Case study:
Bringing 3D Printed Electronics into Mass Production – Lessons Learned

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About Optomec

Leader in Printed Electronics and Additive Manufacturing

- Production Printers for Electronics, Sensors, Metals…
- Print Full Products or Add Functionality to Existing Parts
- Cost and Functional Advantages over Current Manufacturing Solutions

300+	50+ Issued 60+ Pending	40+	75+
Optomec Global Installations	Optomec IP	Optomec Material and Automation Partners	Optomec Employees Albuquerque & St. Paul

Privately Held – Profitable – Recent Investment from GE

LITE-ON TECHNOLOGY CORPORATION

Founded in 1975, LITE-ON (Lite-On Technology Corporation) is a leading supplier in the global opto-electronic components industry. LITE-ON's product offerings are leading the industry and widely applied in areas such as computer, communication, consumer electronics and car electronics. LITE-ON is committed to global citizenship and recognized with several CSR awards.

60 000+	US$7.3B	40+	300+
LITE-ON employees worldwide	LITE-ON Net Sales in 2014	LITE-ON's partners from the world's leading brands	Worldwide LITE-ON Locations

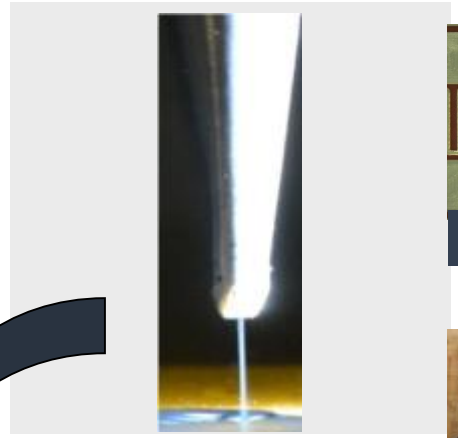
LITEON® In US$ Millions

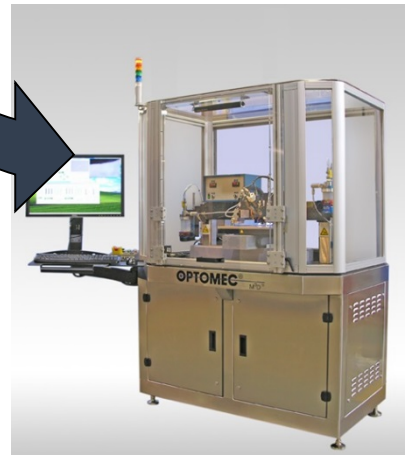
	2008	2009	2010	2011	2012	2013	2014
Net Sales	7 208	5 725	7 373	7 822	7 301	7 178	7 300

Aerosol Jet Print Solution Overview

- Patented Material Deposition Process
- "Input" Fine Particle Inks and Standard Pastes
  - Conductors, Insulators, Semiconductors, Biomaterial…
- "Output" Fine Features to ~10µm to mm & Coatings from 50nm
  - Non-contact process
  - 2D / 3D Printing
- Cost and Functional Advantages
  - Lower Material and Process Costs
  - Improved End-Product Performance

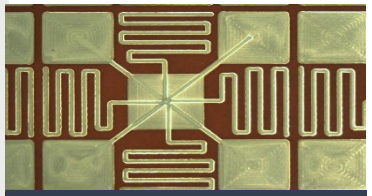
Aerosol Jet Process





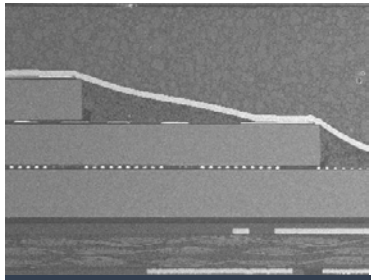
Standard Systems

Application Examples



EMI Sensor Array

3D Antenna



Staggered Die

3D Solutions for Mainstream Electronics Production

Process	2D Antenna	3D Antenna	Digital	Common Plastics	No Plating	Feature Size	Uniform Material Thickness
Direct Write *Aerosol Jet*	√	√	√	√	√	< 50 um	√
Direct Write *Dispense*	√	√	√	√	√	>150 um	
LDS Additive	√	√	√			150 um	√
2 Shot	√	√		√		400 um	√
Hot Foil	√			√	√	1000 um	

