إِنَّا كُلَّ شَيْءٍ خَلَقْنَاهُ بِقَدَرٍ

PAE

Pakistan Academy of Engineering

PROCEEDINGS

36th Symposium

"Prospects of Additive Manufacturing in Pakistan"

June 21st, 2025

Contents

Contents

1. Message from the President

My Dear Fellows and Readers,

اَلسَّلَامُ عَلَيْكُمْ وَرَحْمَةُ اللهِ وَبَرَكَاتُهُ

With the great feeling of accomplishment and satisfaction, on behalf of The Pakistan Academy of Engineering (PAE), I present to you the proceedings of the **36th Symposium** of The PAE on the topic of **"Prospects of Additive Manufacturing in Pakistan"**, held on **June 21st, 2025**, at PAE, Gulshan-e-Iqbal, Karachi.

First I would like to thank

Mr. Syed Ahmad Nameer*, Partner Manager, Middle East and Eastern Europe , EOS, Germany*

Dr. Khalid Rahman, Professor - Faculty of Mechanical Engineering, Ghulam Ishaq Khan Institute of Engineering Sciences and Technology, Topi, Pakistan.

Engr. Dr. Shaheryar Atta Khan, HoD (Mechanical Engineering), DHA Suffa University, Karachi, Pakistan.

Mr. Nabeel Khan, Project Manager, Binghalib Engineering Ltd, Dubai, UAE.

Here I would also acknowledge the support of the Council members & Staff of The Pakistan Academy of Engineering (PAE) for their relentless support and assistance.

Finally, I hope that the readers will find the document useful and will gain knowledge and insight in the context of this complex and critical topic.

Very sincerely yours,

Dr.-Ing. Jameel Ahmad Khan
President,
The Pakistan Academy of Engineering (PAE)

2. Programme of the 36th Symposium

The Pakistan Academy of Engineering

On behalf of the President, Dr.-Ing Jameel Ahmad Khan, and the Council Members of the Pakistan Academy of Engineering, we cordially invite you to grace the 36th Symposium on "**Prospects of Additive Manufacturing in Pakistan**" The event details are as follows:

Date: Saturday, June 21, 2025
Time: 10:00 AM – 1:30 PM (GMT +5)
Platform: In-person and Online via Zoom
Link: https://us06web.zoom.us/j/84314695435

The program will feature distinguished speakers who will shed light on Prospects of Additive Manufacturing in Pakistan.

Attached is detailed information about the program, including the schedule and the distinguished speakers who will address the event.

Thank you for considering our invitation, and we eagerly await your presence at this prestigious event.

Sincerely,

Prof. Brig.(R) Dr Nasim A. Khan (SI),
Executive Secretary,
Pakistan Academy of Engineering.
Tel.: +92 213 483 17 26, Tel.2: +92 213 341 821 05
E-mail: drnasimakhan@pacadengg.org
Website: http://www.pacadengg.org

2. Programme of the 36th Symposium

The Pakistan Academy of Engineering

36th Symposium: **Prospects of Additive Manufacturing in Pakistan**

scheduled on Saturday, June 21, 2025

Online via Zoom

Programme

Details	Time
1. Recitation from the Holy Quran *By **Mr Hafiz Mustafa Ahmed Sharief**, Manager Operations,* The Pakistan Academy of Engineering, Karachi, Pakistan.	**1000 hrs**
2. Presidential Address *By **Dr – Ing.** **Jameel Ahmad Khan**, The President,* The Pakistan Academy of Engineering, Karachi, Pakistan.	**1005 hrs**
Where can Laser Powder Bed Fusion make an impact in the Pakistani Market? *By **Mr. Syed Ahmad Nameer**, Partner Manager, Middle East and Eastern Europe ,* EOS, Germany.	**1010 hrs**
Printed Electronics *By **Dr. Khalid Rahman**, Professor - Faculty of Mechanical Engineering,* Ghulam Ishaq Khan Institute of Engineering Sciences and Technology, Topi, Pakistan.	**1050 hrs**
Additive Manufacturing in Pakistan: Current Penetration and Key Challenges *By **Engr. Dr. Shaheryar Atta Khan**, HoD (Mechanical Engineering),* DHA Suffa University, Karachi, Pakistan.	**1130 hrs**
Opportunities and Challenges for Pakistan in Additive Manufacturing *By **Engr. Dr. Waqas Ahmed**, Associate Professor,* NUST Business School, Islamabad, Pakistan.	**1210 hrs**
3. Discussion and Closing Remarks	**1250 hrs**

36th Symposium:
"Prospects of Additive Manufacturing in Pakistan"

scheduled on Saturday, June 21st, 2025
Address of the President
Dr. -Ing. Jameel Ahmad Khan

Respected Speakers,

My dear fellow Engineers,

Honourable Guests,

Ladies and Gentlemen!

SALAMUN ALA MANIT-TABA'AL-HUDA

It is my honour and privilege to address this esteemed gathering at the symposium on "Prospects of Additive Manufacturing in Pakistan." We stand at the crossroads of an industrial transformation, where additive manufacturing (AM) is redefining production processes, reshaping global economies, and enabling technological breakthroughs in multiple sectors.

Additive manufacturing, commonly known as 3D printing, has evolved from a prototyping tool into a cornerstone of Industry 4.0. The global AM market is projected to reach $57.1 billion by 2028, driven by aerospace, automotive, healthcare, and consumer goods applications. Countries such as the United States, Israel, China, Germany, and Japan are leading in AM adoption, investing heavily in research and commercialisation.

With **advancements in material science**, including polymers, metals, ceramics, and composites, AM is now enabling mass production, supply chain resilience, and sustainable manufacturing. The U.S. leads in industrial AM adoption, with **China, Japan, and Germany** also advancing rapidly.

The **Asia-Pacific AM market** was valued at **$4.3 billion in 2023** and is forecasted to reach **$11 billion by 2028**. **China dominates** this sector, focusing on large-scale AM applications. **Japan and South Korea** are pioneering high-precision technologies, while **India** is expanding its AM ecosystem through government-backed initiatives.

A key industry trend is the shift from **proprietary closed-loop systems to open-material platforms**, reducing costs and promoting innovation. Hybrid manufacturing—combining AM with traditional machining—is also improving efficiency and scalability.

Despite global growth, **Pakistan's AM sector remains in its infancy**. Its adoption is primarily limited to **universities, research institutions, and small-scale service providers. GIKI, NUST, and a few other institutions** have made commendable progress, but industrial-level implementation is minimal due to:

- **High initial investment costs**
- **Limited availability of advanced AM materials**
- **Lack of skilled workforce**
- **Limited industry awareness and adoption**
- **Absence of a structured AM policy framework**

Currently, Fused Deposition Modeling (FDM) and Stereolithography (SLA) are the most widely used AM technologies in Pakistan, mainly in healthcare and jewellery. However, Selective Laser Sintering (SLS) and Direct Metal Laser Sintering (DMLS) are virtually absent.

Pakistan must embrace additive manufacturing as a driver of economic growth, import substitution, and industrial self-reliance. Together, we can position Pakistan as a leader in advanced manufacturing technologies.

I extend my sincere gratitude to the esteemed speakers for their valuable contributions to this symposium. Together, let us pave the way for a future where Pakistan stands at the forefront of scientific and industrial innovation.

Thank you, Ladies & Gentlemen.

3.2."Where can Laser Powder Bed Fusion make an impact in the Pakistani Market"

by

***Mr. Syed Ahmad Nameer**, Partner Manager, Middle East and Eastern Europe , EOS, Germany.*

Who Am I?

- Syed Ahmad Nameer
- Partner Manager, Middle East and Eastern Europe
- 7+ years at EOS GmbH

- Profile
- B.Eng in Mechanical Engineering from NUST in 2015
- M.Sc Management, Majors in Business Analytics from ESMT Berlin in 2019
- Executive Advanced Business Analytics, MIT Sloan School of Management in 2021

3.2."Where can Laser Powder Bed Fusion make an impact in the Pakistani Market"

***by Mr. Syed Ahmad Nameer**, Partner Manager, Middle East and Eastern Europe , EOS, Germany.*

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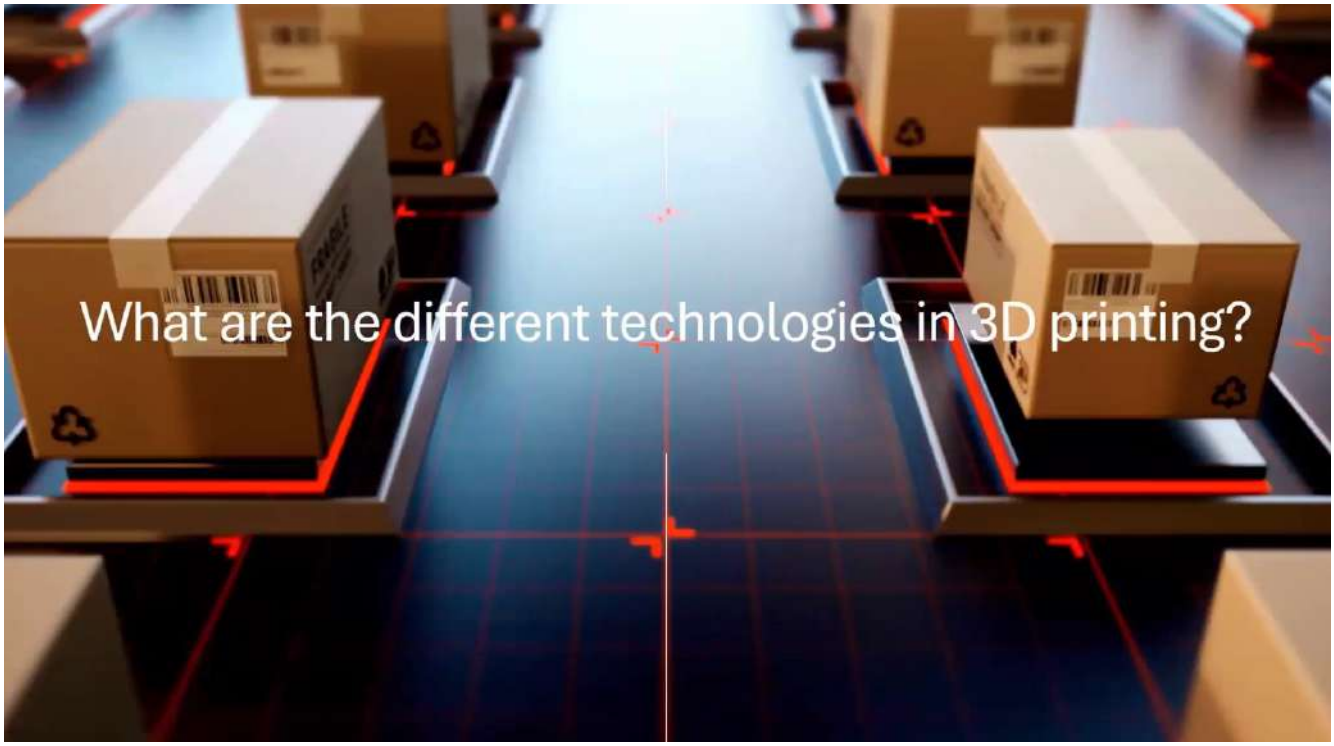

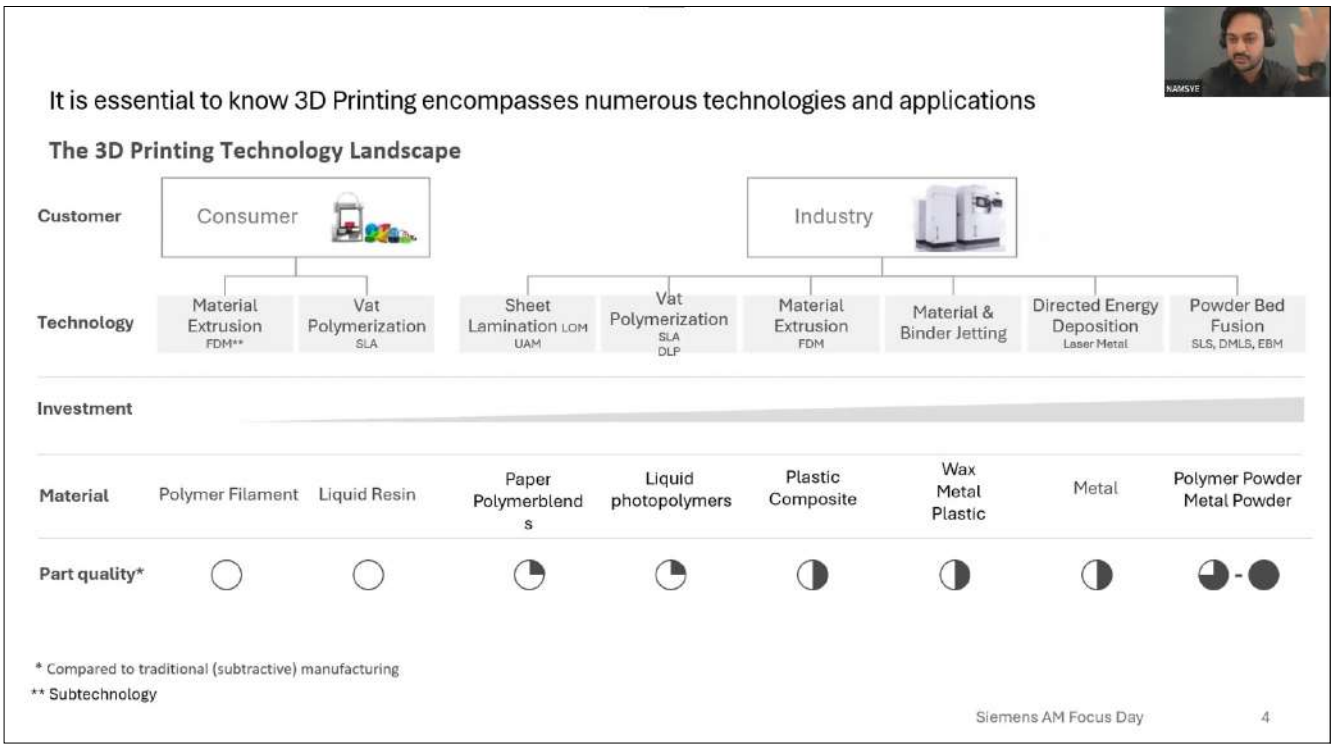

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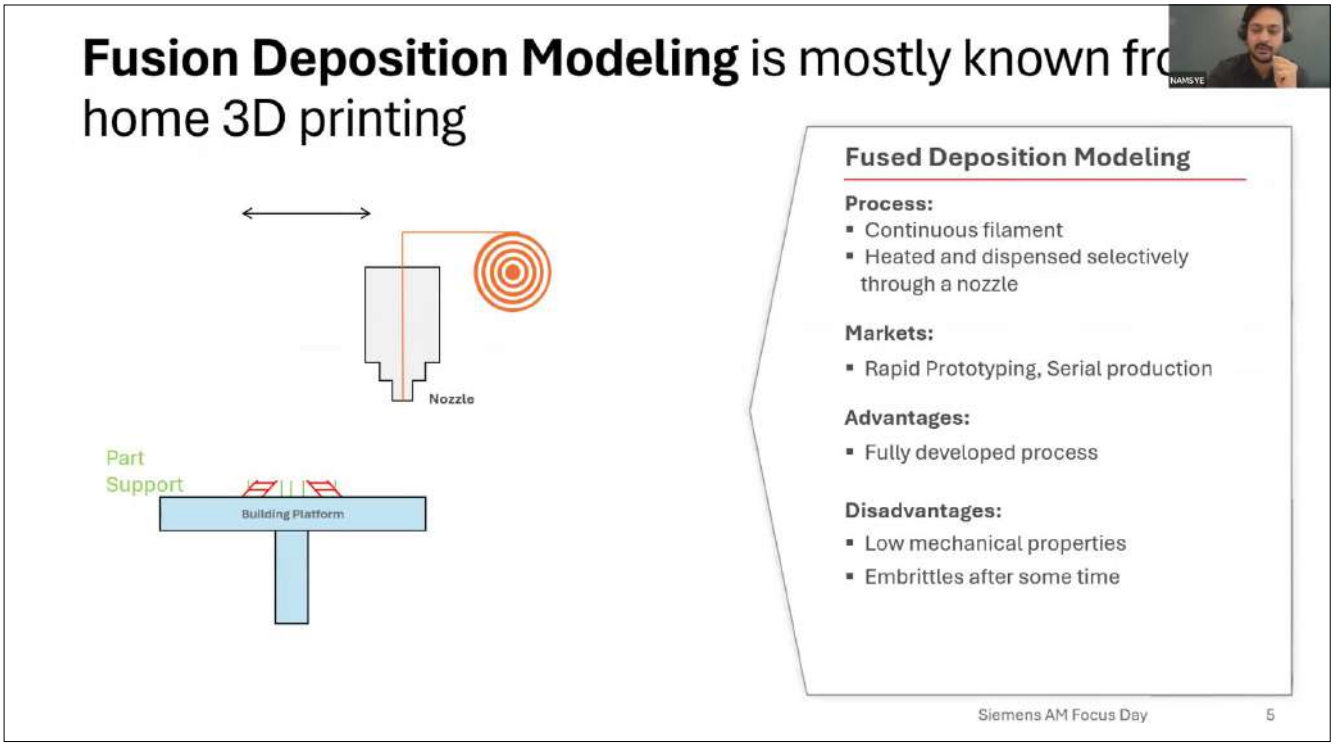

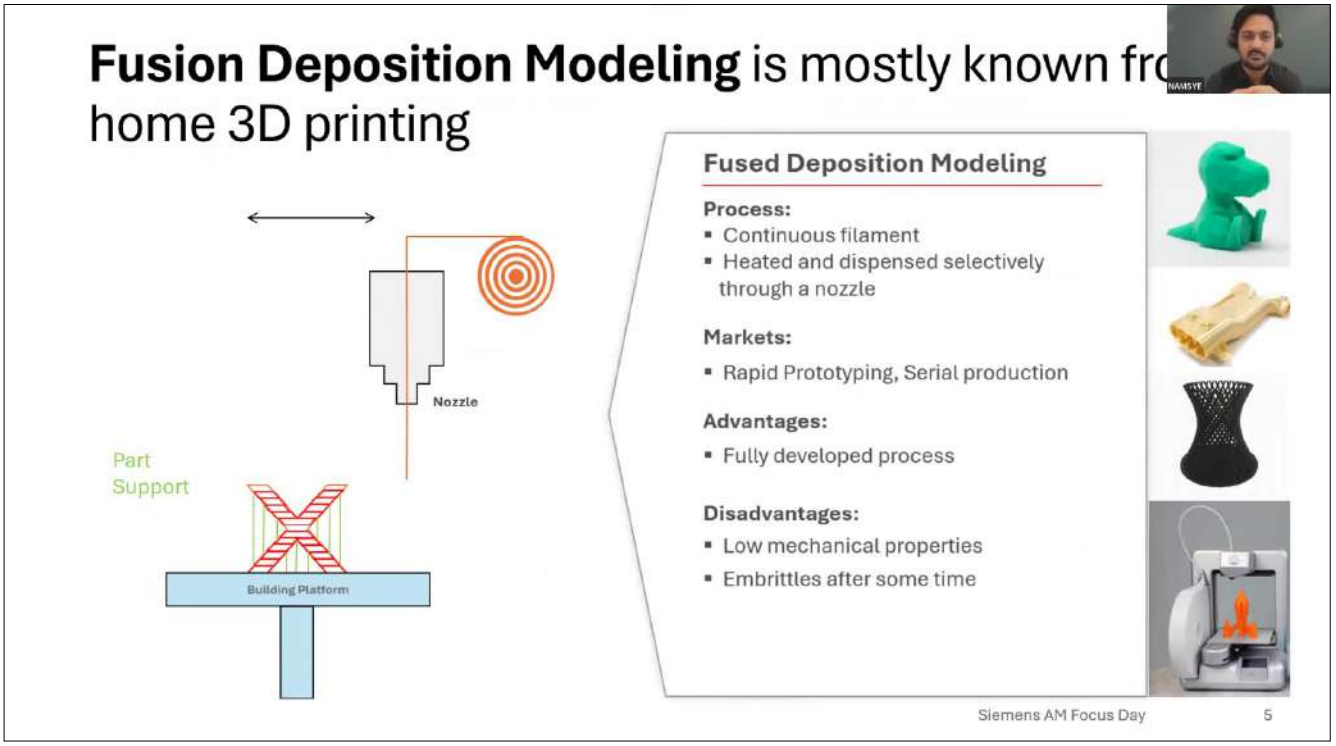

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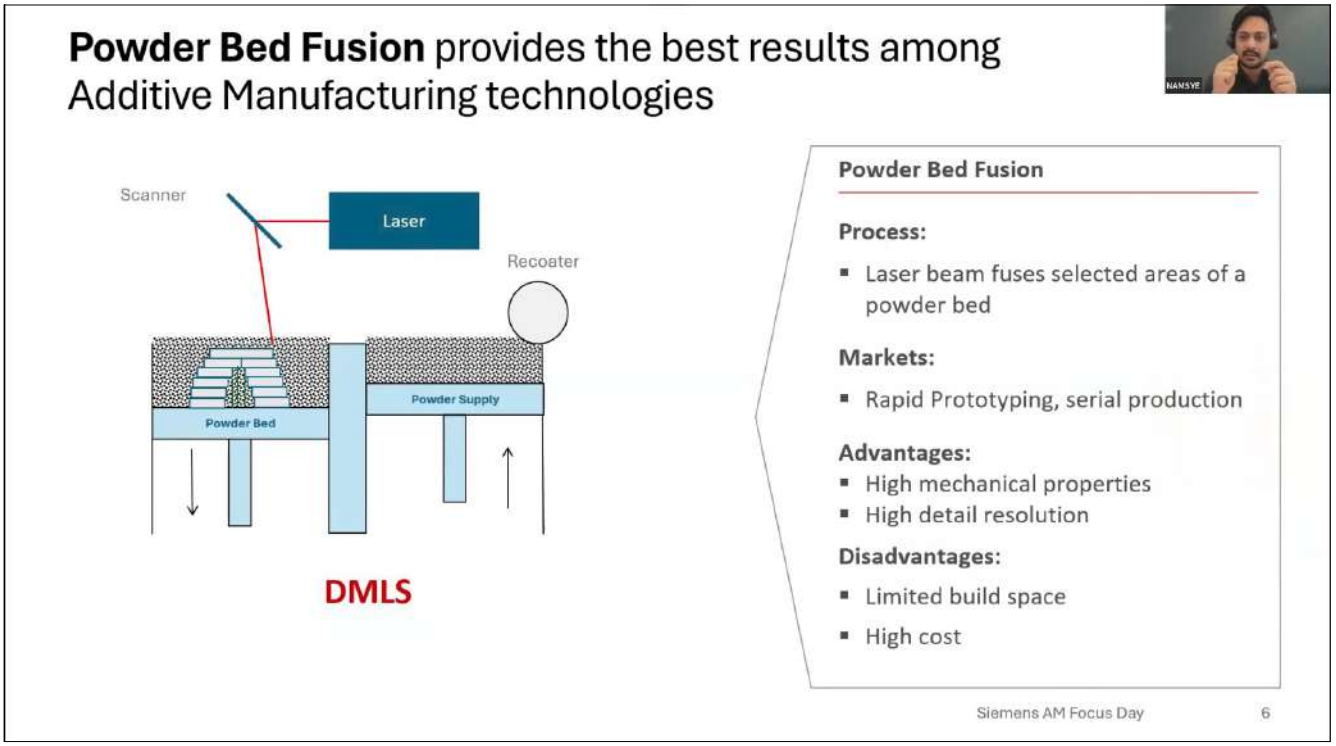

