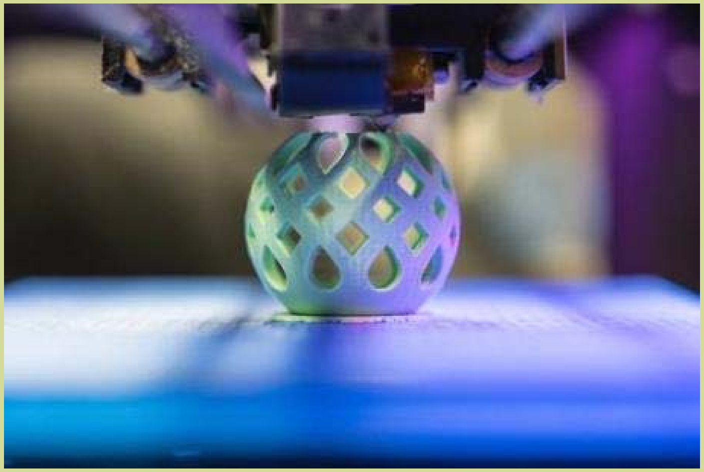

Image Source: www.highlive.org

# 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 |

- 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

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

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9

## 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

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## 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

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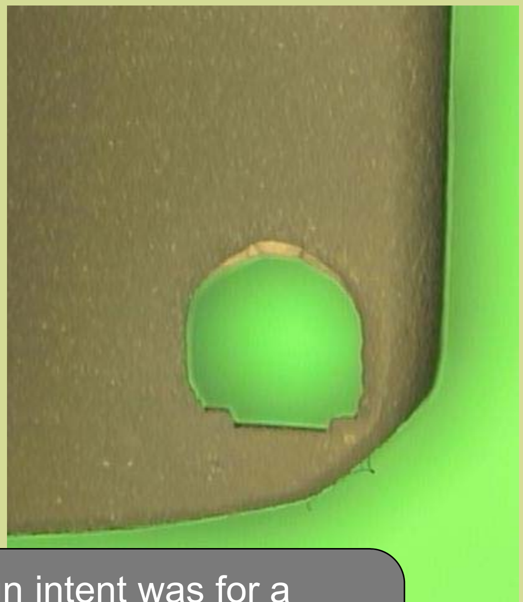
11

## 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

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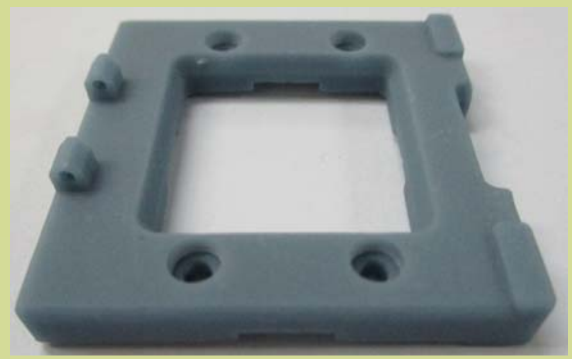
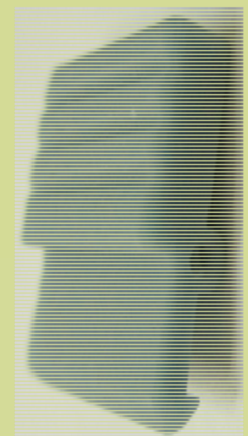
12

## 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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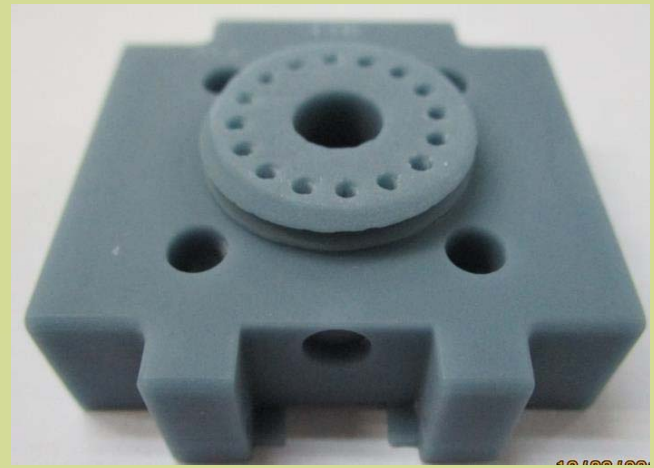
## Sample Part Highlights

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



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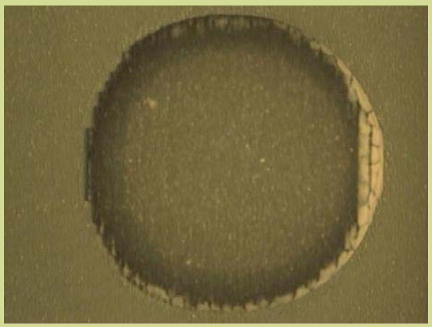
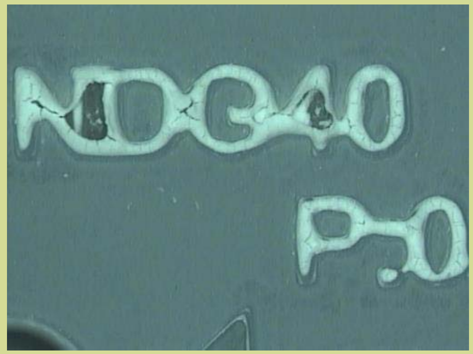
14