- *Direct Write Advantages over current antenna and sensor manufacturing processes*
  - Standard Plastics, No Additives or Special Coatings
  - No Plating, No Nickel, Environment Friendly
  - Fewer Steps, Less Floor Space, Simplified Logistics
  - Projected cost savings as much as 15% or more compared to LDS'

Optomec's Scalable 3DP Solutions Family

- Aerosol Jet - From Material and Process Development to Full Scale Production

AJ 200 Standard Series
Material & Process
Development

AJ 300 Standard Series
R&D to Low Volume
Production

AJ 5X Standard Series
R&D to Low Volume
Production

AJ High Volume
Production Series

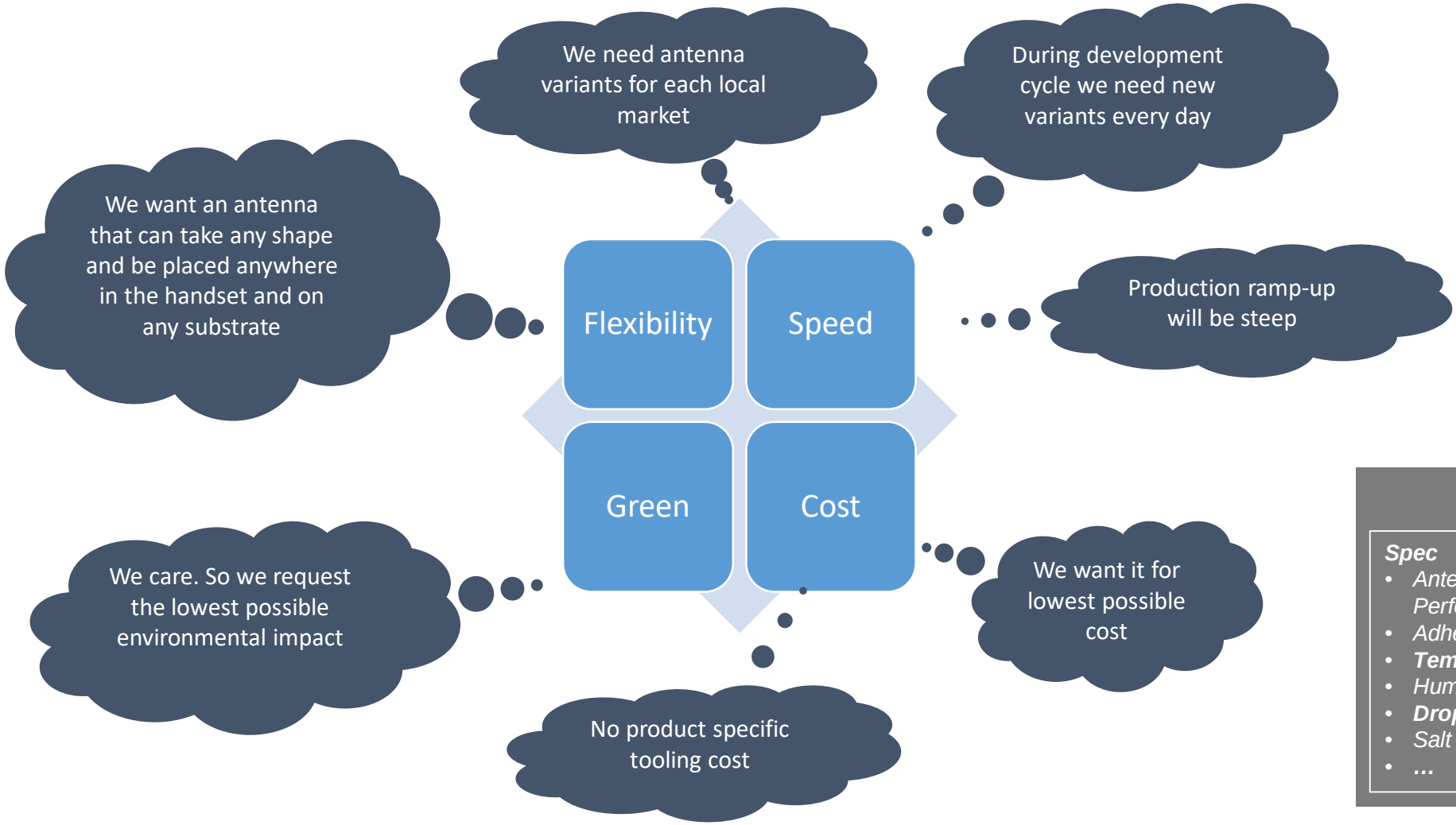
3rd Party Automation

Printing in Mass Production for Antennas & Sensors

LITE-ON Antenna Production Capabilities

PRODUCT & SERVICE	CAPABILITIES
Antenna Research, Design and Verification	•Three full scale antenna labs around the world, with world class Antenna Engineering R&D resources •Vast experience in design of the full spectrum of antennas used in mobile handsets and tablets today, as well as research for antenna technologies for the future
Stand-alone Antennas	•Laser-Direct Structuring ('LDS'), Flex-Film antennas ('FPC'), and Sheet Metal antennas •In-house tooling, injection molding, and metal punching of the full antenna product range •Manual, semi-automatic, and fully automatic manufacturing and production testing