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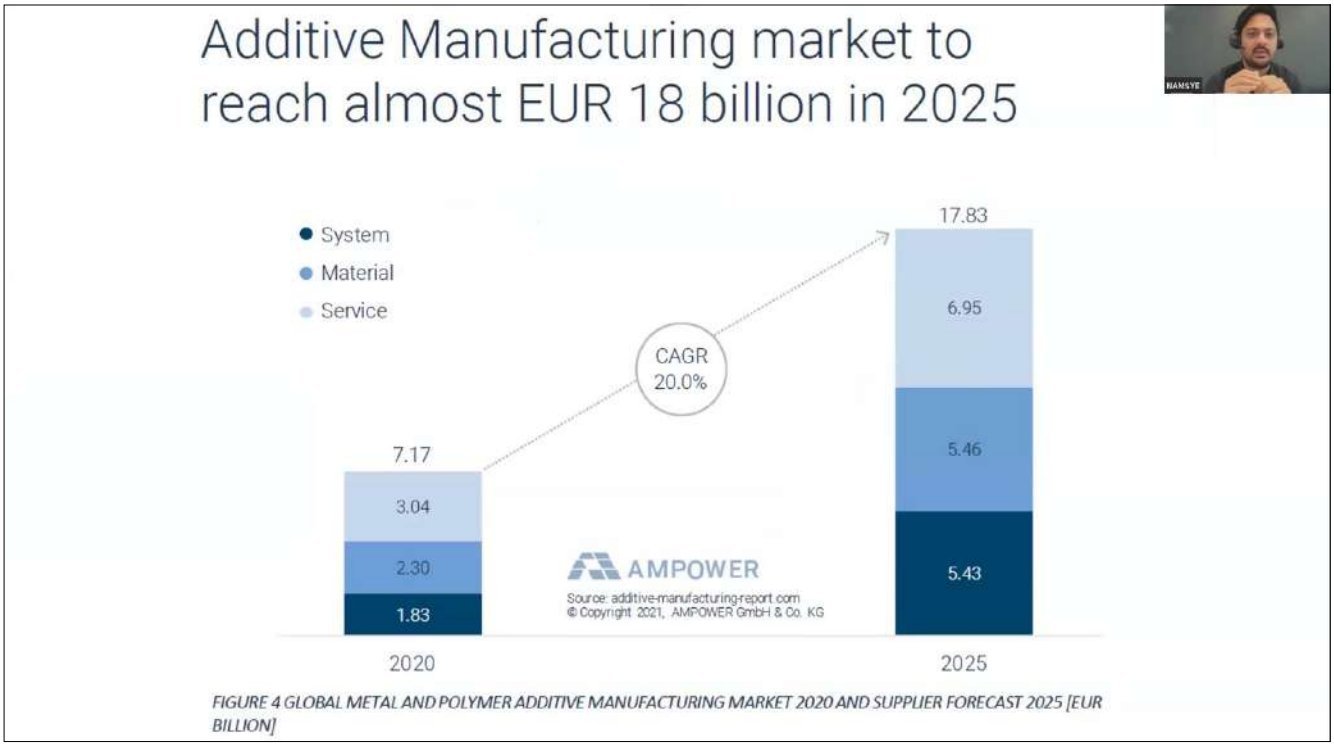


FIGURE 4 GLOBAL METAL AND POLYMER ADDITIVE MANUFACTURING MARKET 2020 AND SUPPLIER FORECAST 2025 [EUR BILLION]

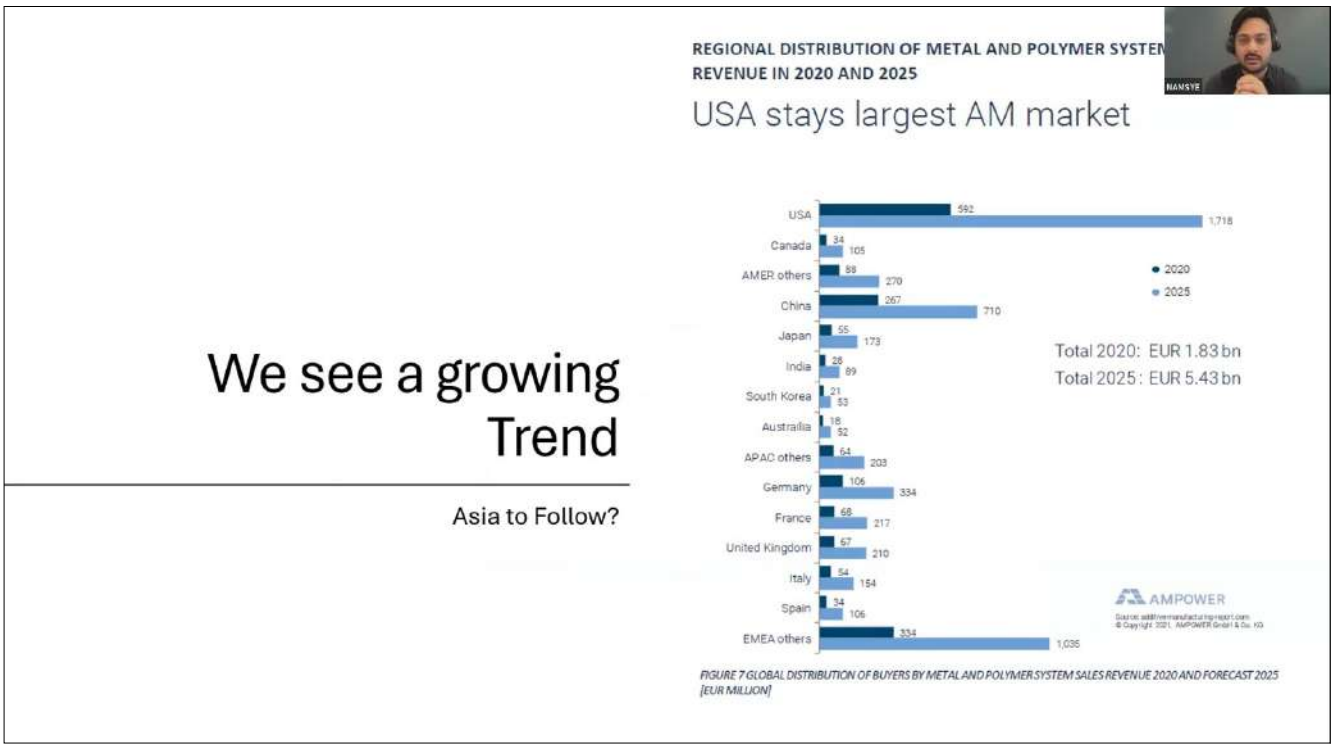


FIGURE 7 GLOBAL DISTRIBUTION OF BUYERS BY METAL AND POLYMER SYSTEM SALES REVENUE 2020 AND FORECAST 2025 [EUR MILLION]

3.2."Where can Laser Powder Bed Fusion make an impact in the Pakistani Market"

by Mr. Syed Ahmad Nameer, *Partner Manager, Middle East and Eastern Europe , EOS, Germany.*

Continued...

Competitive Landscape of Pakistani Market

3D Printing in Islamabad Pakistan

Print 3D Pakistan

Arc3D Technologies | 3D Printers & 3D Printing servi...

HANPRO - 3D Printing & Model Making Services in L...

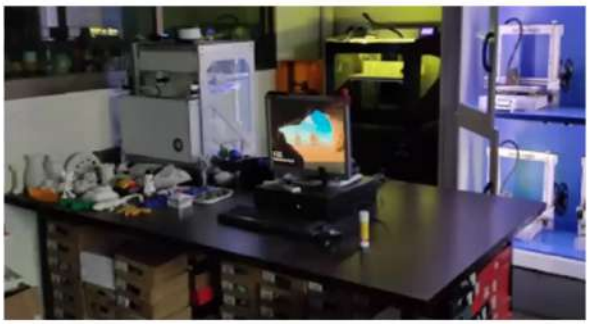
Axis 3D

Browide3D: Premium 3D Printing in Pakistan

SLANTY STICKERS- First 3D Lenticular Printing Lahore Karachi...

Source: Arc3d

- 10+ vendors operating in Pakistan only on FDM low end quality market
- No vendor in Laser powder bed fusion
- No vendor in high end FDM market
- No manufacturing company owns or has a 3d printer in-house
- No process plants in Pakistan owns a 3d printer in-house
- Confined to service provider business and university projects and that too only focused on FDM low end quality
- Medical market untapped – implants still imported



Neighbouring Market

Are we not even in the same league?

- India has already surpassed 100M€ only in spending on 3d printer machines – this number is already on the rise and expected to be 150M€ end of 2024
- India has 10k+ FDM machines and 200+ L.PBF machines
- China is another league matching European and US market
- China has spent 1B€+ only in spending on 3d printers
- Pakistan has not even reached 1M€ in machine sales
- This represents Pakistan's inactive presence in purchasing of 3d printers
- No information found on a laser powder bed fusion machine in Pakistan
- All FDM machines

India's 3d printing market on the rise

China already a leader in 3d printing

We are already too far behind but it is never too late... More delays will take us completely out of the game

3.2."Where can Laser Powder Bed Fusion make an impact in the Pakistani Market"

by Mr. Syed Ahmad Nameer, *Partner Manager, Middle East and Eastern Europe , EOS, Germany.*

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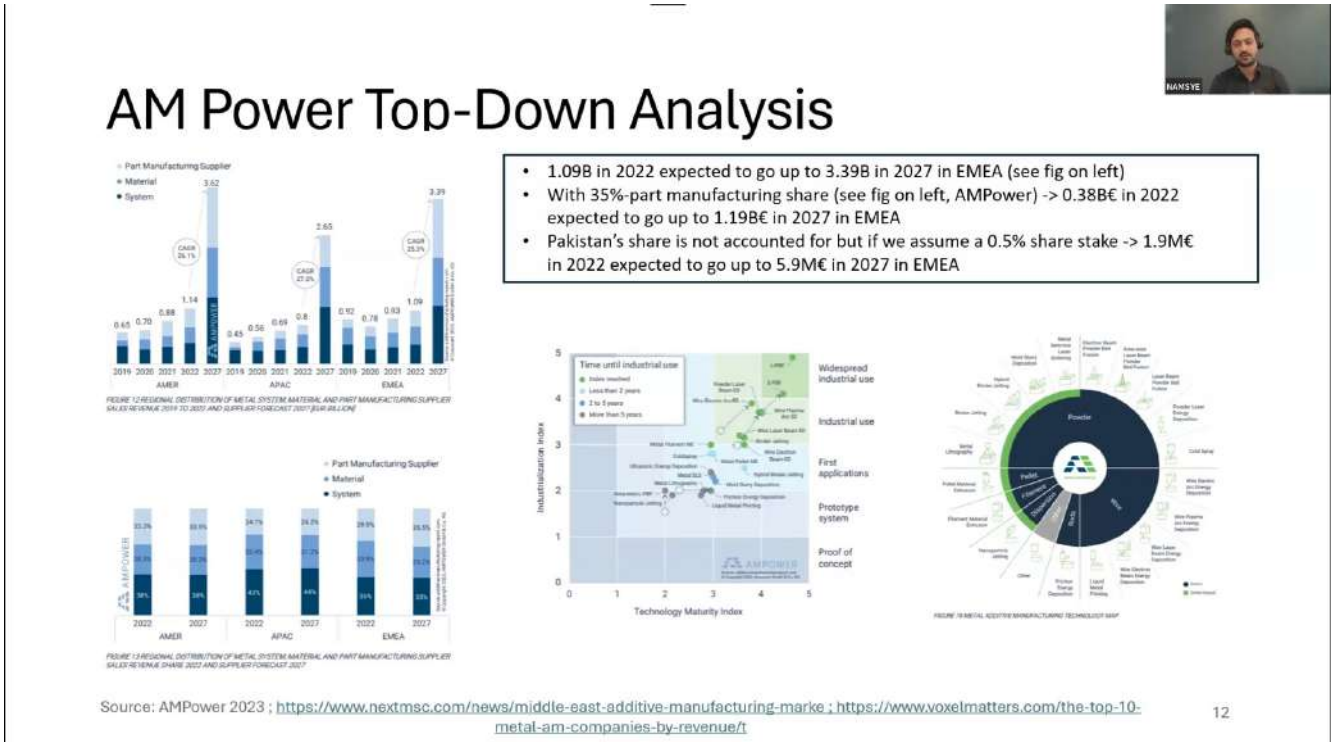

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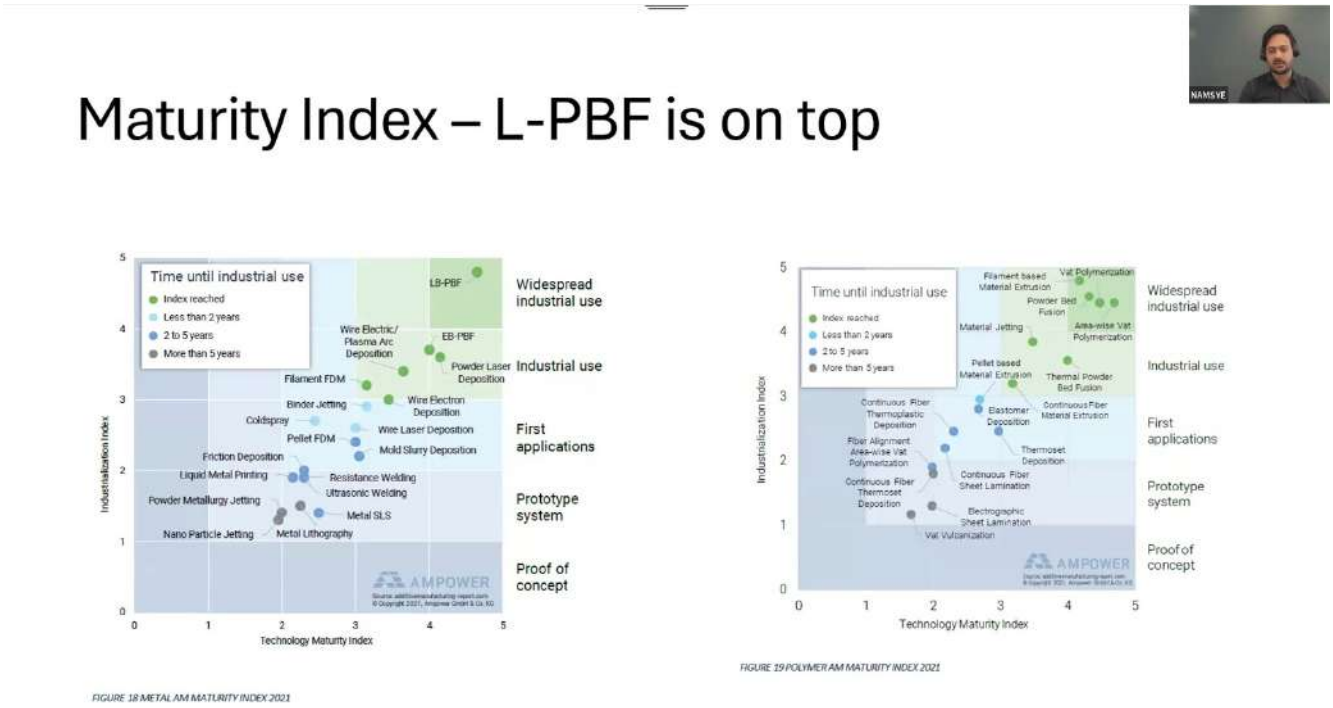
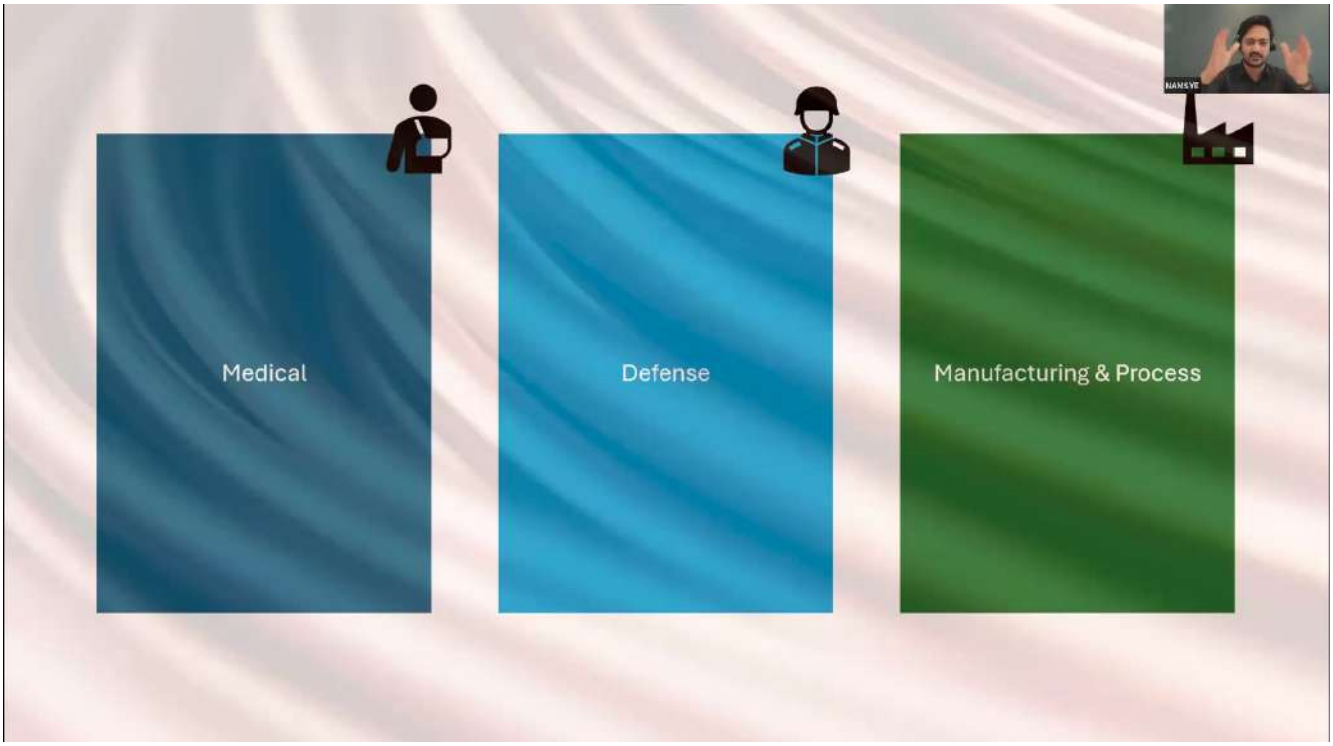


FIGURE 18 METAL AM MATURITY INDEX 2021

FIGURE 19 POLYMER AM MATURITY INDEX 2021



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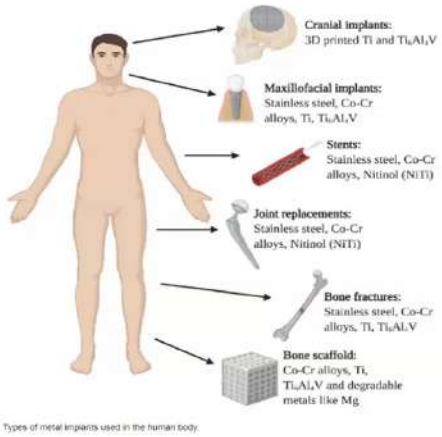
Potential of Pakistani Market?



Types of metal implants used in the human body.