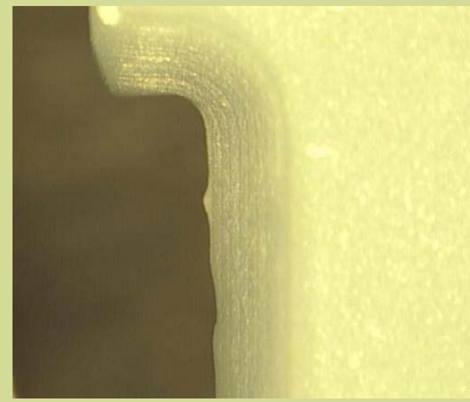
## Sample Part Lowlights

Sanding and material removal in blind holes is difficult

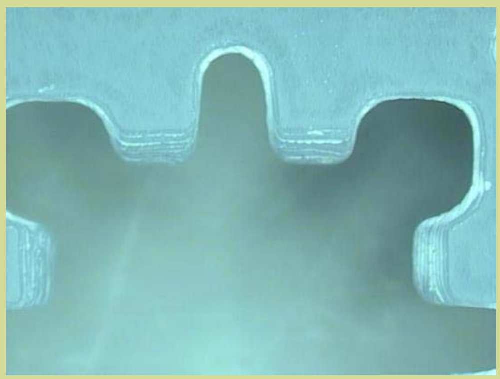




Lettering groove smaller than min feature size



Excessive stepping on draft edges



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

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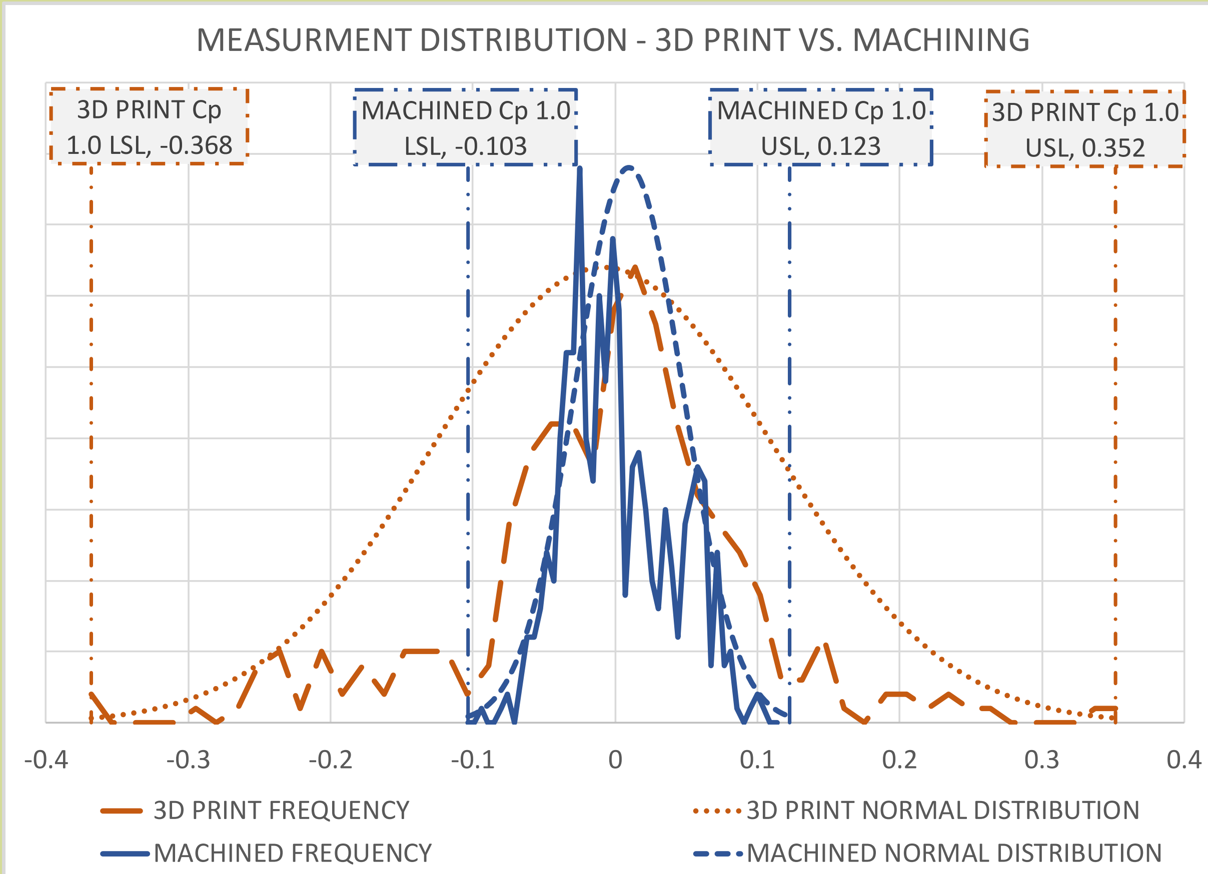


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16

## 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

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17

## 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