Module Antennas	•LDS, FPC, and sheet metal antennas combined with other electromechanical components •Customized Speaker Box Antenna modules
Mechanically Integrated Antennas	•Main, diversity, and complementary (BT, WLAN, GPS, NFC, etc) antennas, fully integrated into structural chassis and covers including 'uni-body' •Antennas integrated into cosmetic cover products

Production Drivers – Why printing?



Spec

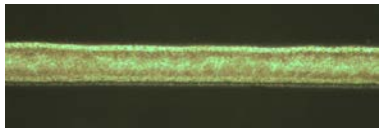
- *Antenna Performance*
- *Adhesion*
- ***Temp cycle***
- *Humidity*
- ***Drop Test***
- *Salt mist*
- ***…***

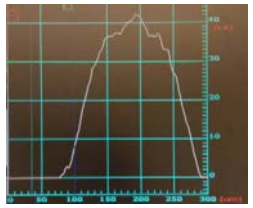
What is LITE-ON 3DP?

- LITE-ON leading the development for printed mobile antennas in 3D for 5 year. Development partners Optomec for Aerosol Jet print engine and Neotech for motion system
- Aerosol jet technology used to print highly conductive nano-particle ink, onto 3D surfaces, without need for masks, screens, or plating
- 4 parallel print stations with 5 axis motion system, 3 linear and 2 rotational axis, enables full access for all surface to be printed with high production throughput

Printing in 3D – Technology Challenges

- Sources of ink for production manufacturing
- Ink process development for a series of substrates
  - Kapton, PA, PC, PC/ABS, Glass, etc.
- Print Quality