More than 200,000 hip replacement surgeries occur in Pakistan per each year

One Implant can cost around 500$

All via either traditional methods or export as 3d printed metal implant market is non existing in Pakistan

In one hospital: (LNH)

- 14,875 people had total knee replacement
- 5,167 people had total hip replacement

Source: Benčina, Metka & Resnik, Matic & Starič, Pia & Junkar, Ita. (2021). Use of Plasma Technologies for Antibacterial Surface Properties of Metals. Molecules. 26. 10.3390/molecules26051418.
Bukhari, Syed Imran & Allana, Asad & Rahim Najjad, Muhammad & Noor, Shahid. (2023). Epidemiology of hip & knee replacement across Pakistan according to Pakistan national joint registry: A cross-sectional study. Pakistan Journal of Medical Sciences. 39. 10.12669/pjms.39.5.7006.
https://www.drwajid.com/orthopedic-surgeon/facts-about-joint-injuries-hip-replacement-surgery-in-pakistan

16

Orthosis & Prosthesis

More than 1,000,000 people in Pakistan are physically disables

One prosthetic limb can roughly cost around Rs350,000 /-

All via either traditional methods or export as 3d printed prosthetics and orthotics market is non existing in Pakistan

According to Dr Sarwar, with a population of 45 million people, Sindh is estimated to have about 450,000 people in need of prosthetics and orthotics services.

Source: BASF ; Dawn; https://folhus.org/prosthetic-limb/

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3.2."Where can Laser Powder Bed Fusion make an impact in the Pakistani Market"

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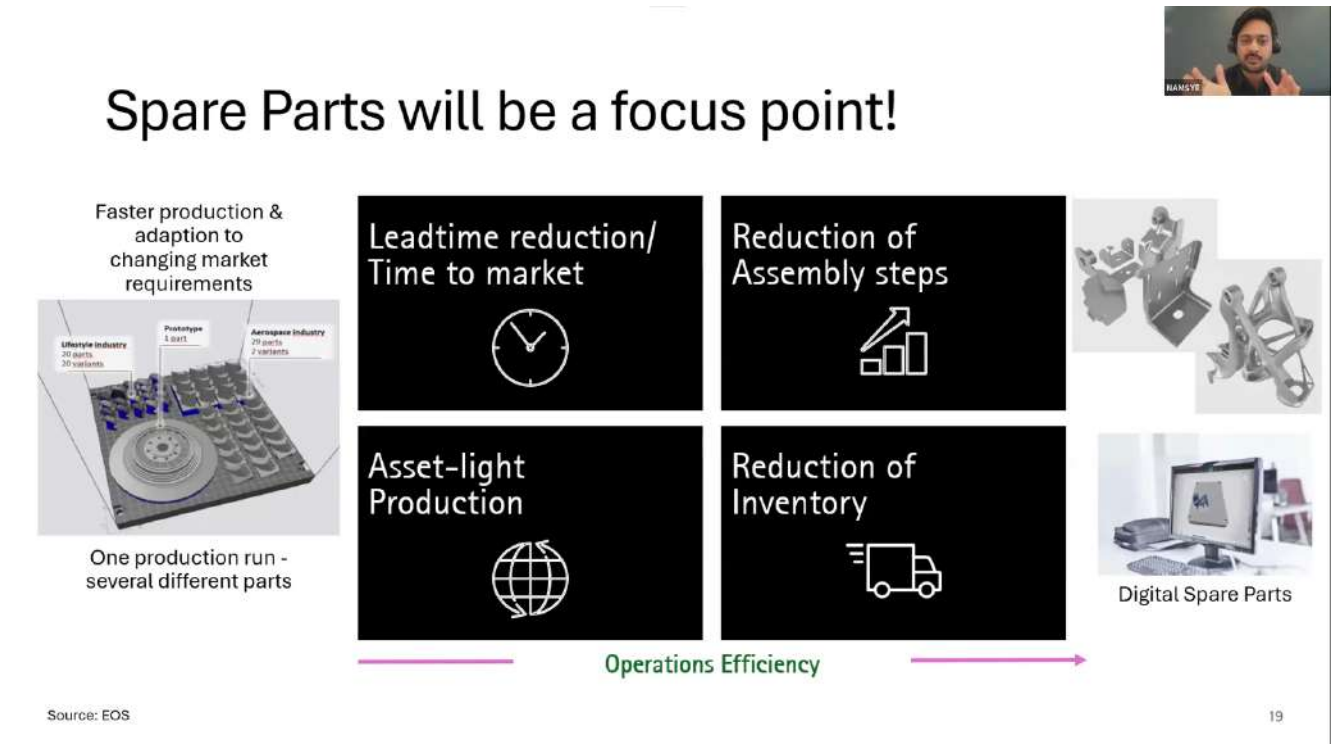

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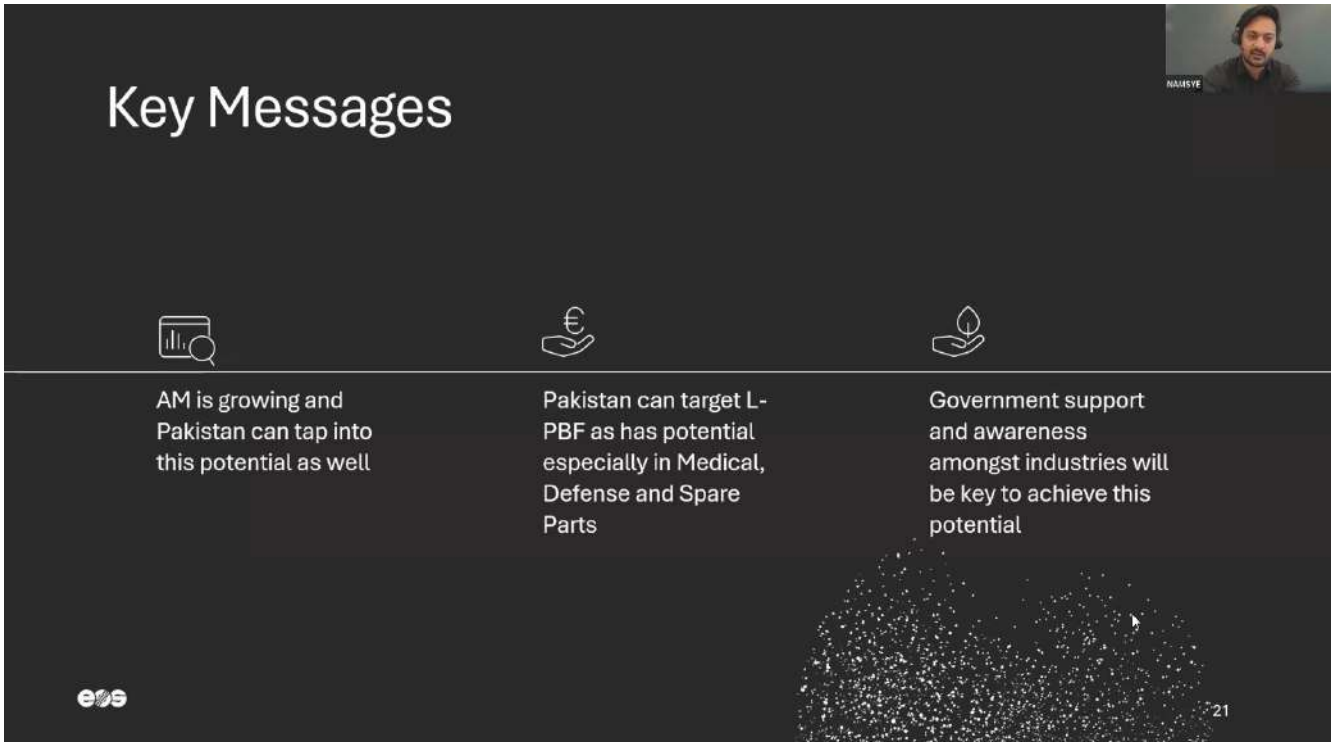

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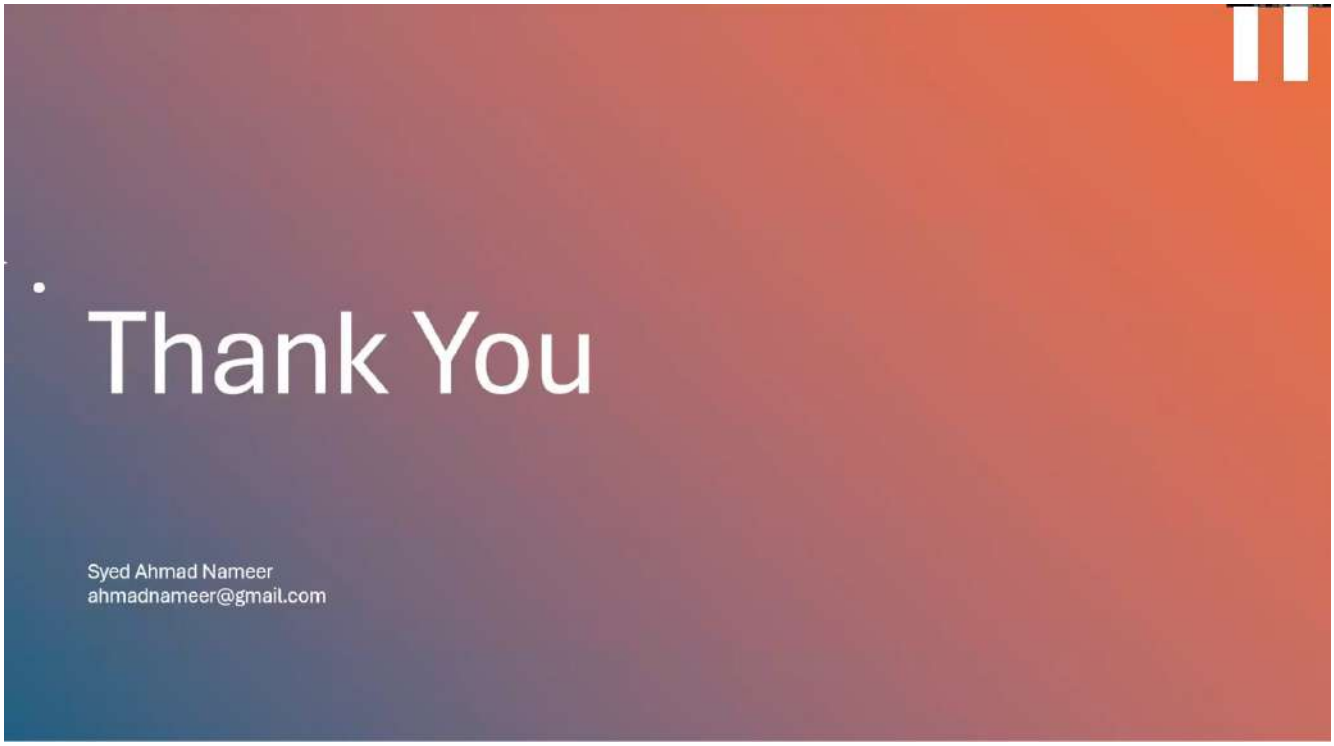


3.3. "Printed Electronicx"

by

***Dr. Khalid Rahman**, Professor - Faculty of Mechanical Engineering, Ghulam Ishaq Khan Institute of Engineering Sciences and Technology, Topi, Pakistan.*

36th Symposium on
"Printed Electronics – Prospects of Additive Manufacturing in Pakistan"
The Pakistan Academy of Engineering.
June 21, 2025

Khalid Rahman (PhD)

Faculty of Mechanical Engineering

PRINTED ELECTRONICS LAB, FME, GIKI

1

Self-Introduction

Khalid Rahman (PhD)

Khalid.rehman@giki.edu.pk

Address:

G-01, Faculty of Mechanical Engineering (Since 2012)

Ghulam Ishaq Khan Institute of Engineering Sciences and Technology

Work Experience:

- Professor - Faculty of Mechanical Engineering at Ghulam Ishaq Khan Institute of Engineering Sciences and Technology.
- Senior Scientist - Ubiquitous Sensing (USE) Lab, Klagenfurt University and Silicon Austria Labs, Austria (from July 2023 till January 2024)
- 7 years of industrial experience

Research Interests:

- Electrohydrodynamic Inkjet Printing, Direct Write Technology, Printed Electronics, ANSYS (linear and nonlinear Structural Analysis)

2

3.3. "Printed Electronics"

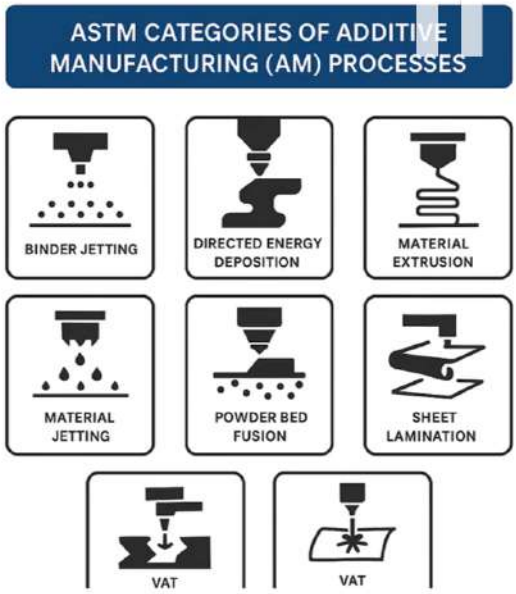
by Dr. Khalid Rahman, Professor - Faculty of Mechanical Engineering, Ghulam Ishaq Khan Institute of Engineering Sciences and Technology, Topi, Pakistan

Continued...

Additive Manufacturing

"Additive Manufacturing is the process of joining materials to make parts from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing and formative manufacturing methodologies"

ASTM F2792



3

Future Electronics

Minority Report 2002

Sony 2007

LG 2015

Samsung 2019

3.3. "Printed Electronics"

by Dr. Khalid Rahman, Professor - Faculty of Mechanical Engineering, Ghulam Ishaq Khan Institute of Engineering Sciences and Technology, Topi, Pakistan

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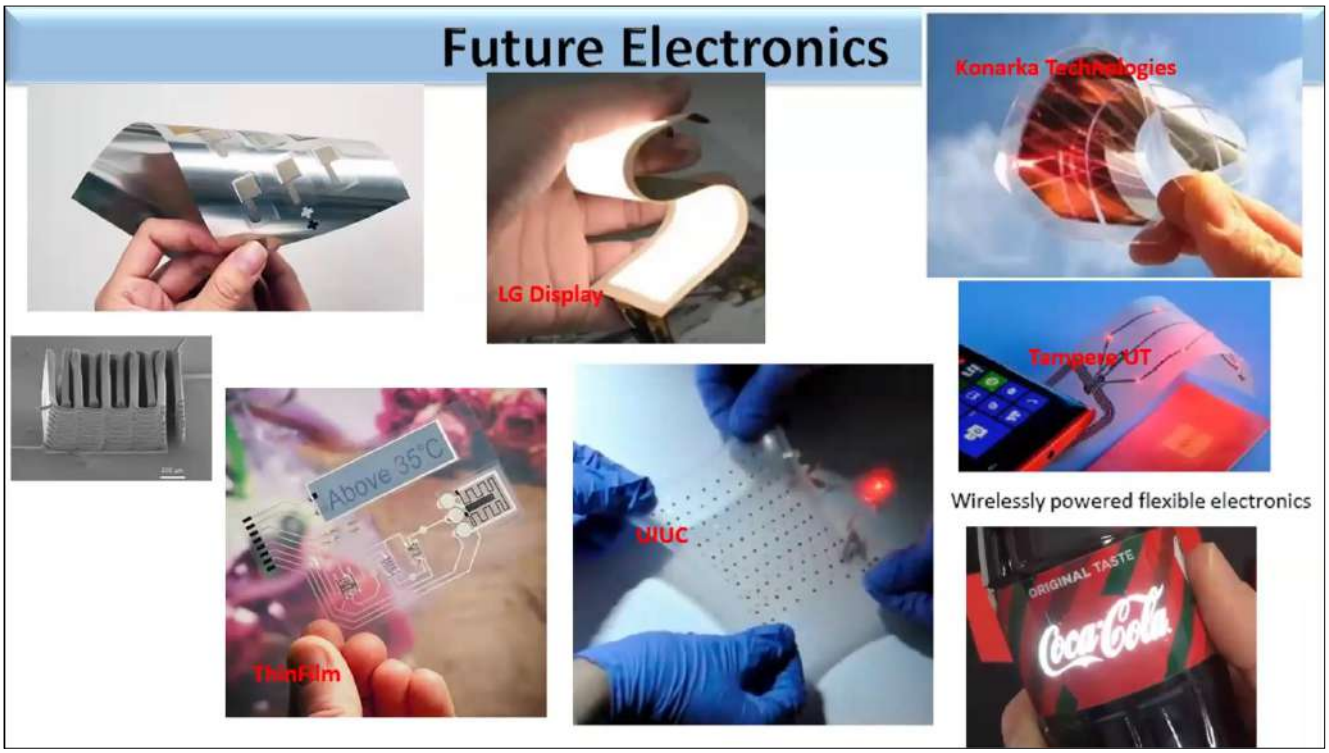

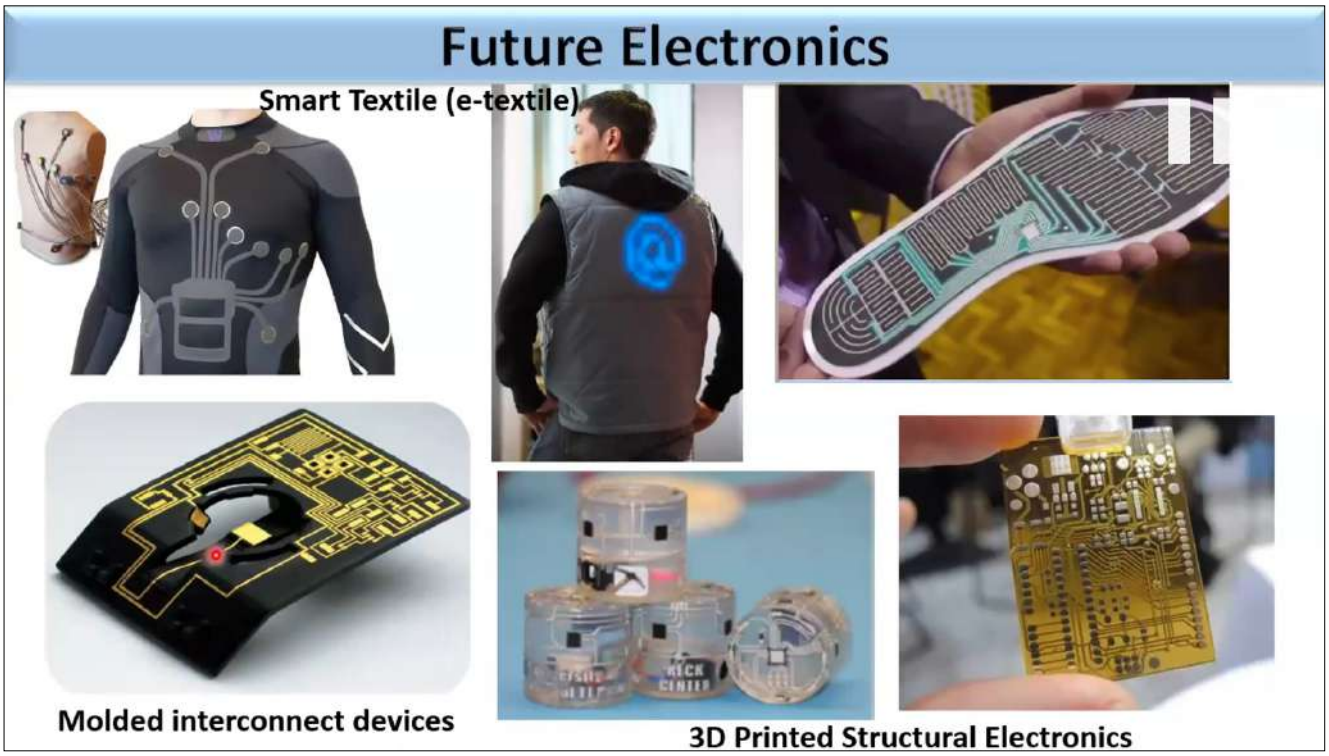

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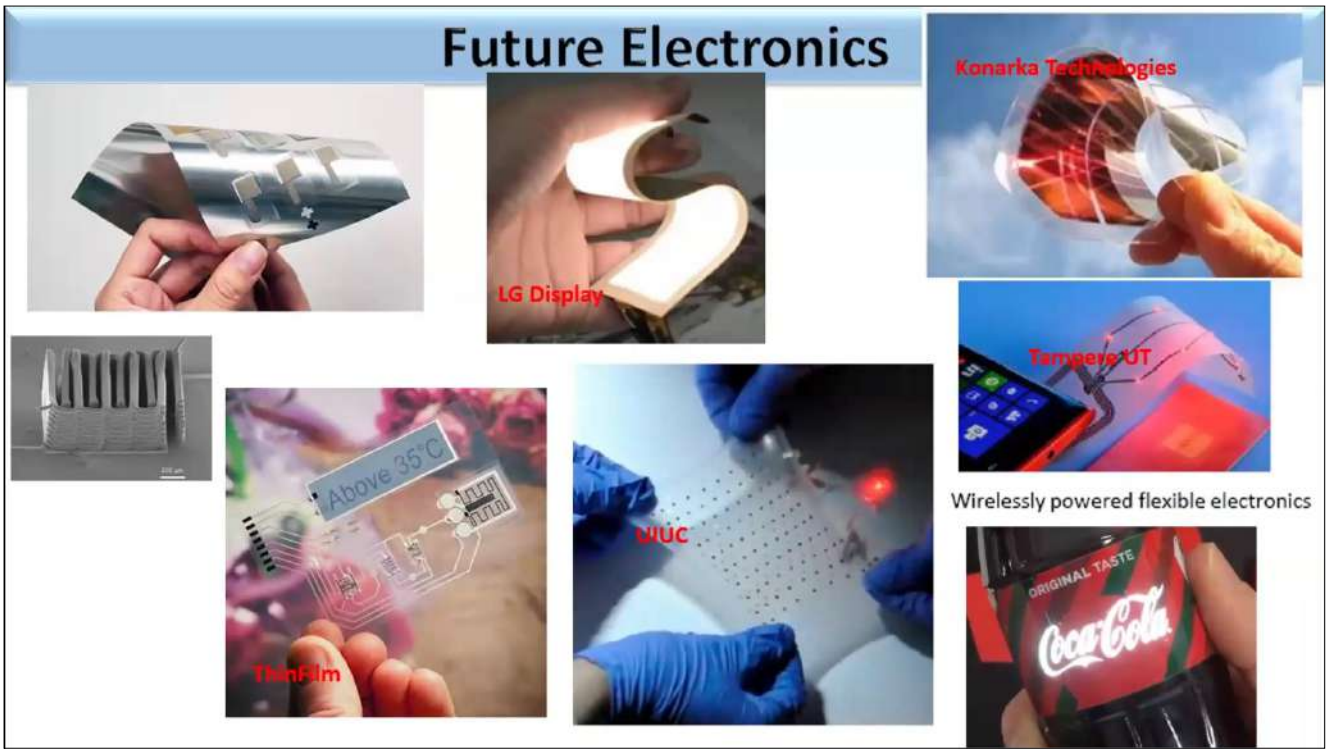

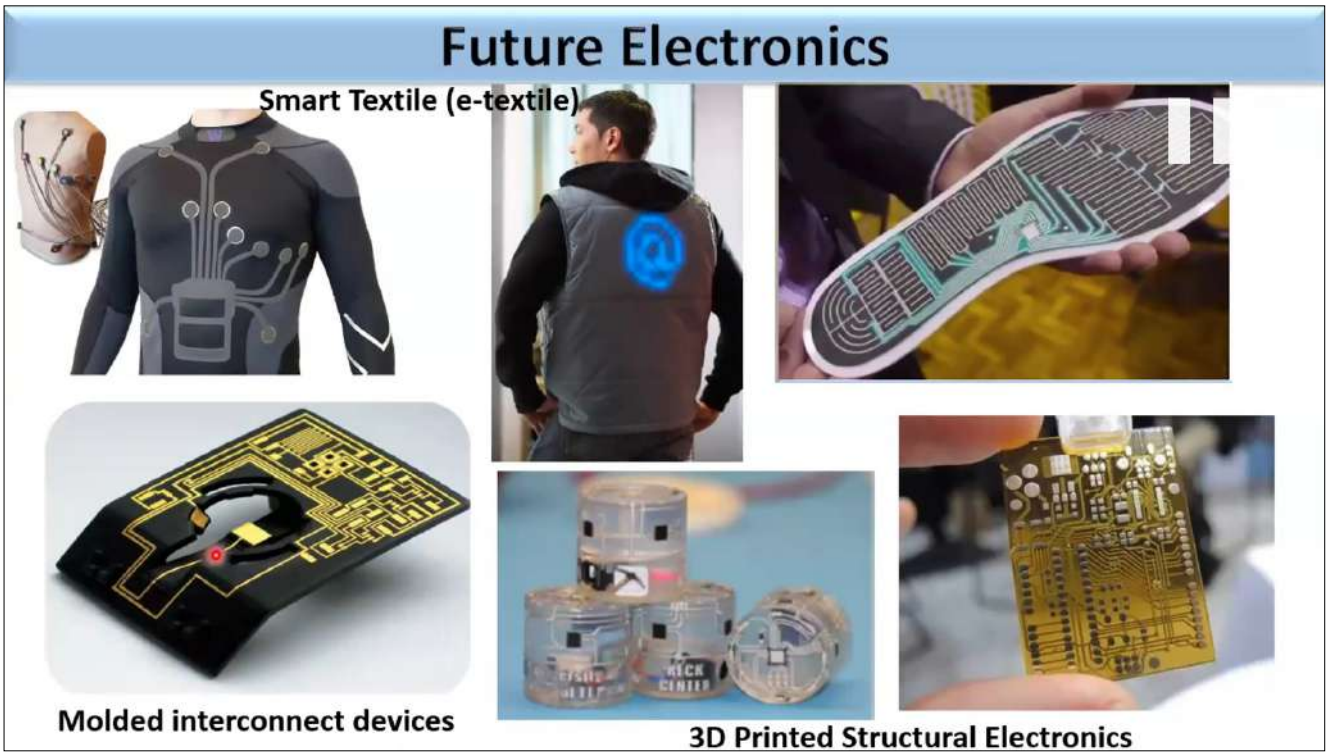

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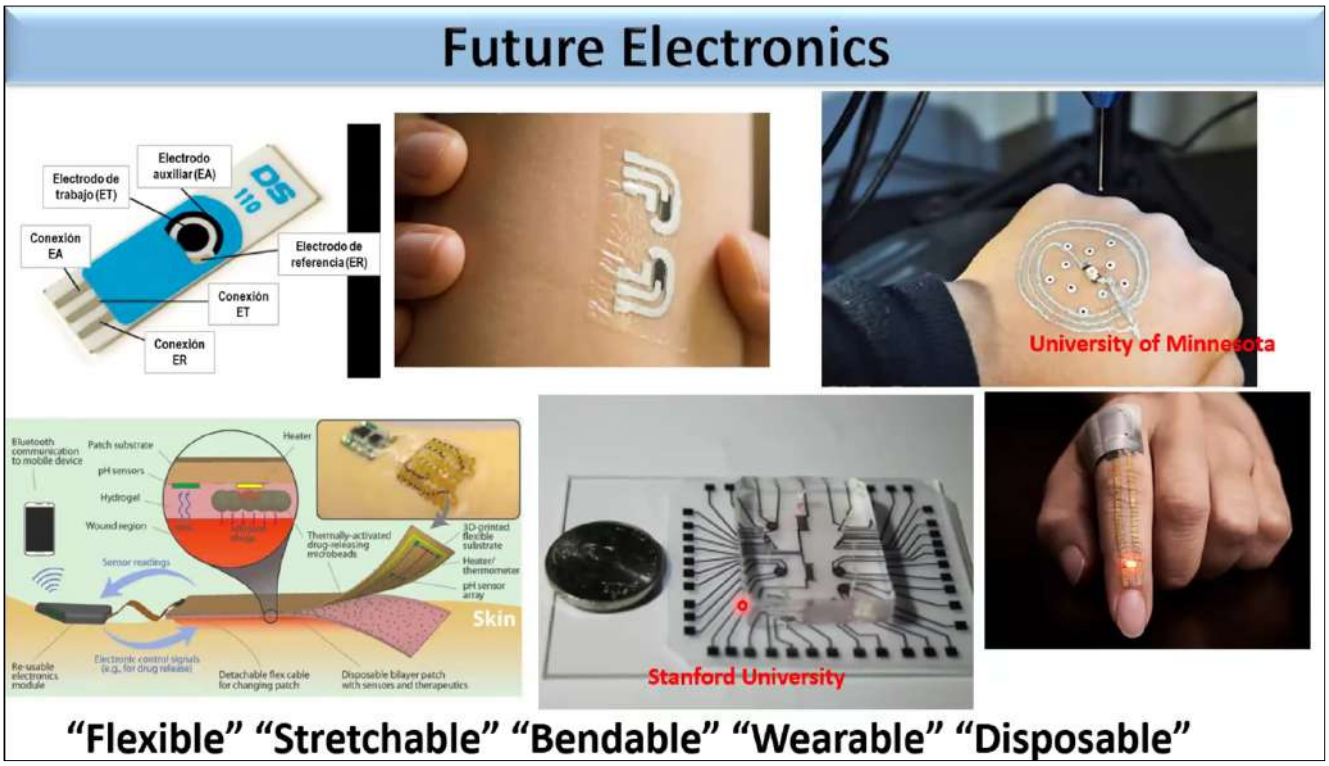
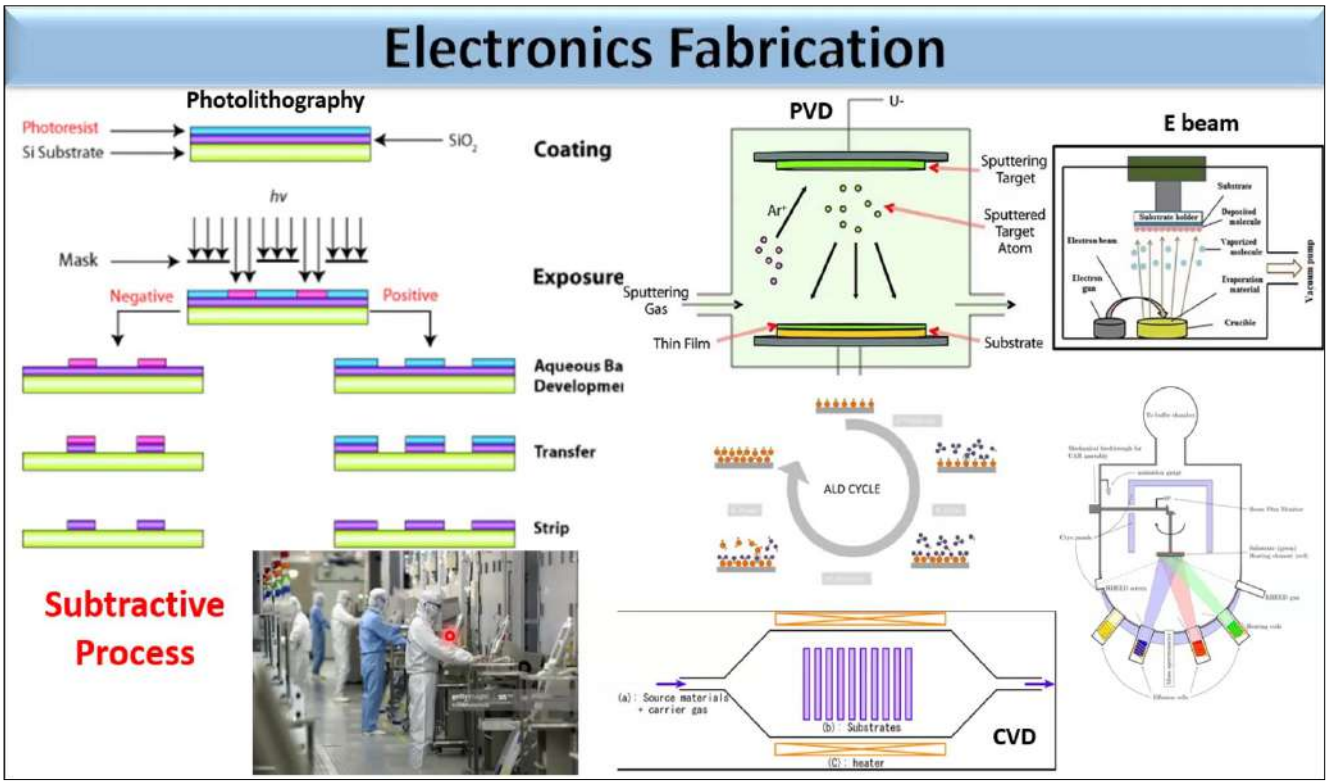
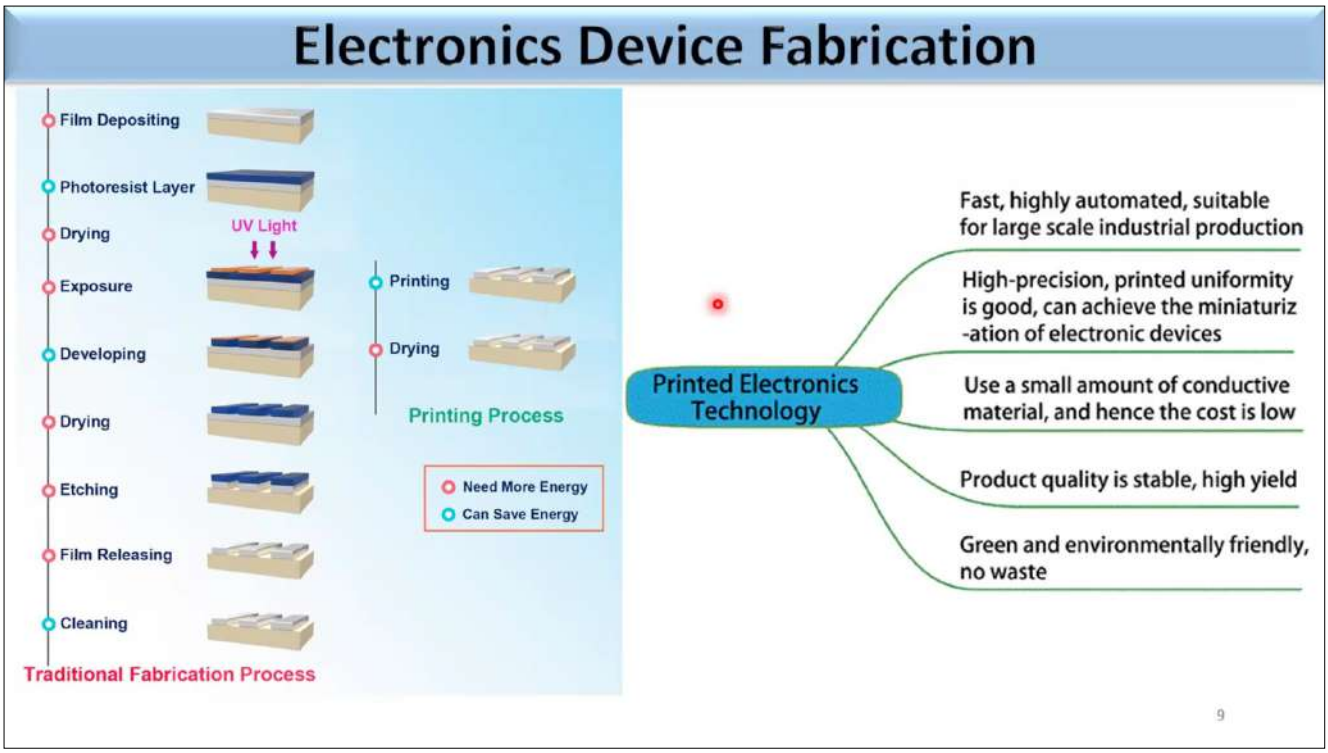
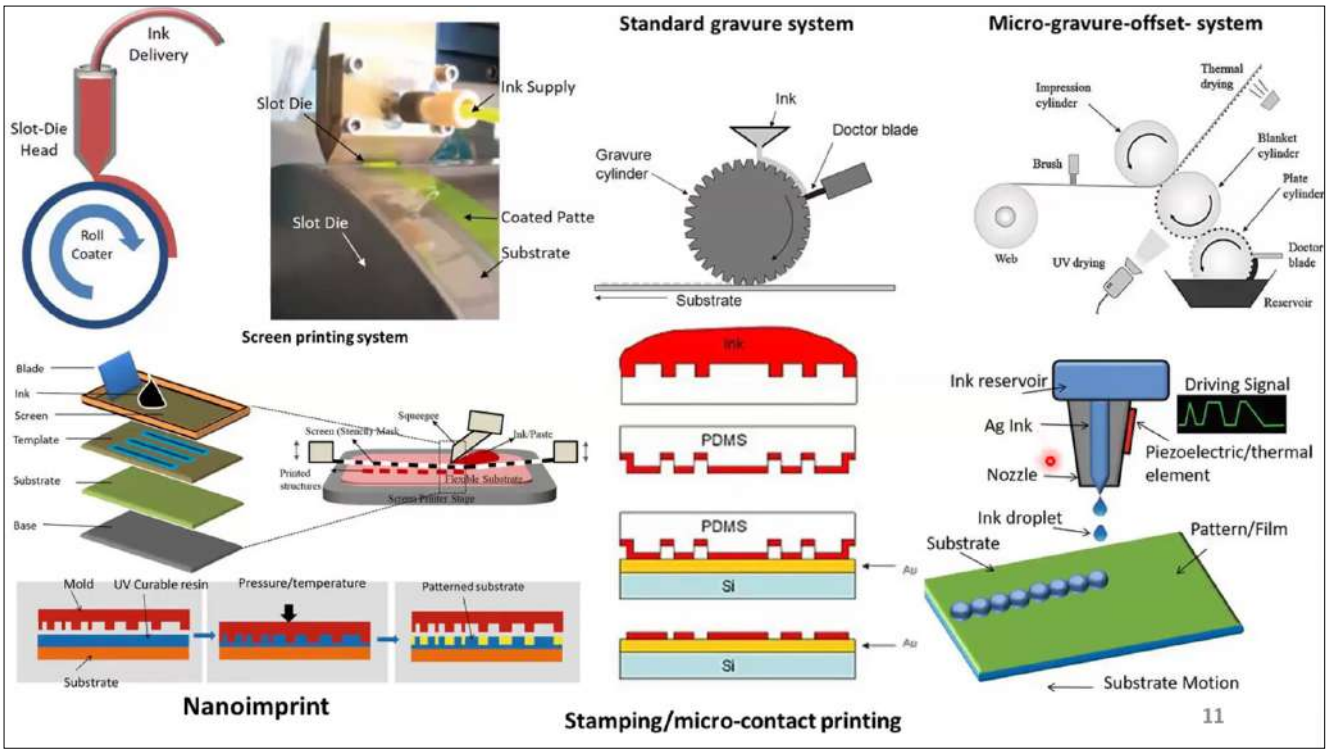
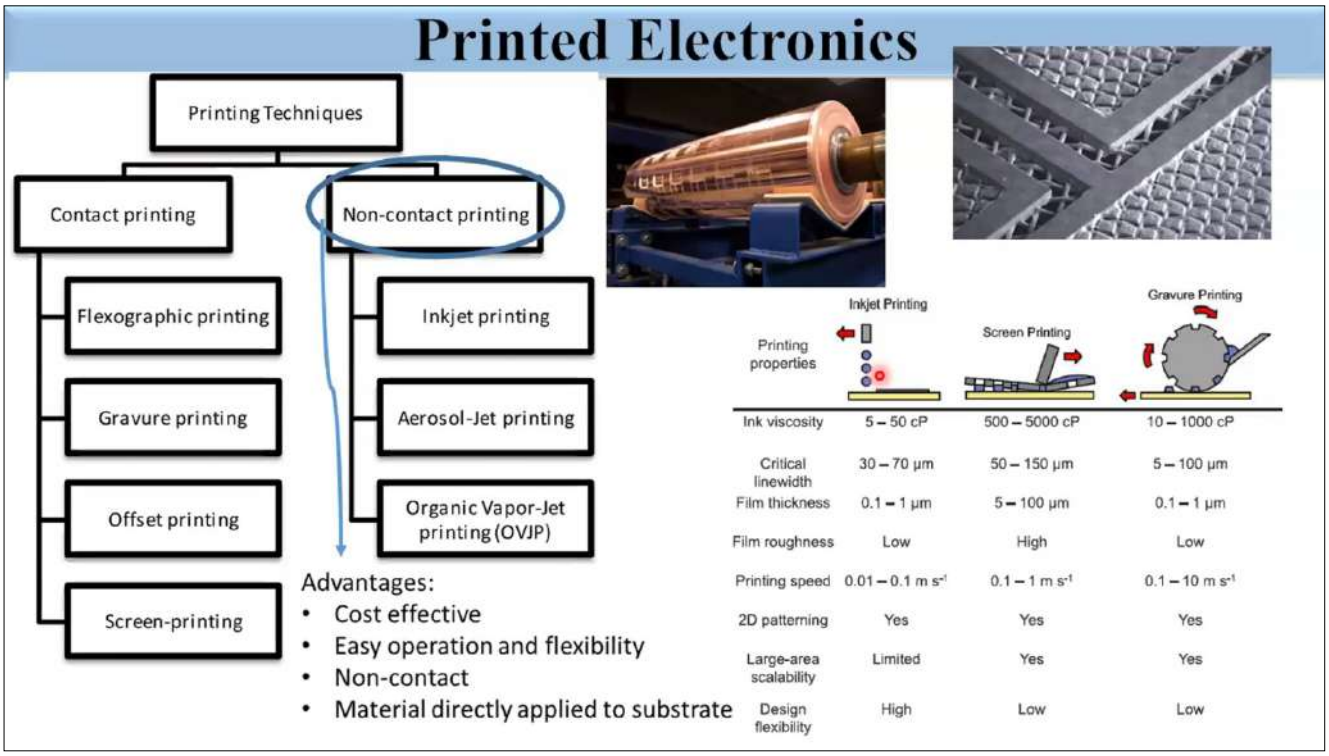




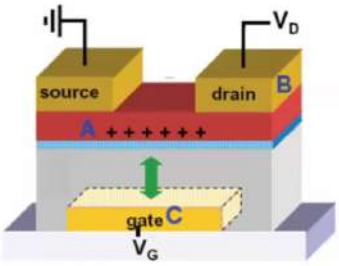

Electronics Device Fabrication
Film Depositing
Photoresist Layer
Drying
UV Light
Exposure
Developing
Drying
Etching
Film Releasing
Cleaning
Traditional Fabrication Process
Printing
Drying
Printing Process
Need More Energy
Can Save Energy
Printed Electronics Technology
Fast, highly automated, suitable for large scale industrial production
High-precision, printed uniformity is good, can achieve the miniaturiz -ation of electronic devices
Use a small amount of conductive material, and hence the cost is low
Product quality is stable, high yield
Green and environmentally friendly, no waste
9


Printed Electronics as Additive Manufacturing
Printed electronics is a subset of additive manufacturing that involves the layer-by-layer deposition of functional materials—such as conductive, semiconductive, and dielectric inks—onto various substrates using printing techniques (e.g., inkjet, screen, aerosol jet).
Printing Beyond Color
OK

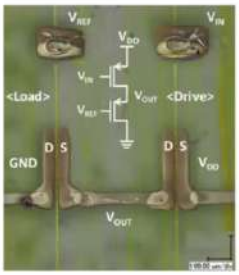

Ink Delivery
Slot-Die Head
Roll Coater
Slot Die
Ink Supply
Slot Die
Coated Patte
Substrate
Screen printing system
Standard gravure system
Ink
Doctor blade
Gravure cylinder
Substrate
Micro-gravure-offset- system
Thermal drying
Impression cylinder
Blanket cylinder
Brush
Plate cylinder
Web
UV drying
Doctor blade
Reservoir
Blade
Ink
Screen
Template
Substrate
Base
Squeegee
Ink/Paste
Printed structures
Mold
UV Curable resin
Pressure/temperature
Patterned substrate
Substrate
Nanoimprint
PDMS
PDMS
Si
Si
Ink reservoir
Driving Signal
Ag Ink
Piezoelectric/thermal element
Nozzle
Ink droplet
Substrate
Pattern/Film
Substrate Motion
Stamping/micro-contact printing
11


Printed Electronics
Printing Techniques
Contact printing
Non-contact printing
Flexographic printing
Gravure printing
Offset printing
Screen-printing
Inkjet printing
Aerosol-Jet printing
Organic Vapor-Jet printing (OVJP)
Advantages:
• Cost effective
• Easy operation and flexibility
• Non-contact
• Material directly applied to substrate
Inkjet Printing
Screen Printing
Gravure Printing
Printing properties
Ink viscosity 5 – 50 cP 500 – 5000 cP 10 – 1000 cP
Critical linewidth 30 – 70 µm 50 – 150 µm 5 – 100 µm
Film thickness 0.1 – 1 µm 5 – 100 µm 0.1 – 1 µm
Film roughness Low High Low
Printing speed 0.01 – 0.1 m s-1 0.1 – 1 m s-1 0.1 – 10 m s-1
2D patterning Yes Yes Yes
Large-area scalability Limited Yes Yes
Design flexibility High Low Low

Printed Electronics



Thin film Transistor (TFT)



Conductor

Carbon, silver, aluminum flakes, Polypyrrole, polyacetylene, thiophenes (PEDOT:PSS), Metal nanoparticles (Ag, Au, Cu, Ni), Carbon nanotubes, metal nanowires, Graphene

Insulator

Oxides, nitrides, Polymer dielectrics (PVP, PMMA, ...)