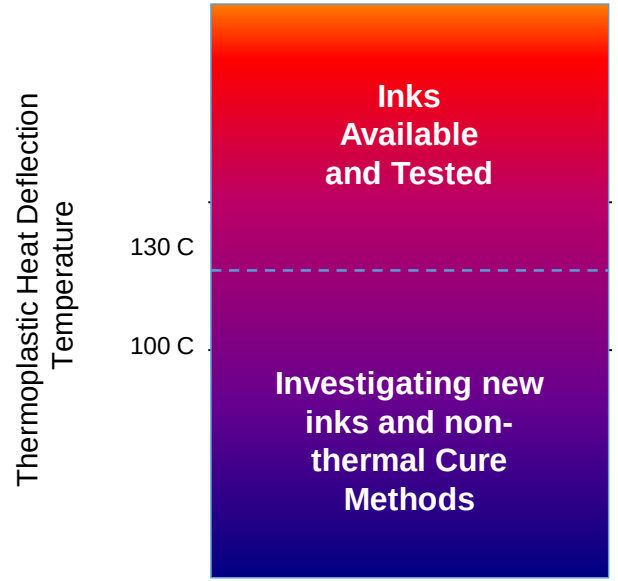




Speed: 20 mm/s
Width: 150um
Thickness: 4 um

- Resistivity

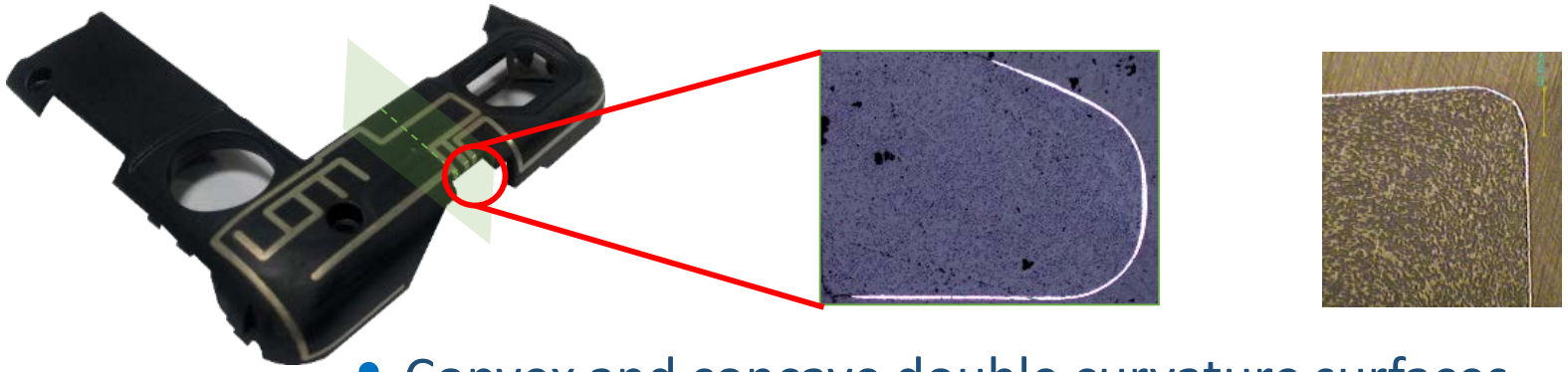
Temp (°C)	Time (min)	Resistivity (Ω-m)	X Bulk Ag
120	60	1.29x10^-7	8.1
200	60	7.74x10^-8	4.8



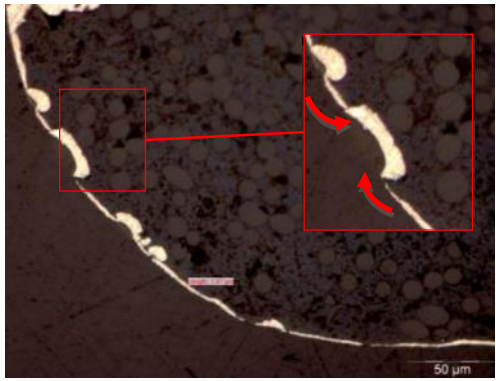
- Environmental Testing – Customer Specific
  - Humidity/Damp Heat
  - Salt Spray Testing
- Adhesion
  - ASTM D3359-02 Adhesion Tape Test

Printing in 3D – Technology Challenges

- Printing on complex geometry in 3 dimensions presents new challenges



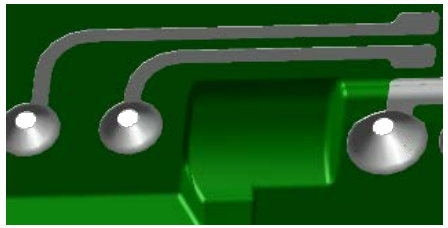
- Convex and concave double curvature surfaces