Semi Conductors

Organic semiconductors (small molecule, polymer), Oxide Semiconductors (ZnO, InGaZnO), CNT, Nanowires, nanoribbons (Si, GaAs), Nanoparticles (Si, CdSe, ZnSe)

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Printed Electronics

- **Traditional Electronics**
  - Made in batches on wafers in cleanroom
  - Devices run fast
  - Layers added in furnace, vacuum or crystal growth
  - High resolution
  - Expensive processing
  - Rigid silicon wafers or glass
  - Devices are small
  - Not transparent
  - Established
  - A cohesive industry

- **Printed Electronics**
  - Can be printed on a roll (or batch processed) non-cleanroom
  - Devices run slowly (no plastic Pentium)
  - Layers added by printing (or vacuum)
  - Lower resolution
  - Cheap processing
  - Flexible films –paper plastic, or rigid (glass)
  - Devices small or large
  - Can be transparent
  - Early-Stage Technology
  - Diverse industry

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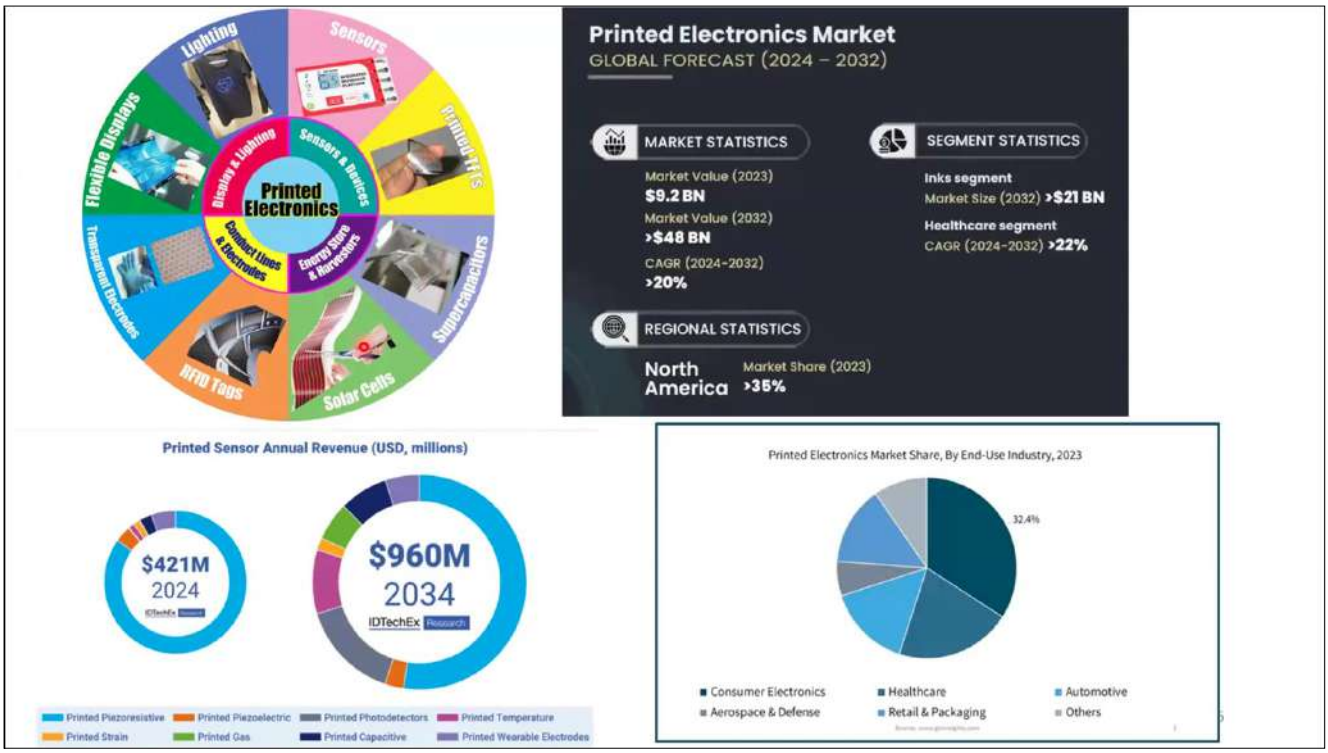
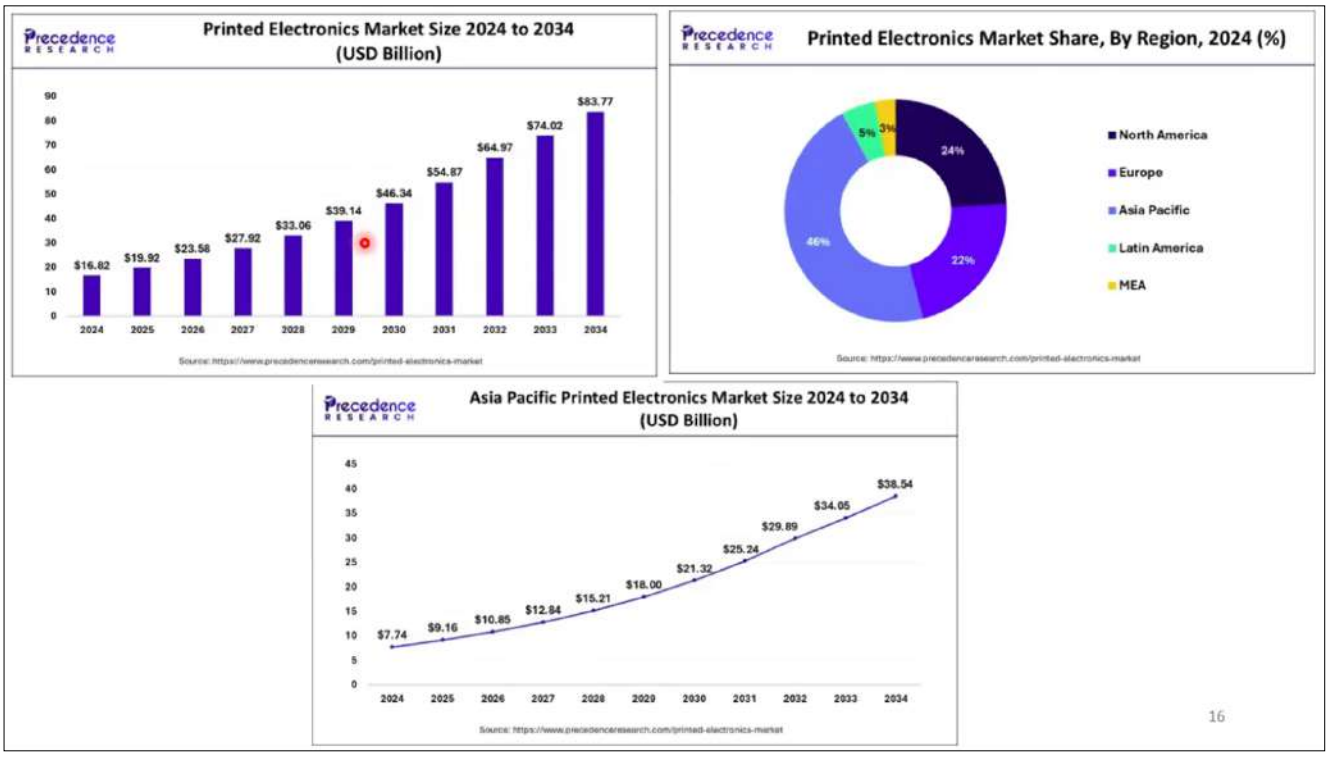
3.3. "Printed Electronics"

by Dr. Khalid Rahman, Professor - Faculty of Mechanical Engineering, Ghulam Ishaq Khan Institute of Engineering Sciences and Technology, Topi, Pakistan

Continued...

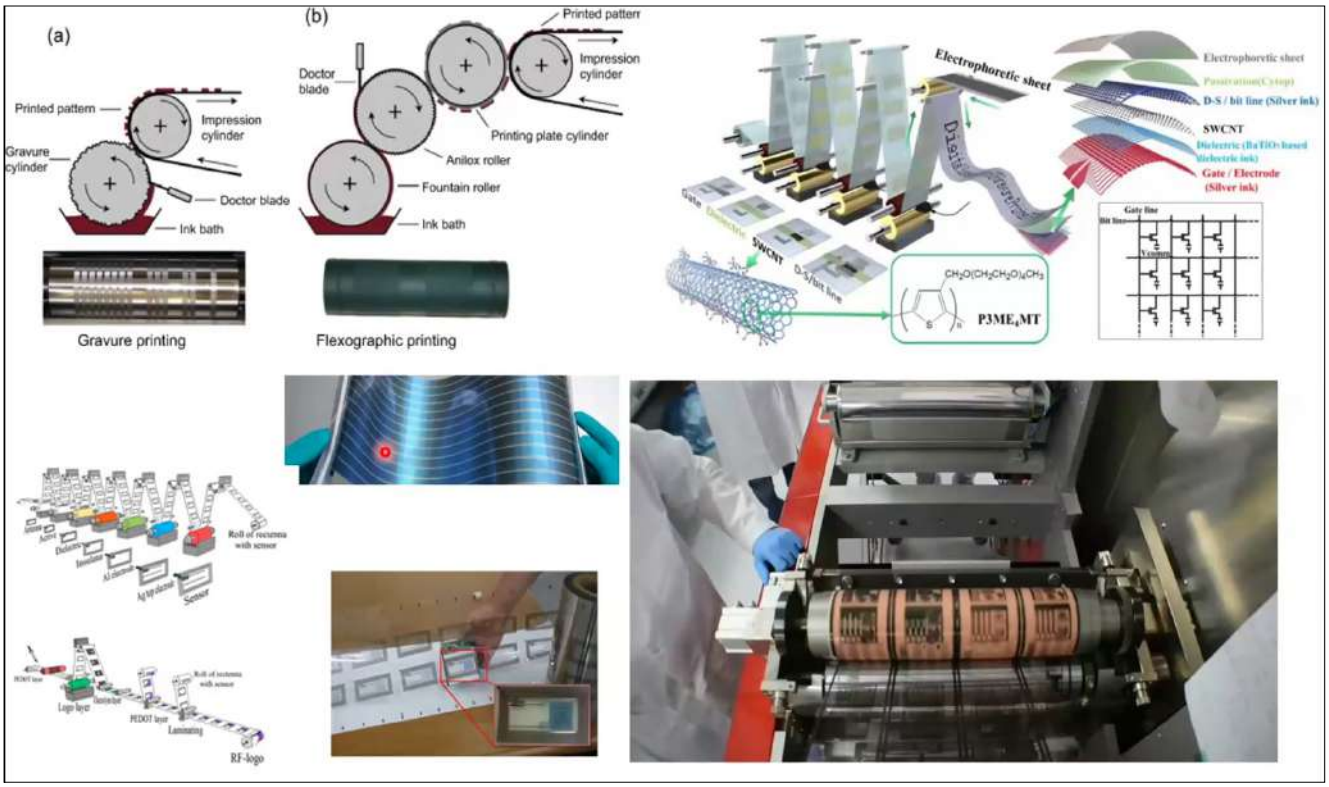


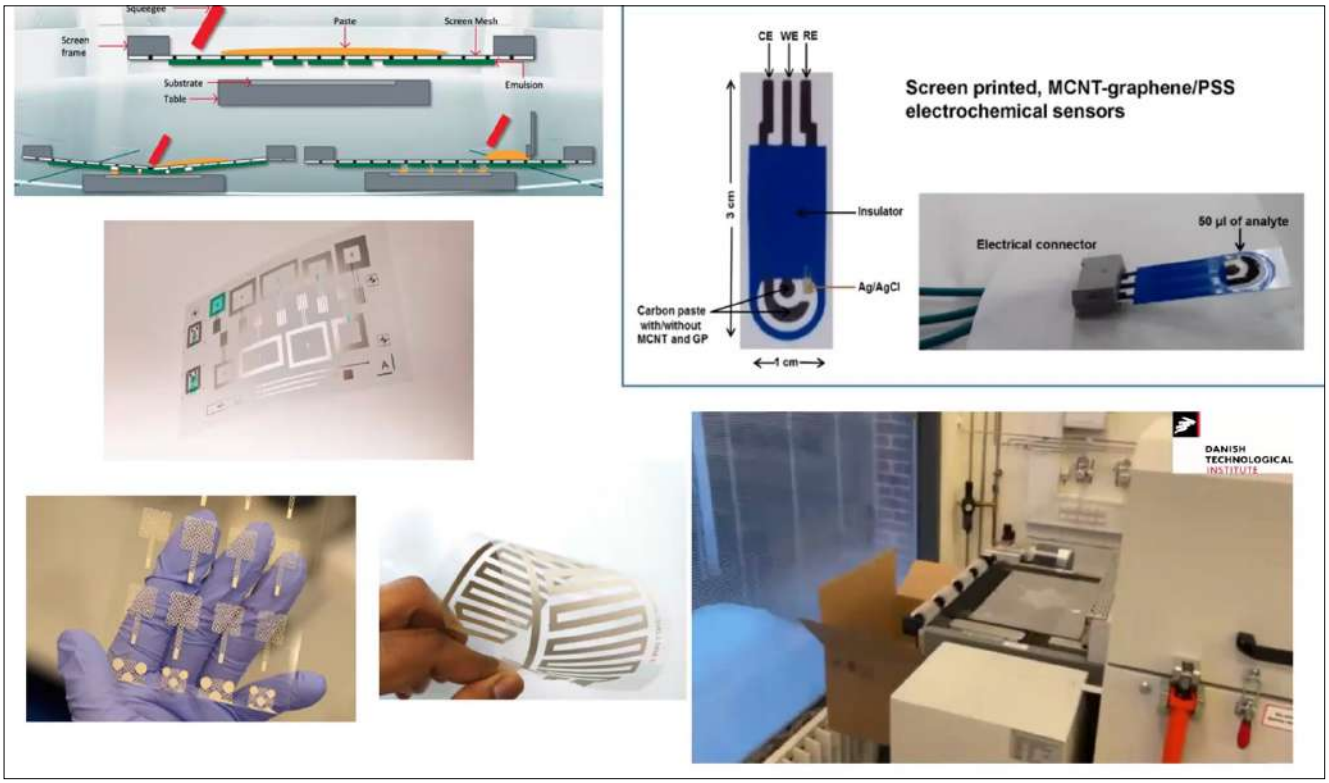


3.3. "Printed Electronics"

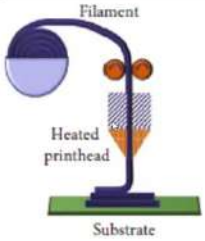
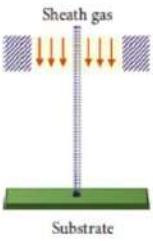
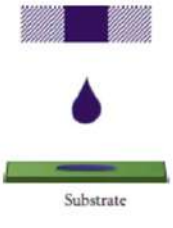
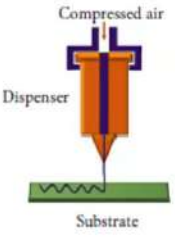
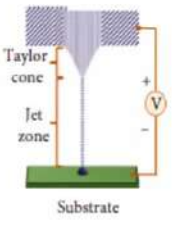
by Dr. Khalid Rahman, Professor - Faculty of Mechanical Engineering, Ghulam Ishaq Khan Institute of Engineering Sciences and Technology, Topi, Pakistan

Continued...





Non-Contact Printing Technologies

Fused filament fabrication (FFF) [18, 233]	Aerosol jet printing	Inkjet printing [33]	Direct ink writing (DIW)	Electrohydrodynamic printing (E-jet) [44, 234, 235]
				
Technology				
Heated nozzle by thermal energy	Aerodynamic focussing	Thermal or piezoelectric	Pneumatic or syringe nozzle	Driven by electric field
Flexibility of printed element				
★★★☆☆	★★★★☆	★★★★☆	★★★★★	★★★★★
Stretchability of printed element				
★★☆☆☆	★★★★☆	★★★☆☆	★★★★★	★★★★★
Flexible/stretchable element (FSE) material				
Thermoplastic, composites made into filaments	Conductive inks, dielectrics of viscosity (1–1000 cP)	Any low viscosity inks (1–20 cP)	Any type of flowable ink	Polymer, nanoparticle inks
Dimensional accuracy				
50–500 μm	10–250 μm	20–100 μm	250 nm–100 μm	Few hundred nm-μm

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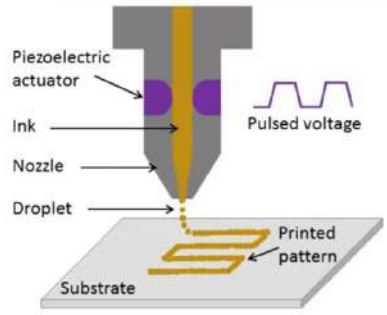
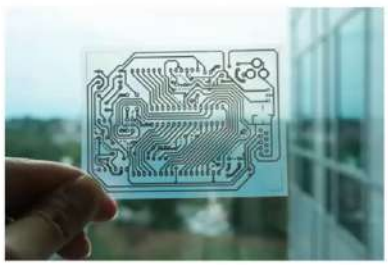
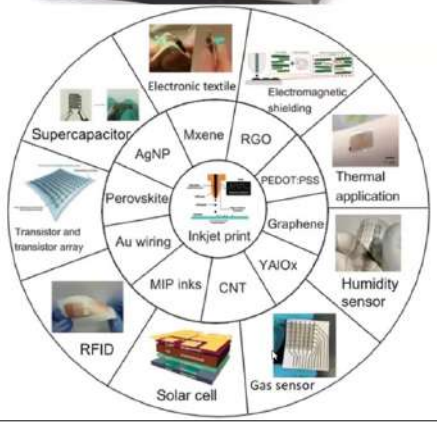
Inkjet Printing







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3.3. "Printed Electronics"

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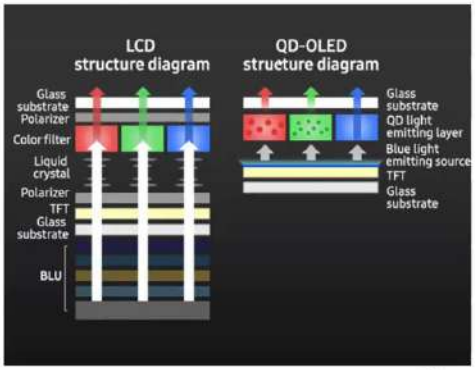
Continued...

Process	normal 4 Mask	Printed TFT 1st stage	Printed TFT 2nd state
Photo	4	2	0
CVD	2	0	0
Sputter	3	2	0
Cleaning	5	6	6
Wet etch	4	1	0
Strip	4	2	0
Dry etch	3	1	0
Printing	-	4	6
Total	25	18	12
Step reduce	-	28%	52%

1st stage : Gate, Active, Passi. → Printing
2nd stage : all TFT Layer Printing.

8.5-Gen Inkjet Printer for Display Manufacturing



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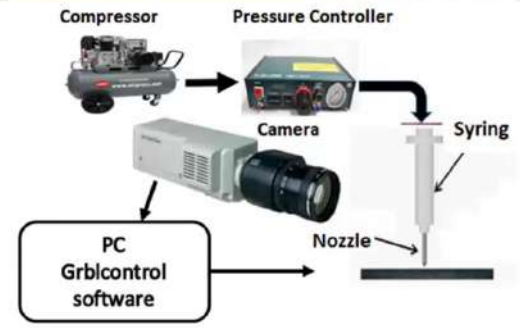
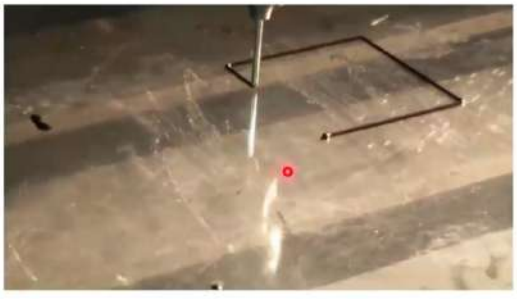
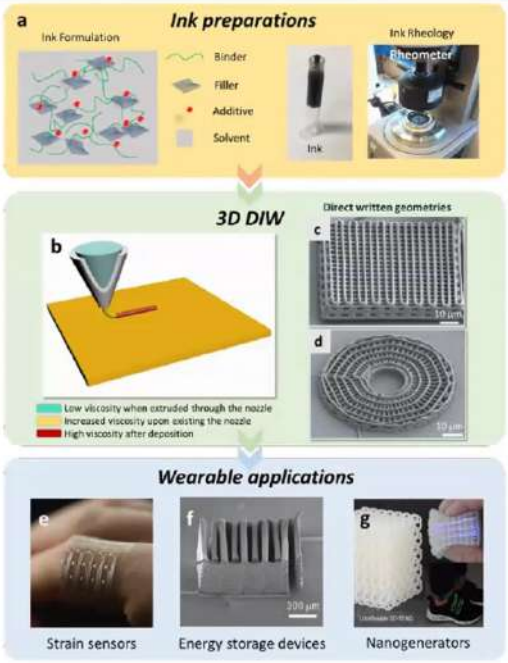
Micro Extrusion DIW Printing







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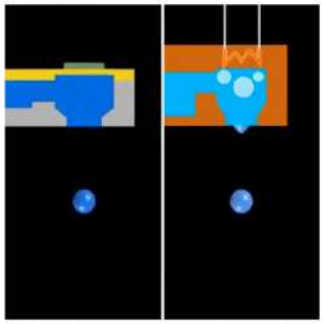
3.3. "Printed Electronics"

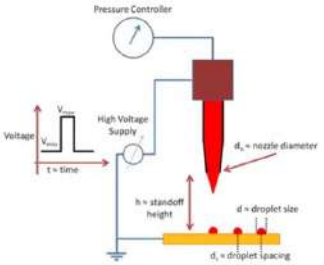
by Dr. Khalid Rahman, Professor - Faculty of Mechanical Engineering, Ghulam Ishaq Khan Institute of Engineering Sciences and Technology, Topi, Pakistan

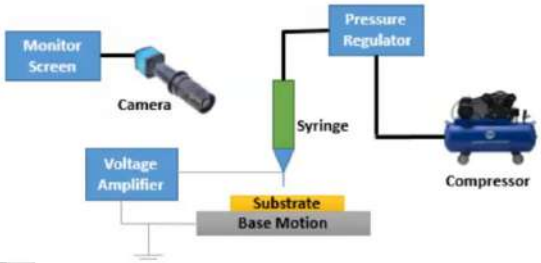
Continued...

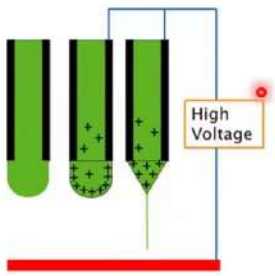
Electrohydrodynamic (EHD) Printing



Piezoelectric Thermal







Continuous EHD

On-Demand EHD

Benefits:

1. Liquid is pulled out from the nozzle
2. No mechanical parts (electric field)
3. High viscosity inks
4. Continuous and DOD mode
5. Patterns resolution less than10 µm
6. Thin film deposition (electrospray)

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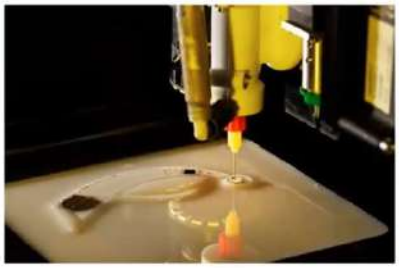
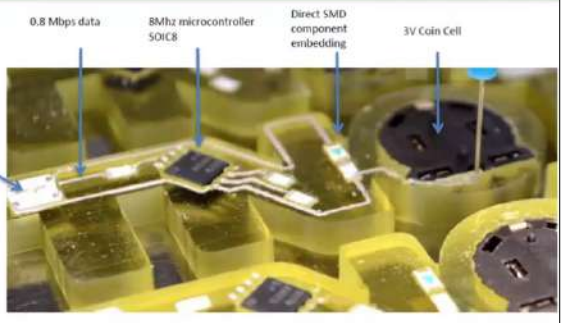
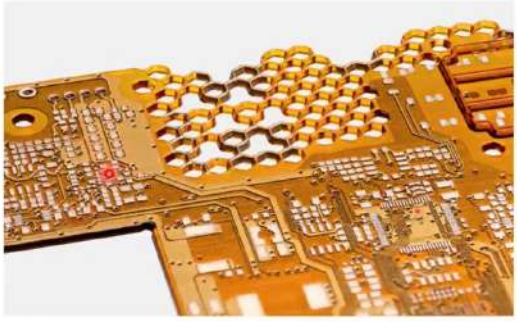
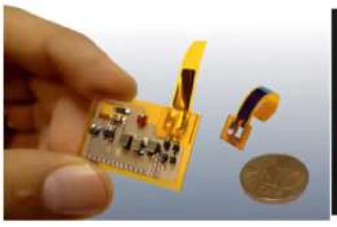
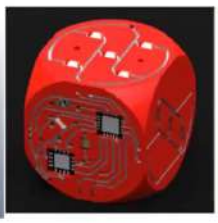
3D Printed Structural Electronics











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3.3. "Printed Electronics"

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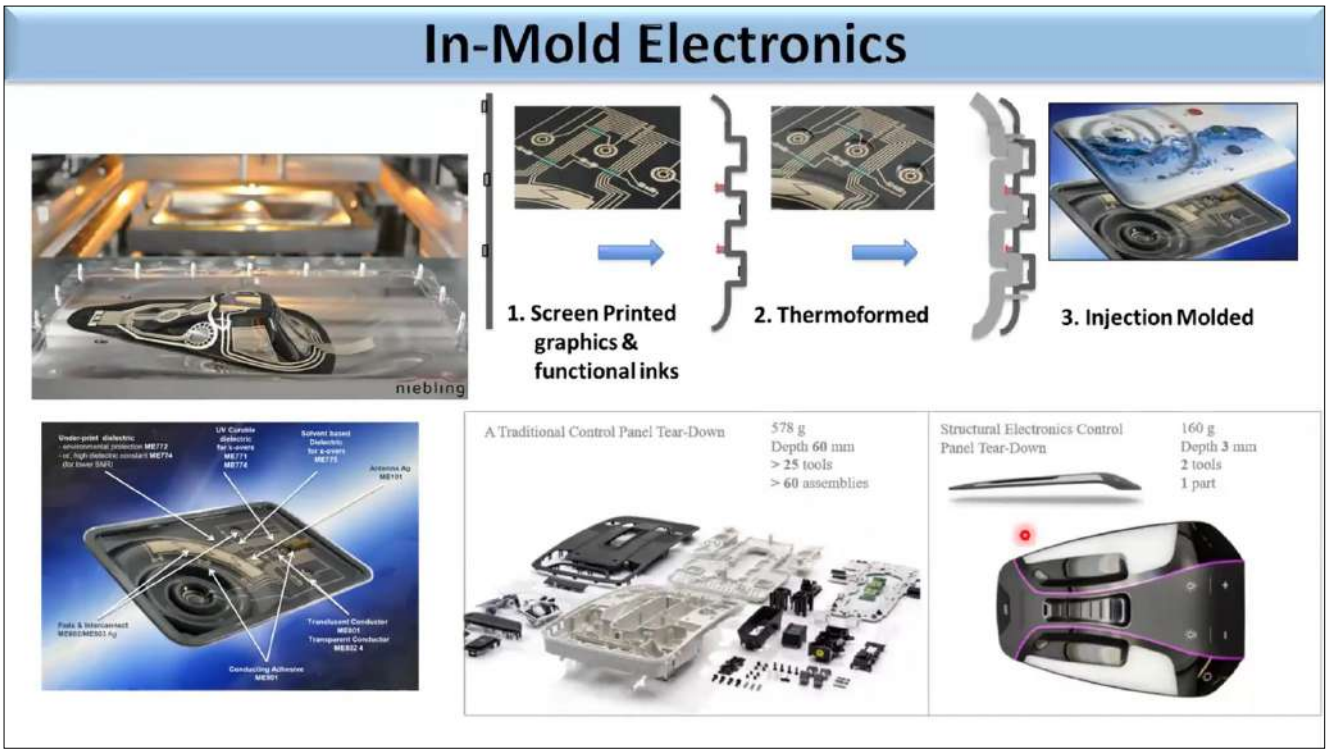
Continued...



3.3. "Printed Electronics"

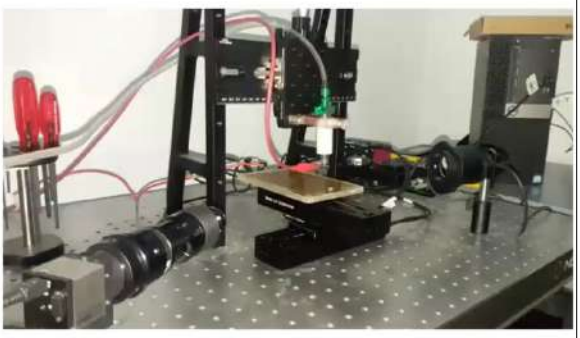
by Dr. Khalid Rahman, Professor - Faculty of Mechanical Engineering, Ghulam Ishaq Khan Institute of Engineering Sciences and Technology, Topi, Pakistan

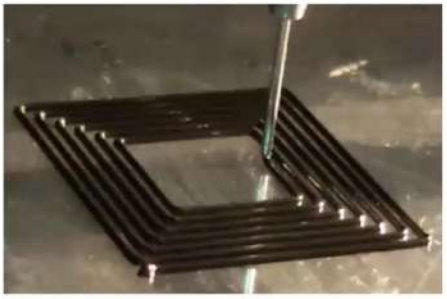
Continued...

Printed Sensors

- **Printed Strain gauge**
- **Printed Flex sensor**
- **Printed Humidity sensor**
- **Printed Temperature sensor**
- **Printed thermocouple/TEG**
- **Printed Micro-heaters**

*Sensors were printed at **Printed Electronics Lab**, Faculty of Mechanical, Ghulam Ishaq Khan Institute of Science and Technology, Topi-Swabi, Pakistan.*





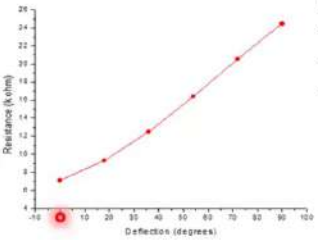
Printed Flex Sensor

Fabrication of flex sensors through direct ink write technique and its electrical characterization: ***Applied Physics A [20]***

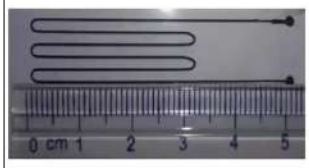
Material:
- Carbon

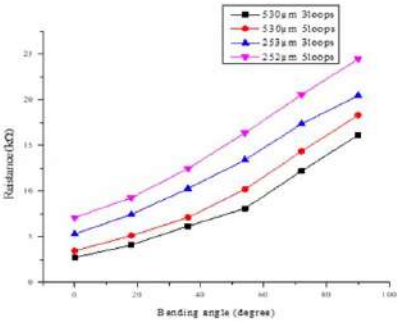
Dimension:
- 4 X 1.5 cm

Substrate:
- PET



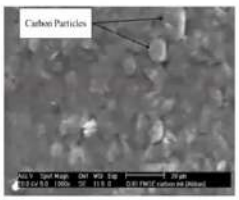
Printed width:
- 253 µm

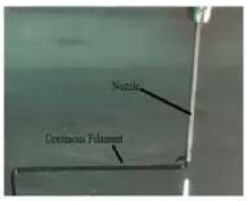




Controlling Parameters:
- Pressure
- Feed rate
- Stand-off distance

200µm nozzle
- Pressure 84 psi
- feed rate 1.2mm/s
- standoff distance 0.4mm





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3.3. "Printed Electronics"

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Continued...

Printed Strain Gauge

Fabrication of cost effective and high sensitivity resistive strain gauge using DIW. ***Sensors and Actuators A: Physical [21]***

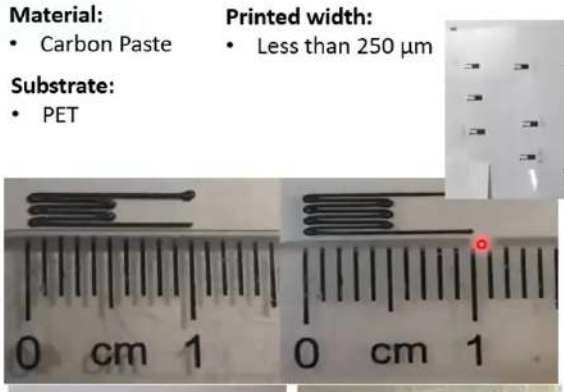
Material:
- Carbon Paste

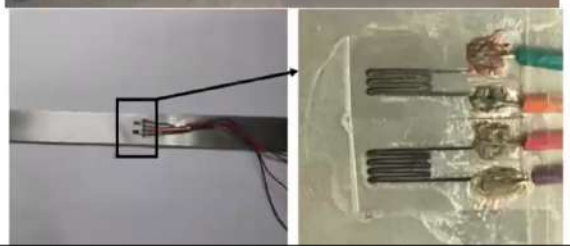
Printed width:
- Less than 250 µm

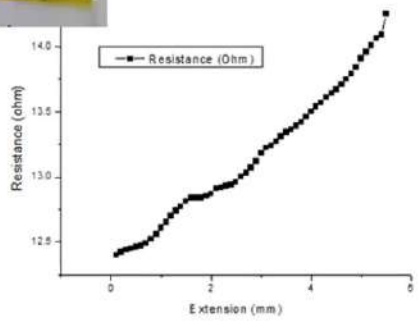
Substrate:
- PET

Controlling Parameters:

	200µm nozzle
• Pressure	• Pressure 50 psi
• Feed rate	• feed rate 1mm/s
• Stand-off distance	• standoff distance 0.1mm







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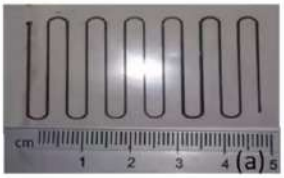
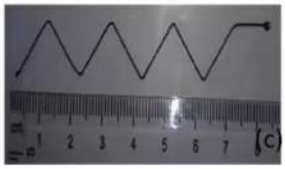
Patterns Deposition



535µm average width

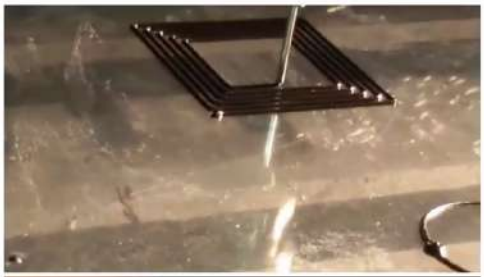
255µm average width



532µm average width

250µm average width

Patterns on Flexible substrate



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3.3. "Printed Electronics"

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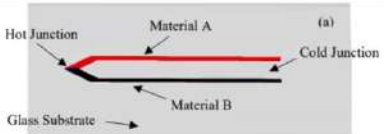
Continued...

Printed Thermocouple

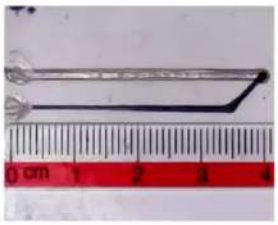
A Weldless Approach for Thermocouple Fabrication Through Direct Ink Writing Technique: **IEEE sensors [22]**

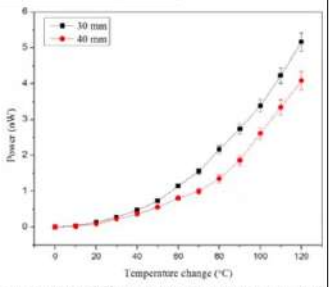
A low-cost printed organic thermoelectric generator for low-temperature energy harvesting: **Renewable Energy [23]**



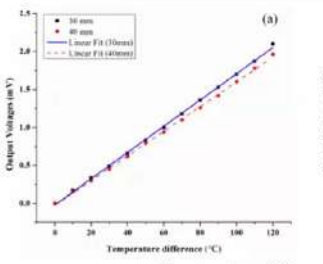
Materials

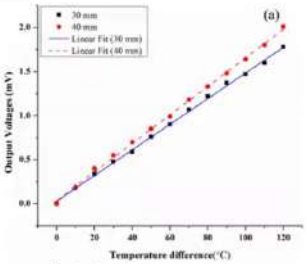
- Silver paste
- PEDOT:PSS/Carbon





Temperature difference vs Power generated

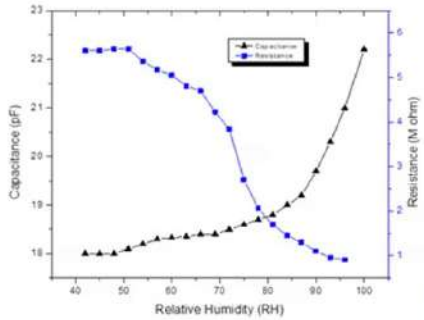




Temperature difference vs Output voltage

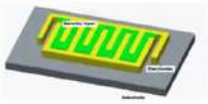
Printed Humidity Sensor

A low-cost printed humidity sensor on cellulose substrate by EHD printing: **Journal of Materials Research [24]**

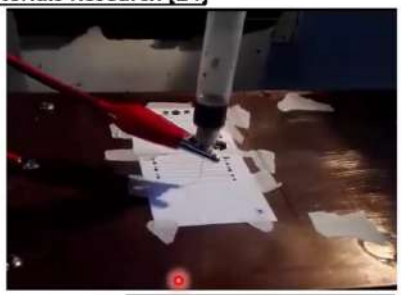


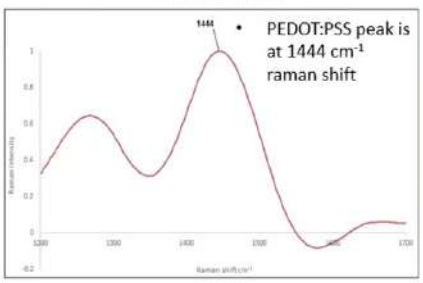
EHD parameters

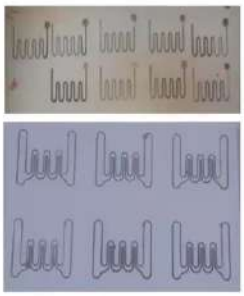
- 70% Ag. ink
- Pressure = 3.2 kPa
- Voltage = 1.63 kV
- Substrate speed = 2000 mm/min
- Strand off distance = 1mm

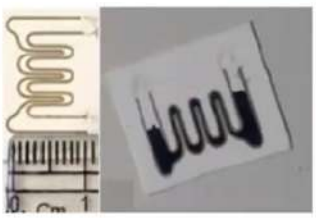


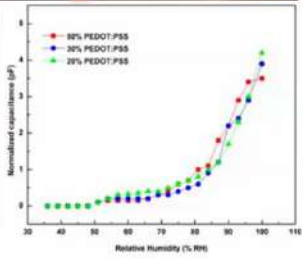
EHD printed humidity sensor on paper











Printed Width

Figure :Raman spectroscopy of PEDOT.PSS

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Printed Temperature Sensor

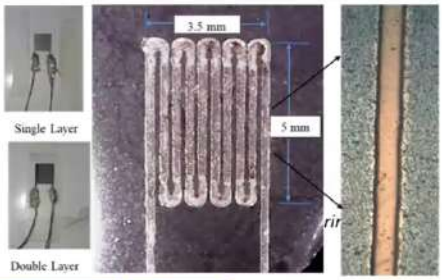
Fabrication of flexible temperature sensor through DOD EHD on PET substrate

Material:
- Silver nano particles

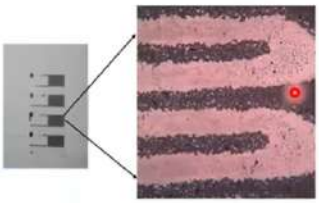
Substrate:
- PET

Printed width:
- 100 µm

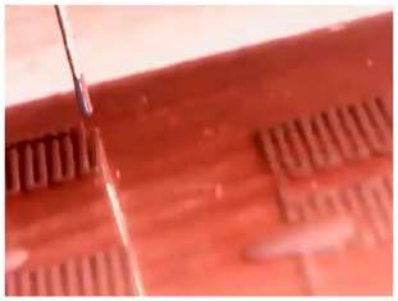
Controlling Parameters:
- Nozzle diameter
- Base voltage
- Pulse voltage
- Duty cycle
- Pressure
- Feed rate
- Stand-off distance