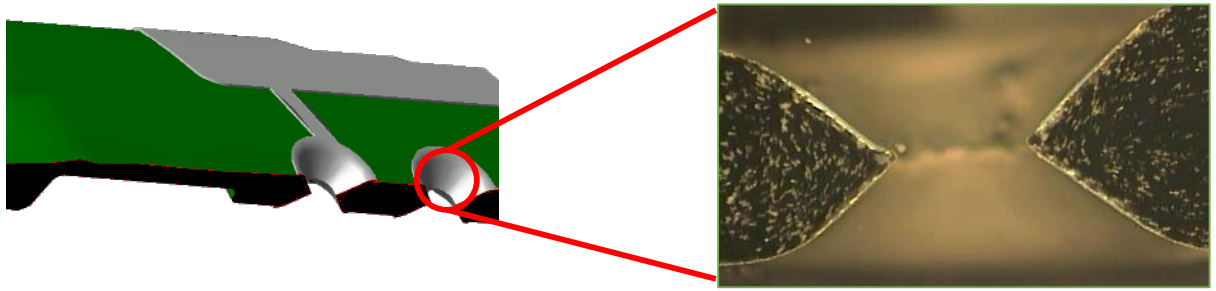


- Capillary action effects

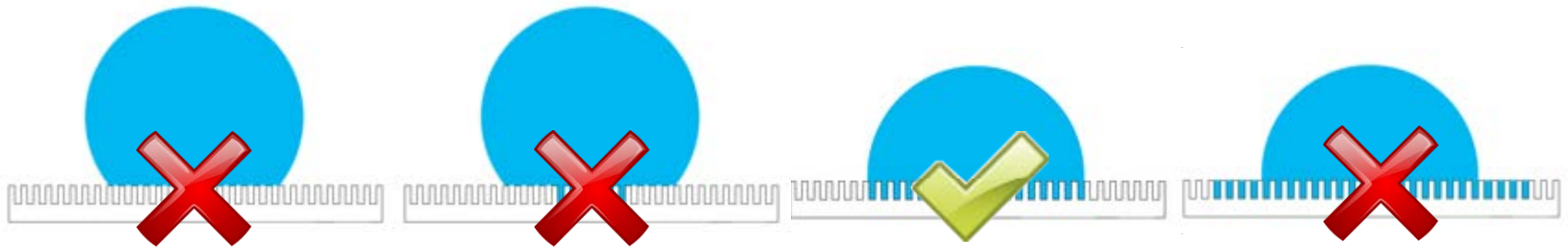
Printing in 3D – Technology Challenges

- Sharp radius and parting lines, “via” hole



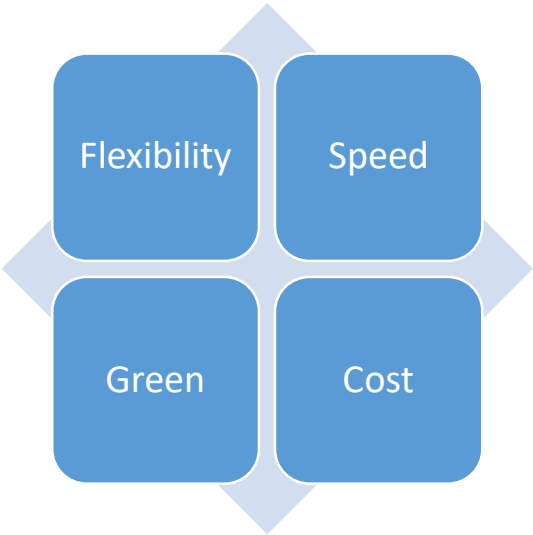


- Surface energy variation, ink wetting



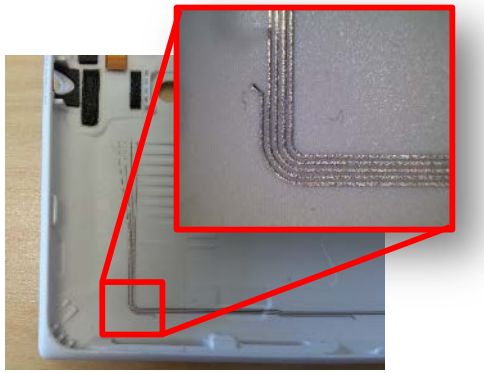
LITE-ON 3DP – Meeting 3D Technology Challenges

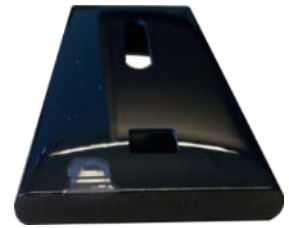
- Access to a wide variety of inks that are performance and environmental test qualified
- Printing on a wide range of resins and materials, plastics, glass, ferrites, metals...
- Full three-dimensional printed features with consistent widths & thicknesses
- High efficiency & consistent RF performance
- High output due to multi-station set-up, cost competitive
- LITE-ON in-house technology enabling rapid design changes and product supply lead-times
- Additive with no plating required - an environmentally conscious technology