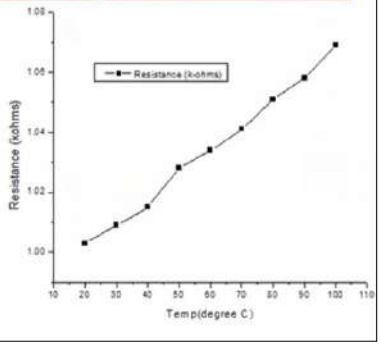


EHD Parameters	Values
Base voltage	2 kV
Pulse voltage	2.6 kV
Feed rate	1200(mm/min)
Stand-off distance	< 1 mm
Pressure	< 0.5 kPa

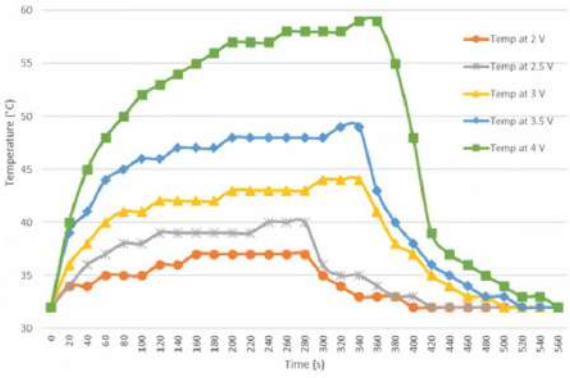


EHD printed temperature sensor on paper





Printed Heater for Wearable Applications



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3.3. "Printed Electronics"

by Dr. Khalid Rahman, Professor - Faculty of Mechanical Engineering, Ghulam Ishaq Khan Institute of Engineering Sciences and Technology, Topi, Pakistan

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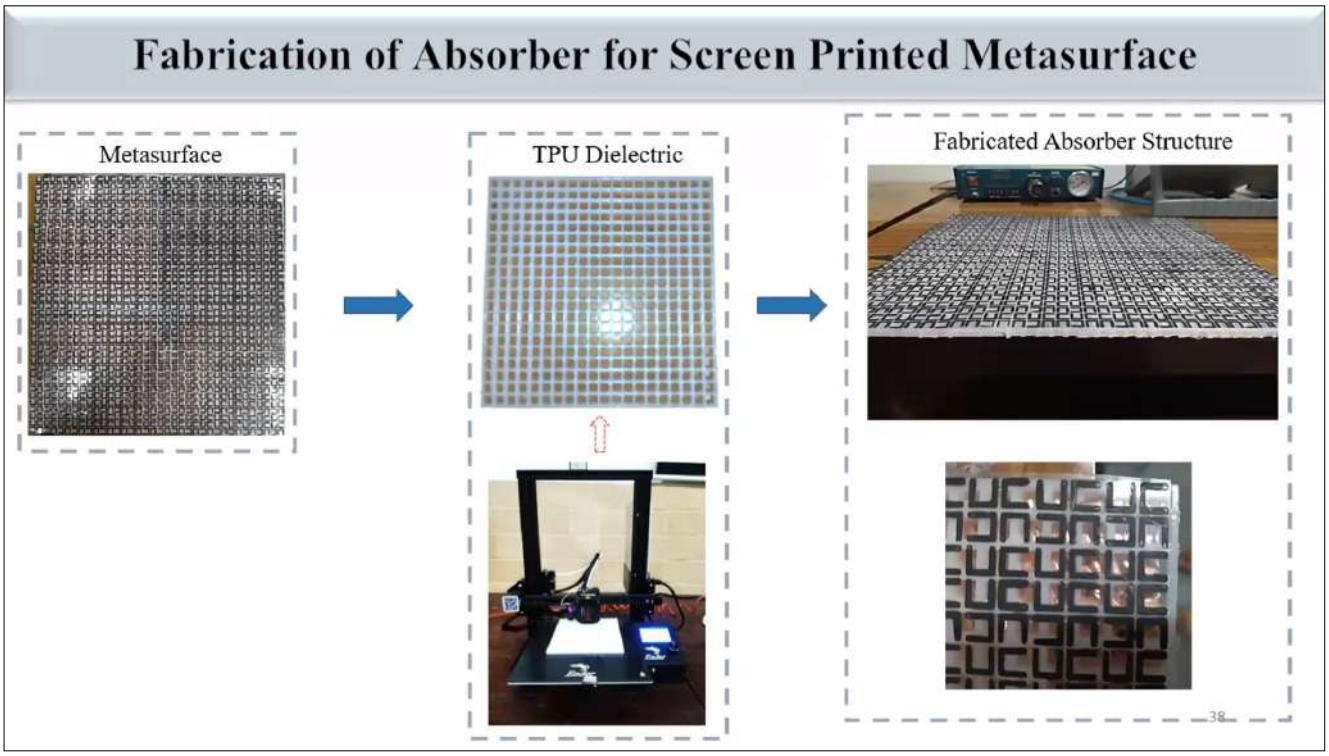


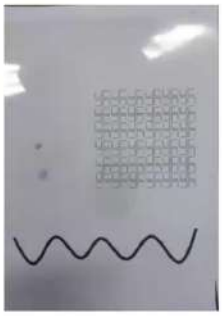
3.3. "Printed Electronics"

by Dr. Khalid Rahman, Professor - Faculty of Mechanical Engineering, Ghulam Ishaq Khan Institute of Engineering Sciences and Technology, Topi, Pakistan

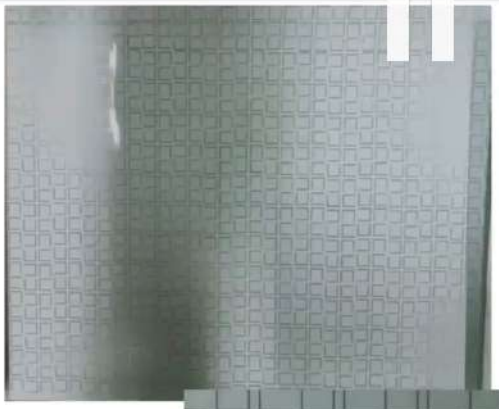
Continued...

Inkjet Printed Metasurface

Inkjet Printer (single ink)



Carbon Ink



Silver Ink

Inkjet Printer (multimaterial inks)

- Carbon printed structure – high resistance
- Silver printed structure – low resistance

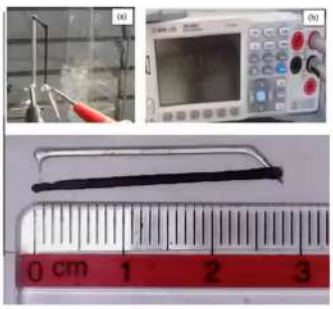
Printed Electronics Lab

Facilities Available

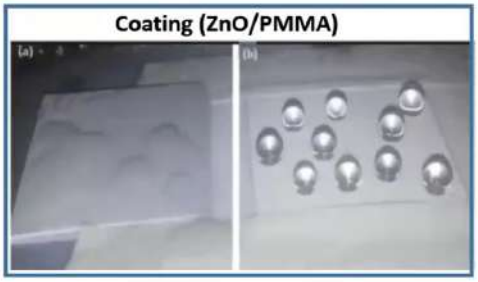
- EHD printing
- Direct Ink Writing technique
- Spray coating through EHD (electrospray and spray gun)
- Sample sintering/curing
- Characterization of printed samples
- Ink preparation apparatus

Research in-progress

- EHD printing resolution
- Printed Thermocouples
- Printed sensors
- Printed TEGs
- Spray coatings



Coating (ZnO/PMMA)



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Limitations and Challenges

- **Ink formulation (adjusted viscosity, surface tension, evaporation rat)**
- **Ink stability (e.g. particle agglomeration, settling,...)**
- **Substrate quality (surface energy, roughness control)**
- **Layer to layer registration (self-alignment)**
- **Jetting-reliability (monitoring, redundancy)**
- **Process/solvent compatibility**
- **Device performance**
- **Resolution**

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Prospects of Printed Electronics for Pakistan

- **Low-Cost, Scalable Manufacturing**
  - PE uses inexpensive materials (e.g. carbon-based inks, silver nanoparticles) and simple printing techniques.
  - Ideal for resource-limited environments where affordability is crucial.
- **Enabling Technologies for Local Challenges**
  - Healthcare: Printed biosensors for diagnostics in rural areas.
  - Agriculture: Smart packaging and environmental sensors.
  - Energy: Printed solar cells and thermoelectric harvesters for off-grid regions.
  - Education: Low-cost educational electronics and lab kits.
- **Industrial Potential**
  - Opportunity to build local supply chains for inks, substrates, and printed components.
  - Integration with existing textile, paper, and packaging industries.
  - Possibility of attracting foreign direct investment (FDI) in flexible electronics and IoT manufacturing.

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Prospects of Printed Electronics for Pakistan

- **Academic and R&D Growth**
  - Pakistan's universities and research centers can develop expertise in: Materials science (nano-inks, substrates)
  - Printable energy devices
  - Sensor design International collaboration can boost technology transfer and training.
- **Sustainability and Energy Efficiency**
  - PE supports green manufacturing: low material waste, energy-efficient processes.
  - Printable solar panels and energy-harvesting devices support sustainable development goals (SDGs).

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Recommendations for Pakistan

- Launch national R&D initiatives focused on printed electronics.
- Encourage public-private partnerships for prototyping and scaling.
- Provide funding and policy incentives for startups and tech incubators.
- Foster international collaboration for capacity building.

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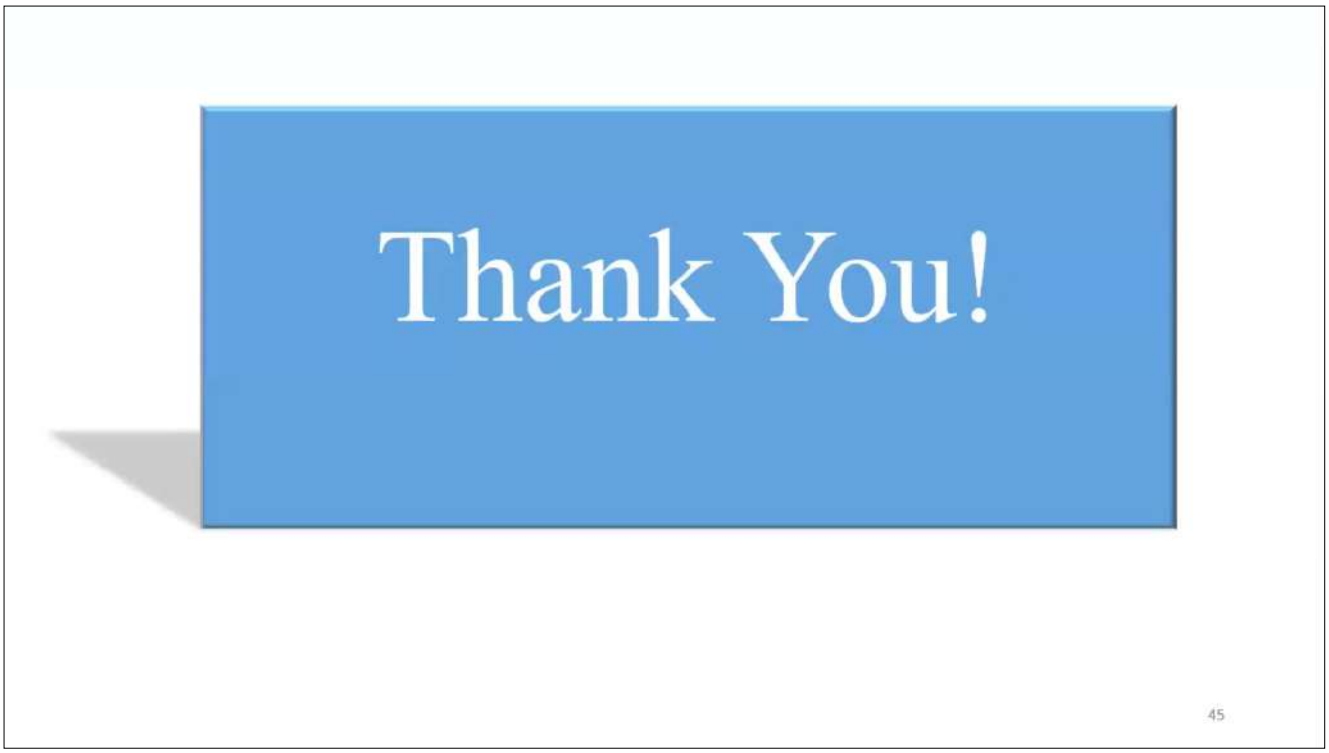

Thank You!
45

3.4. "Additive Manufacturing in Pakistan: Current Penetration and Key Challenges"

by

***Engr. Dr. Shaheryar Atta Khan**, HoD (Mechanical Engineering), DHA Suffa University, Karachi, Pakistan.*

Additive Manufacturing in Pakistan: Current Penetration and Key Challenges

Presented by
Engr. Dr. Shaheryar Atta Khan
HoD Mechanical Engineering
DHA Suffa University

Additive Manufacturing

FROM IMAGINATION TO REALITY

3.4."Additive Manufacturing in Pakistan: Current Penetration and Key Challenges"

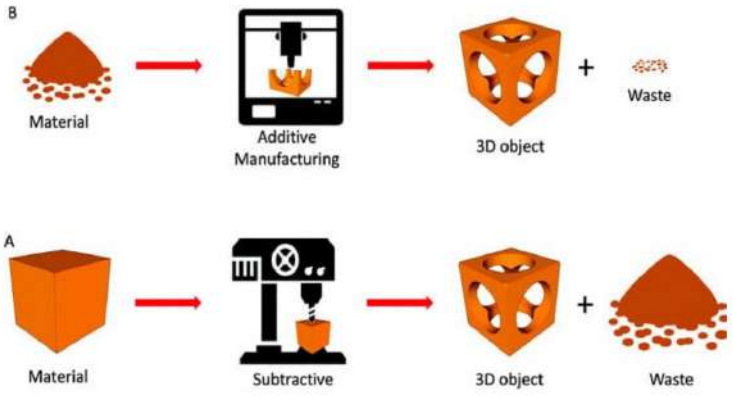
By Engr. Dr. Shaheryar Atta Khan, HoD (Mechanical Engineering), DHA Suffa University, Karachi, Pakistan

Continued...

Additive Manufacturing

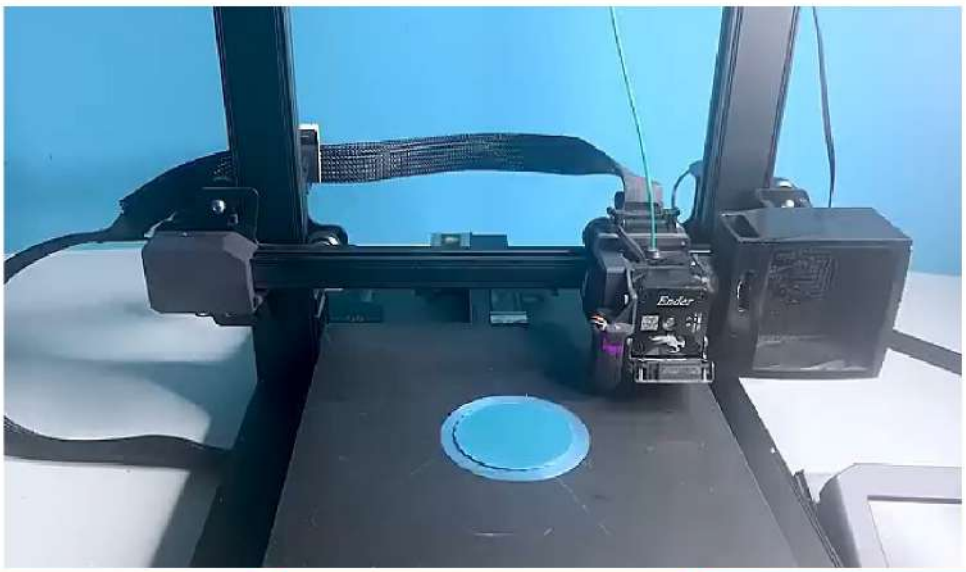
Additive Manufacturing is a process of creating **three-dimensional objects** by building them **layer by layer** from a **digital model**, typically using materials such as plastics, metals, or composites.

Unlike traditional **subtractive methods** that remove material from a solid block, **additive manufacturing adds material only where needed**, enabling **complex geometries**, reduced waste, and rapid prototyping.



Source: https://bitfab.io/blog/additive-manufacturing/

Additive Manufacturing



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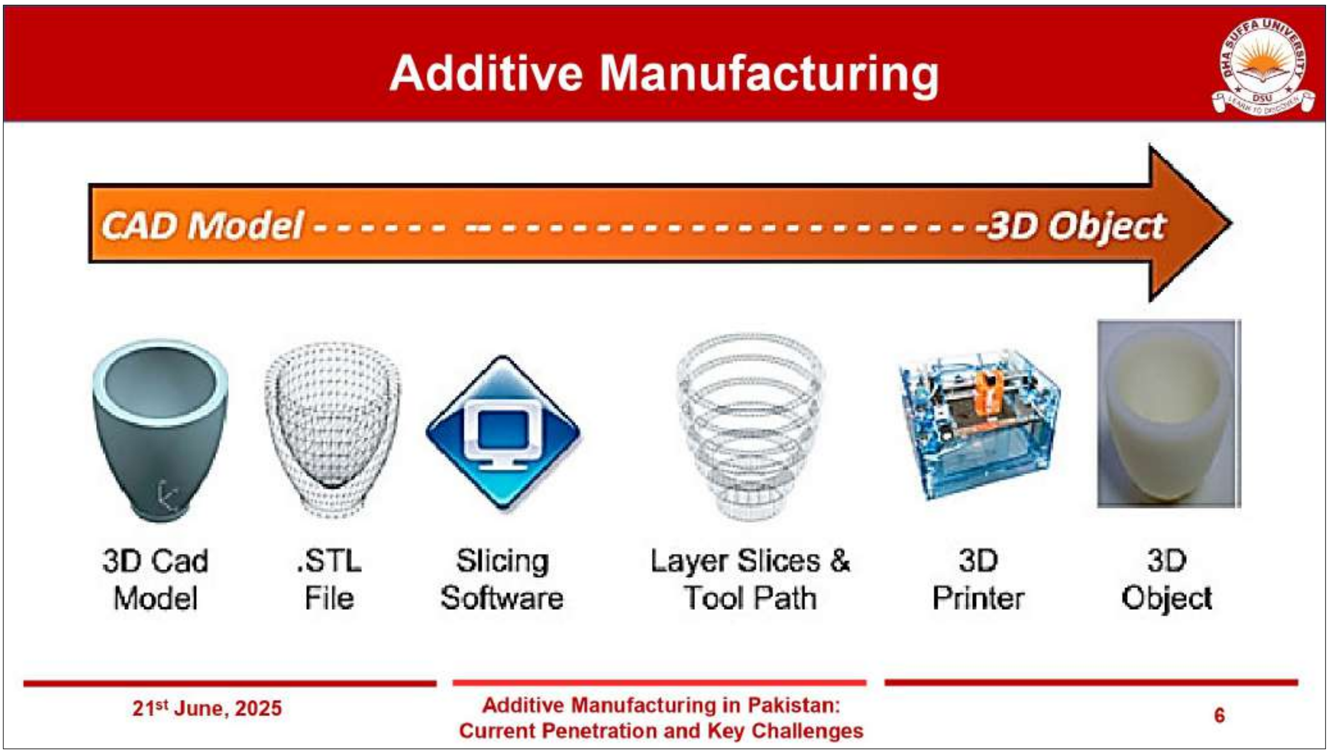

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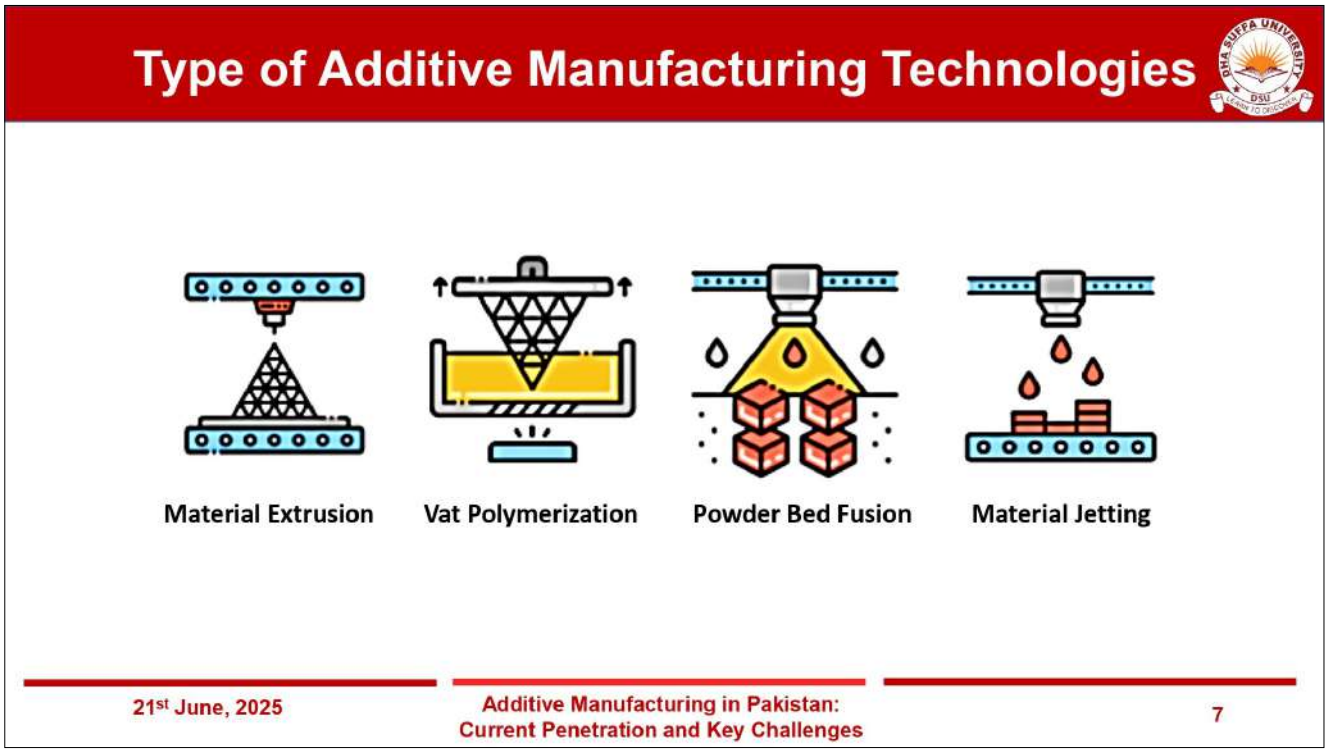