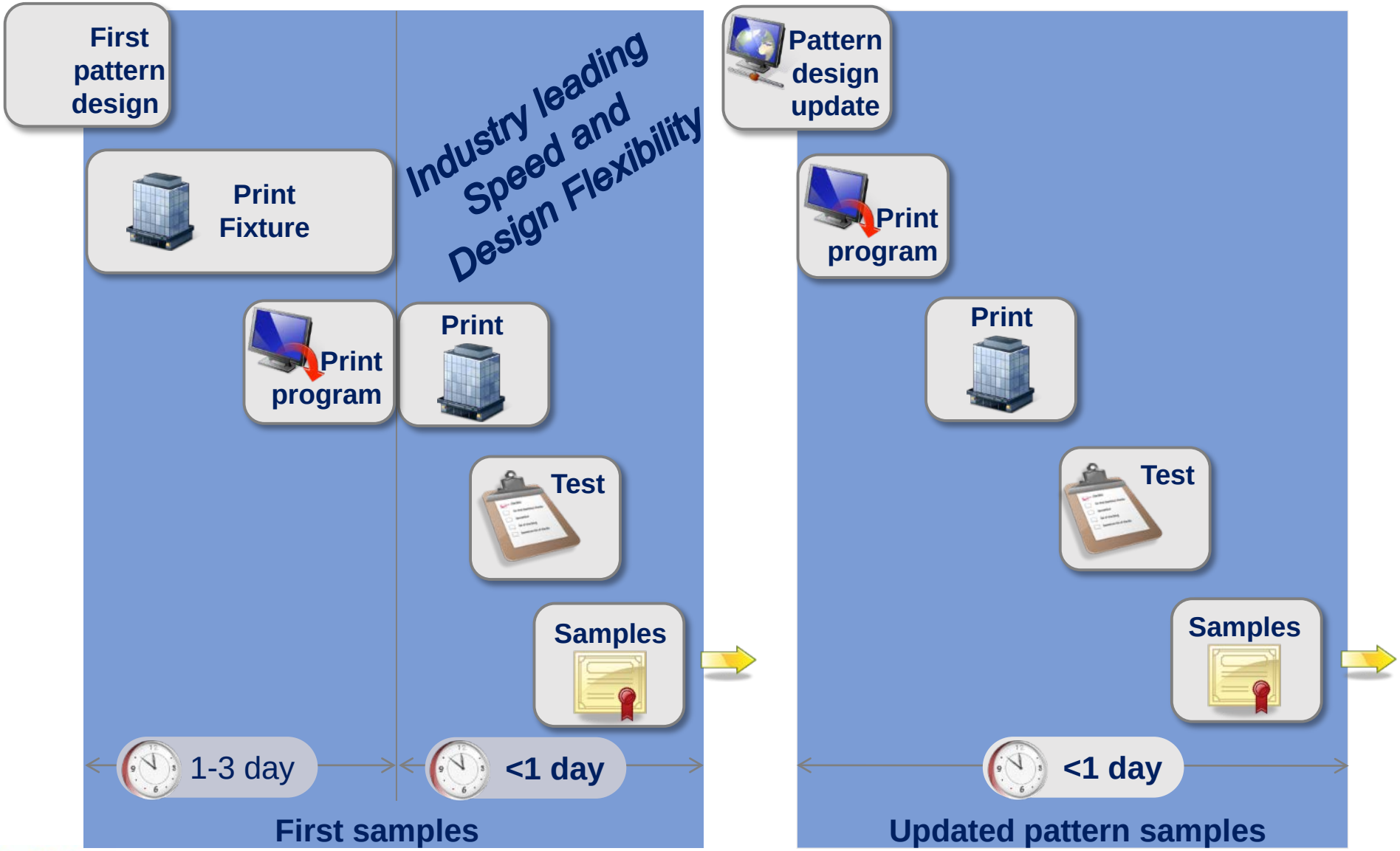
Design Flexibility

- With 3DP, Antennas can be placed anywhere and can take any form
- Placing the antenna as far out as possible in the corners of the device increase signal reception
- For sensor application narrow lines are often needed. Fine line printing also possible with 3DP
- Printing on any plastics, glass panels, outer surface, inside concave undercut corner



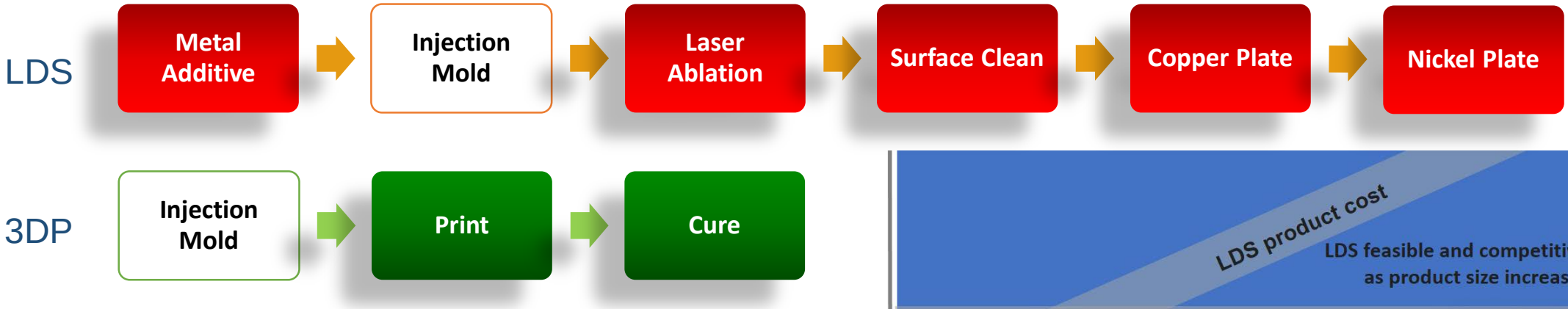


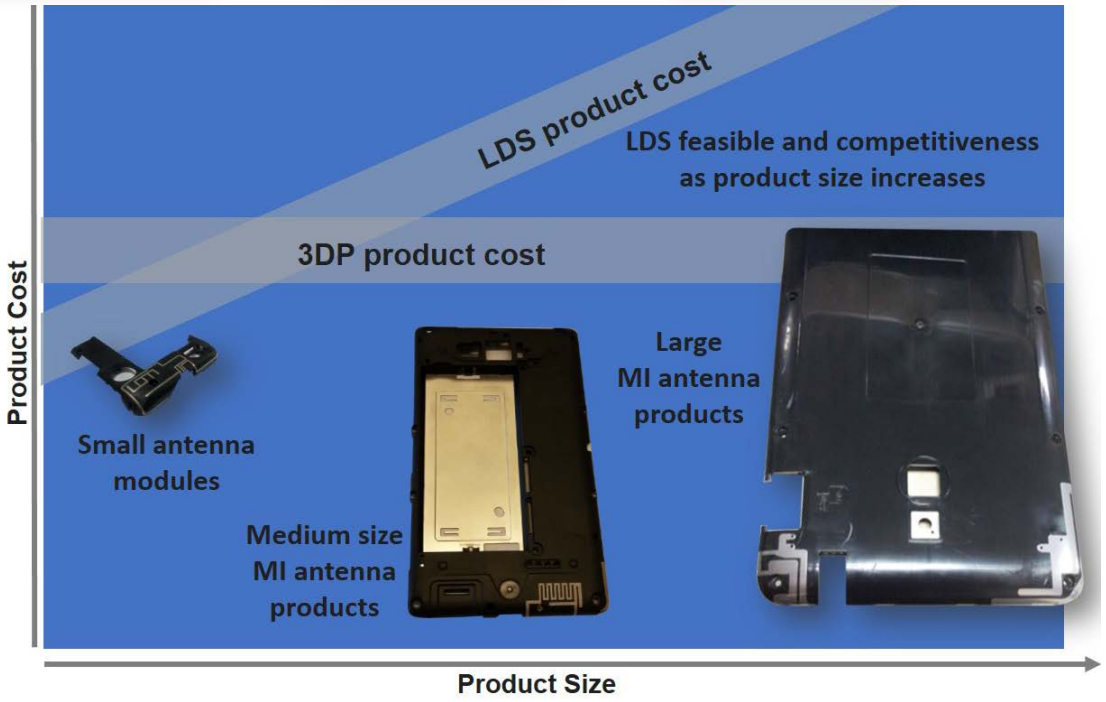
Prototype to Production Turnaround



Cost Efficiency

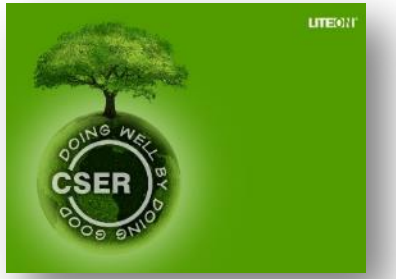
- 3DP product cost is driven by value adding **trace size**, as opposed to LDS where **process steps** and **product size** are heavily affecting product cost





3DP Green Profile

Printing, not Plating	• No electroless plating • No Nickel used
Green Materials	• Additive process, very little process waste • Thin trace layer compared to other solutions • Recyclable and bio-de-gradable resins possible
Optimized Logistics	• 100% in-house – no big transportation impact • All manufacture steps in one production cell