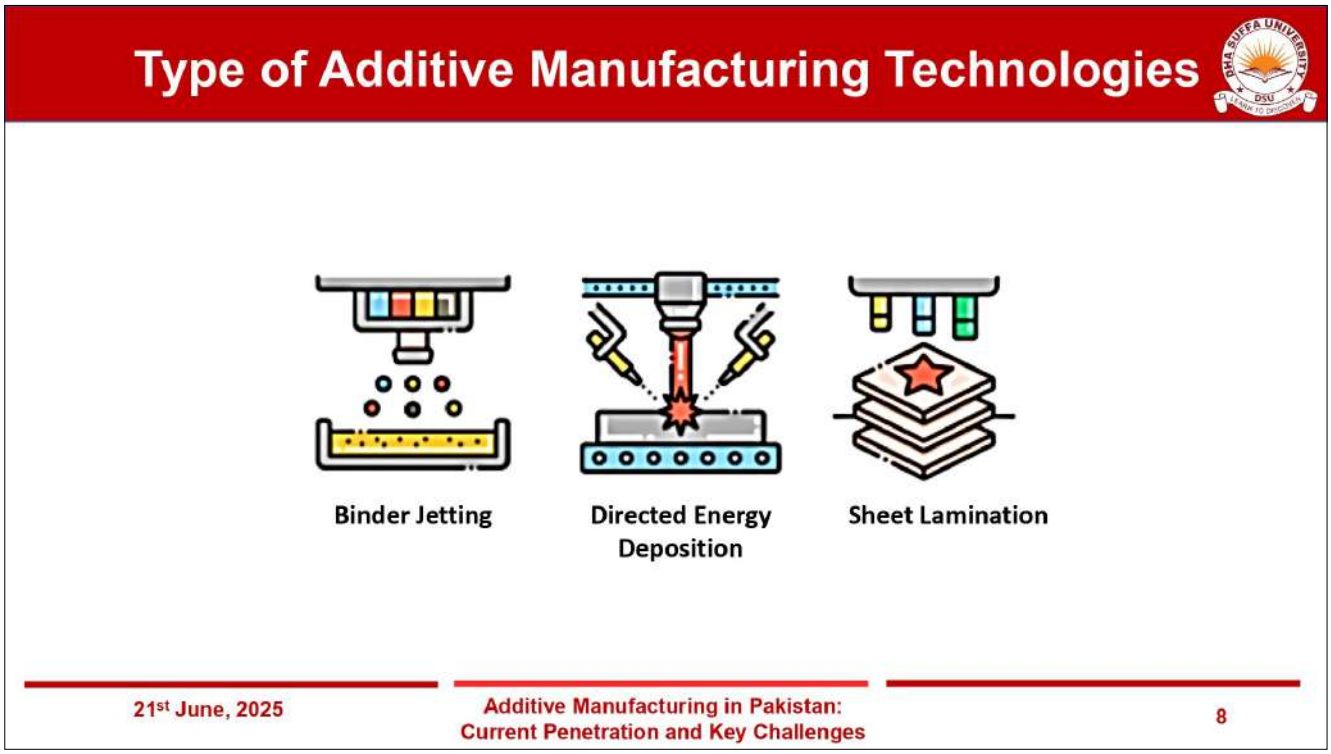

3.4."Additive Manufacturing in Pakistan: Current Penetration and Key Challenges"

By Engr. Dr. Shaheryar Atta Khan, HoD (Mechanical Engineering), DHA Suffa University, Karachi, Pakistan

Continued...

From Prototyping to Smart Manufacturing

- **1980s – The Birth of AM**
  - ***Charles Hull*** *invented* ***Stereolithography (SLA)*** *and filed a patent –* ***1984***
  - *The first commercial 3D printer, the* ***SLA-1****, was released by 3D Systems –* ***1988***
- **1990s – Technology Diversification**
  - ***Fused Deposition Modeling (FDM)*** *was developed and patented by* ***Scott Crump****, who co-founded* ***Stratasys – 1990***
  - *3D printing remained mainly in* ***prototyping and R&D*** *sectors during this period*
- **2000s – Wider Adoption and Research**
  - *Additive manufacturing began moving from* ***rapid prototyping to functional parts***
  - *The open-source* ***RepRap Project*** *was launched, enabling users to build low-cost 3D printers –* ***2005***
  - *The first* ***self-replicating 3D printer*** *was created, significantly reducing the entry cost –* ***2008***

From Prototyping to Smart Manufacturing

- **2010s – Industrial and Consumer Growth**
  - ***Metal 3D printing*** *technologies like* ***Direct Metal Laser Sintering (DMLS)*** *and* ***Electron Beam Melting (EBM)*** *gained traction*
  - *Major industries (aerospace, automotive, healthcare) started using AM for* ***end-use parts***
  - *Additively Manufactured* ***LEAP Fuel Nozzle*** *made its first flight –* ***2016***
  - *Custom medical devices (e.g., implants, prosthetics) and* ***bioprinting*** *saw rapid growth*
- **2020s – Integration into Smart Manufacturing**
  - *AM is now a key part of* ***Industry 4.0****, integrated with* ***IoT****,* ***AI****, and* ***digital twins***
  - *Advances in* ***multi-material****,* ***multi-axis****, and* ***large-scale printing*** *have emerged*
  - *Applications have expanded to construction (3D printed houses), food (3D printed meals), and space (NASA printing tools on ISS)*

3.4."Additive Manufacturing in Pakistan: Current Penetration and Key Challenges"

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Continued...

LEAP Fuel Nozzle a Breakthrough

- The **LEAP (Leading Edge Aviation Propulsion)** engine is a high-bypass turbofan developed by **CFM International,** a joint venture between **GE Aviation** and **Safran Aircraft Engines**.
- GE Aviation redesigned the **traditional 20-part nozzle** as a **single-piece component** using **Direct Metal Laser Melting (DMLM)**, a form of metal 3D printing. 25% lighter and 500% more dureable

Source: https://www.geaerospace.com/

LEAP71 AI Designed Rocket Engine

- **LEAP 71**, a Dubai-based company, developed an **AI system Noyron** that autonomously **generates** the full **3D geometry** of the **rocket engine**, performs thermal and thrust models based on the input thrust, propellant type, chamber pressure as inputs.
- The 3d model is then additively manufactured
- They designed and produced a 5 kN liquid-fuel **rocket engine** and it was **hot-fire tested in 2024**

Source: https://www.leap71.com/

3.4."Additive Manufacturing in Pakistan: Current Penetration and Key Challenges"

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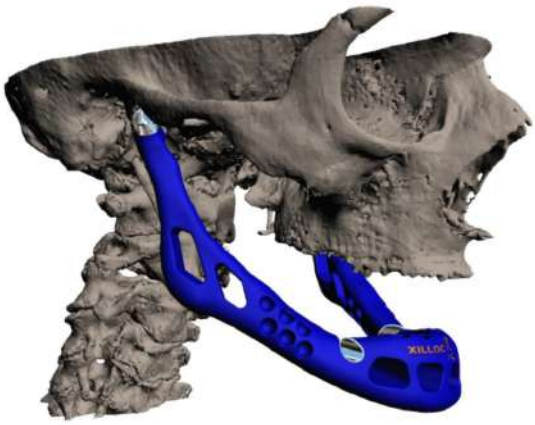
Continued...

LEAP71 AI Designed Rocket Engine

Source: https://www.leap71.com/

Additively Manufactured Implants

- **LayerWise**, a **KU Leuven** spin-off, additively manufactures the world's first **patient-specific lower jaw** which was implanted to treat a senior patient's progressive osteomyelitis of almost the entire lower jawbone, medical specialists and surgeons opted for such a complete patient-specific implant the first time ever.



Source: https://www.kuleuven.be/

3.4."Additive Manufacturing in Pakistan: Current Penetration and Key Challenges"

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Continued...

Additively Manufactured Prosthesis

- **Hero Arm** is a **clinically approved** myoelectric prosthetic for children (8+) and adults with below-elbow limb differences
- Additively Manufactured using Nylon 12, it's custom-fit via 3D scanning.

Source: https://openbionics.com/en/hero-arm/

Additively Manufactured Prosthesis

- **MARC Protez** is Turkey's first indigenous, additively manufactured prosthetic arm developed at Koc University.
- Developed by a Pakistani PhD Scholar to aid day-to-day activities of a university employee.

Source: https://www.ku.edu.tr/

3.4."Additive Manufacturing in Pakistan: Current Penetration and Key Challenges"

By Engr. Dr. Shaheryar Atta Khan, HoD (Mechanical Engineering), DHA Suffa University, Karachi, Pakistan

Continued...

Current Penetration in Pakistan

- **Development Phase (2010–2015)**
  - Universities like NUST and NEDUET Commissioned 3D printers
  - 3D printer was developed in 2011 NUST-PNEC as a student final year projects
  - Some tech enthusiasts and hobbyists started **assembling DIY RepRap printers**
  - Participation in exhibitions like *IDEAS* helped showcase 3D-printed models and tools
  - Local dental labs began exploring resin-based SLA/DLP printers for dental crowns and aligners
- **Expansion and Diversification (2015–2020)**
  - Startups such as **Objexyz**, **Browide3D**, **Grit3D,** and **Quantum3D** began offering commercial 3D printing services for prototyping and small-batch production
  - AM was adopted by defense R&D institutes (NESCOM, NDC) for prototyping UAV and weapon parts
  - Bioniks 3D in collaboration with NEDUET started making opensource prosthesis
  - CoE-PIAM3D established at NCP Islamabad

Current Penetration in Pakistan

- **Healthcare Focus (2020–2024)**
  - NGOs and university teams used AM to build low-cost prosthetics, especially for child amputees and war victims
  - Aga Khan University Hospital (AKUH) led innovation in 2023–24 by Developing DRAP approved PEEK cranial and spinal implants and performing successful surgeries
  - 3D scanning + printing orthotic devices became popular in Lahore, Islamabad, and Karachi clinics using FDM and PETG
  - Pakistan's first concrete 3D printer was developed
- **Recent Advances & Institutional Push (2024–2025)**
  - Pakistan Institute of Additive Manufacturing (PIAM) organized an international AM event, highlighting local research in aerospace and biomedicine

3.4."Additive Manufacturing in Pakistan: Current Penetration and Key Challenges"

By Engr. Dr. Shaheryar Atta Khan, HoD (Mechanical Engineering), DHA Suffa University, Karachi, Pakistan

Continued...

Additive Manufacturing in Pakistan

Source: https://bioniks.org/

PEEK Implants: Unlocking Innovative Surgical Solutions

Key Challenges

- Policy & Regulation: Lack of formal frameworks and incentives
  - **Unclear HS Codes** and the requirement of **NOCs** from **MoI** & **MoD** for importing 3D printers, filaments, powders, and resins often lead to **delays or excessive duties**
  - **No tax exemptions or subsidies** for industrial AM equipment
  - **No AM-specific national strategy**, which leads to **fragmented growth** without targeted investment
- Startups and SMEs hesitate to scale due to high import costs and regulatory ambiguity

Continued...

Key Challenges

- Infrastructure: Unreliable utilities and high operational costs
  - **Unstable electricity supply** leads to frequent failures during long 3D print jobs.
  - **High costs of quality materials** (filaments, powders, resins) due to import dependency.
- Limited throughput, high part rejection, and discouragement for industrial-scale use.

Key Challenges

- Skills Shortage: Limited expertise in design for AM (DfAM)
  - Engineering curricula in most universities **lack modules on AM**, especially in relation to generative design, topology optimization, or multi-material systems
  - Lack of **cross-disciplinary collaboration** (materials, software, mechanical, electrical).
- AM is used to replicate parts traditionally instead of innovating with new geometries, reducing ROI

Continued...

Key Challenges

- Market Demand: Low awareness and commercial confidence
  - Industry stakeholders—especially auto part manufacturers—**lack awareness of AM's potential** beyond prototyping
  - **Return on investment (ROI)** is questioned due to perceived low reliability and material strength
  - There's a **disconnect between academia, startups, and industry**.
- Slow adoption, limited industrial projects, and underutilized lab capacities

Conclusion

- Pakistan is on the right track, yes a few years behind the rest of the world
- Just a nudge in terms of Policy, Training, and Synergy between academia and the industry is required

3.4."Additive Manufacturing in Pakistan: Current Penetration and Key Challenges"

By Engr. Dr. Shaheryar Atta Khan, HoD (Mechanical Engineering), DHA Suffa University, Karachi, Pakistan

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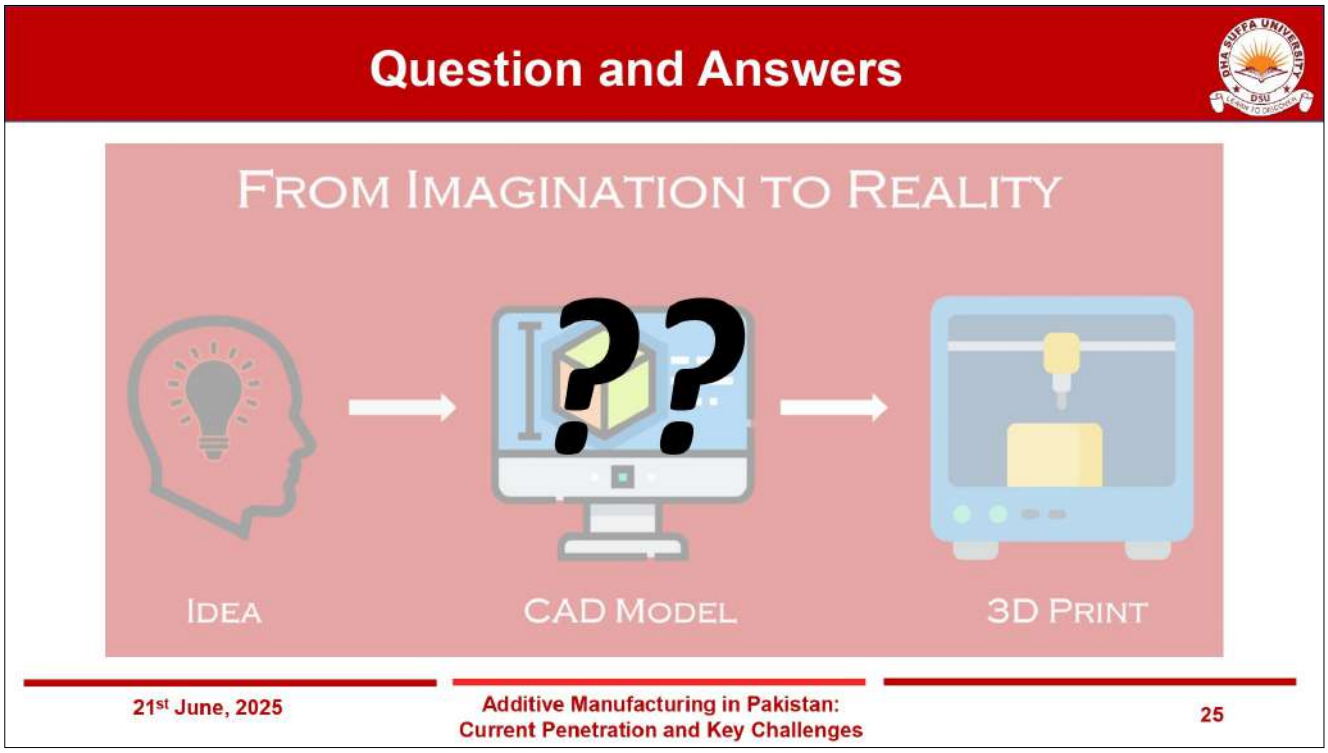


3.5. "Opportunities and Challenges for Pakistan in Additive Manufacturing?"

by

***Engr. Dr. Waqas Ahmed**, Associate Professor, NUST Business School, Islamabad, Pakistan.*

Prospects of Additive Manufacturing in Pakistan

Dr. Waqas Ahmed
Associate Professor
NUST Business School

Global Overview

- Size of the global AM market (e.g., USD 20+ billion and growing)
- Key players and countries leading AM innovation (USA, Germany, China)
- Trends: Customization, Decentralized Manufacturing, Rapid Prototyping

Relevance to Pakistan

- Manufacturing sector's role in GDP (~13-15%)
- Need for innovation to stay competitive
- Young population and growing tech adoption

Current State of AM in Pakistan

- Pioneers: Research institutions like NUST, GIKI, and PIEAS
- Limited industrial adoption but growing interest
- Presence of service bureaus, 3D printing startups

Opportunities

- **Industrial Prototyping:** Fast and cost-effective prototyping for SMEs
- **Tooling & Jigs:** Reduction in lead time and cost
- **Healthcare:** Customized implants, prosthetics
- **Construction:** 3D-printed housing for disaster relief
- **Defense & Aerospace:** Lightweight parts, rapid iteration

Strategic Advantages for Pakistan

- Cost-effective skilled labor
- Strategic location for exports
- Emerging startup ecosystem
- Government incentives for innovation and digitization

Success Stories (Local & International)

- Local: NUST's AM center, Pakistani startups offering 3D printing services
- International: GE, Boeing, Siemens adopting AM at scale

Challenges

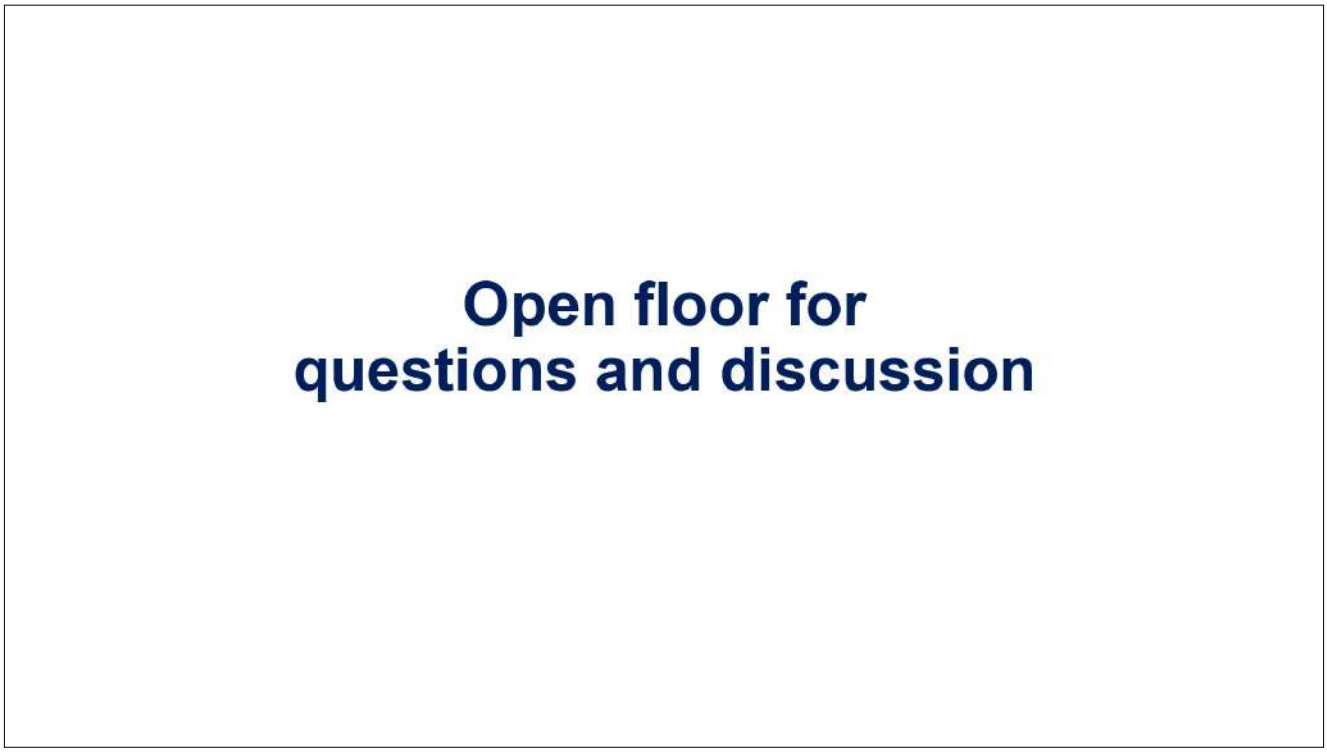
- High initial investment cost
- Lack of skilled workforce
- Limited availability of raw materials
- Need for standardization and regulation

Way Forward

- Industry-academia collaboration
- Investment in R&D and pilot projects
- AM curriculum in engineering and technical programs
- Government support through policy and funding

Call to Action

- For Industry: Explore pilot projects and training
- For Academia: Develop talent and applied research
- For Students: Learn AM tools and software, pursue certifications


Open floor for
questions and discussion

The Pakistan Academy of Engineering (PAE)

Address: E-16/2, Block-7, Gulshan-e-Iqbal, Karachi

Tel.: 021-34831726

E-mail: info@pacadengg.org