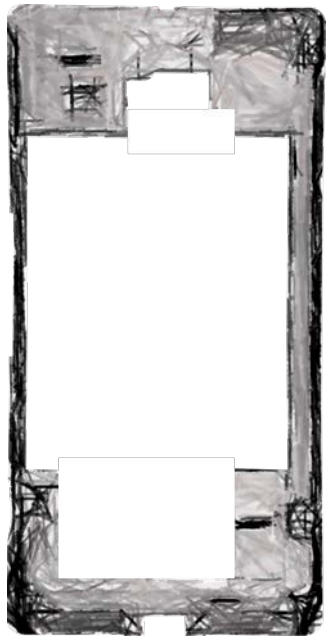
March 2016 3DP technology won LITE-ON group CSER award for its reduction of waist and lowering the environmental impact for production of antennas and sensors

Application - Antenna & Speaker Module

- 3DP of smartphone antennas on electro- mechanical assembly
- Assembly has speaker and gaskets inside before printing
- 4G/LTE Antennas printed on outside of the assembly for late customization
- Speaker inside - LDS can not be used

Application - Sensor Trace

- 3DP Printing of sensor and connection trace
- Structural smart phone frame. Metal plastic hybrid. Al/Mg die-cast with insert-molded glass filled poly carbonate
- Connection done through electrical via-hole
- LDS is not an option due to die-cast component

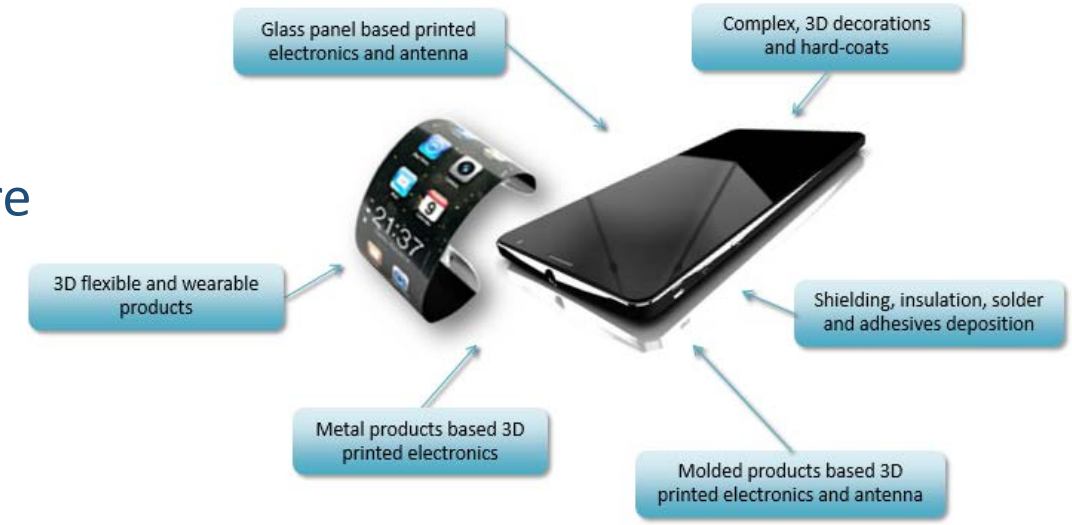


Application – SmartPhone Cover

- 3DP of antennas on cosmetic/visual smart phone cover
- Main, Diversity, GPS, WiFi and BT antennas printed inside of cover
- Antenna traces placed in undercut areas difficult to be reached
- Cover material is poly carbonate in several color variants and high visual requirement

3DP Further Improvements

- Areas where we are still progressing and will continue to work
  - Process speed, print output
  - Ink conductivity – specially for low temperature sinter <120deg C
  - Sintering technologies
  - Printing on new materials, foams and porous materials
  - Copper based ink
- New applications; wearable smart devices and IoT devices,
  - Flexible and stretchable products



Conclusion and Summary

- Aerosol Jet is a cost effective option for mass production of 3D Printed Electronics today.
- LITE-ON MM SBG 3DP is a viable contract manufacturing source for mass production
- LITE-ON has been leading the development of 3D printed antennas and sensors for over 5 years
- LITE-ON have successfully deployed and are currently using 3DP Aerosol Jet based solutions for mass production
- 3DP Aerosol Jet capabilities enable unique solutions and provide significant benefits for:
  - Increased Design flexibility
  - Maximizing Development speed
  - Minimizing Product total cost
  - Reducing Environmental impact

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