SUSTAINABLE MATERIALS & MANUFACTURING

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Opening doors into next-generation sustainable practices in manufacturing
Disruption in Additive Manufacturing: Bio-BAAM and Biodegradability

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Composite Materials Recyclability, Challenges and Opportunities
Towards a Green Bio-economy via Innovative Bio-manufacturing: Unlocking the Potential

Developing Bio-economy: What is at stake?

1) Reducing **dependence on fossil resources** and addressing **climate change**

2) Increasing the **resilience, sustainability** and **productivity** of primary production systems and the food chain

3) Building competitive bio-based industries and manufacturing in US, **particularly in rural areas**

4) Moving towards a **zero-waste society**
Three Main Mission in Bio-Manufacturing

1. Value Added Forest Products

- Fuel efficient car parts
- Bullet-proof suits
- Flexible displays and batteries
- Packages, building materials
- Furniture, electronics
- Food product
- Cosmetics
- Special papers
- Paper coating
- Flexible batteries
Redefining biorefinery:

Develop value added byproducts from Biorefineries

- We import 49% of the petroleum used.
- We send close to $1 billion per day overseas to buy oil.
Next Generation Agribusiness

Next Generation Agribusiness ("NGA") is about growing perennial crops and turning those crops into finished products in the same community.

It combines the two powerful economic drivers of agriculture and manufacturing.

Farm in rural America, just as important, manufacture in rural America
Bio-Materials are high in Value chain and pull can come from Manufacturing
Cellulose Fibrils are in many forms and functionality

Advantages:

- Abundant, renewable resource with price stability
- Compostable
- Biocompatible
- High strength and modulus
- Lightweight
- Shear thinning thickener (stable against temperature and salt addition)

2014: Thomas Reuters names nanocellulose as one of the top 10 technologies that will change the world by 2025.
3D-printing thermoplastic with cellulosic fiber and PLA

Ozcan Group Research in Nanocellulose

Metal oxide nanoparticles from CNF template

Interfacial engineering to improve mechanical properties

CNC composite for Anionic Exchange Membrane

3D-printed thermoset from cellulose/epoxidized soybean oil

Carbohydrate polymers, 2015


RSC Advances, 2015
40% CNF-PLA
- ~93% of specific strength of Aluminum 6061-T4 alloy.
- Stronger and lower cost than CF-ABS composite
- 100% BIO

40% CNF-PLA: \(0.4 \times 2/\text{lb} + 0.6 \times 3/\text{lb} = 2.6/\text{lb}\)

30% CF-ABS: \(0.3 \times 12/\text{lb} + 0.7 \times 3/\text{lb} = 5.7/\text{lb}\)
Materials solutions are most of the time in composites

- High Mechanical
- High Tg Polymer
- Process temp is lower than 200°C
- Printable
- High Volume
- Low Cost
- Biodegradable compostable
Out of Oven Process - Reduced Curl Parts

Dramatically reduced curl

ABS
CF-ABS

Only a slight curling
BAAM-printing of Bamboo with PLA
BAAM-printing of 20% Bamboo fiber-PLA system
Neat Bio-Based Polymer Feedstock

- Non-uniform extrusion
- Significant curling

Needs modification!!!
BAAM-printing of 20% Flax fiber-PLA system
Shop architect’s design is this year’s winner of the Panerai Design Miami/ Visionary Award
Biomanufacturing: Fully bio-based, sustainable composites for large scale additive manufacturing

- A newly developed fully bio-based, sustainable composite system (bamboo fiber-biopolymer) was for the first time 3D-printed in large scale.

- A contemporary pavilion system was additively manufactured for an architecture expo as a part of a large collaborative project.

- ~10,000lbs biodegradable material was printed at up to a 40lbs/hr rate.

- The developed bio-composite system offers advantages over commonly used carbon fiber-ABS in terms of embodied energy, carbon footprint, cost and end-of-life.
Addressing Critical Challenges

Five/Ten Year Technical Goals

• 25/50% lower carbon fiber–reinforced polymer (CFRP) cost
• 50/75% reduction in CFRP embodied energy
• 80/95% composite recyclability into useful products

Impact Goals

• Enhanced energy productivity
• Reduced life cycle energy consumption
• Increased domestic production capacity
• Job growth and economic development
A Quick Question
An aluminum can that is thrown away will still be a can ______ years from now
A) 100
B) 300
C) 500
D) 800
Sustainable Materials & Manufacturing

Manufacturing → Product → End of Life Products and infrastructure → Dissipation

Material Processing → By-product (Scrap) → Collection → Excavation

Recycling Repurposing Processes

Ore → Resource stock

Landfill Stock
Opportunity

• In North America, 29 million pounds (~13,200 MT) of carbon fiber waste estimated going to landfill per year. In the form of
  
  – Pre-preg, primarily aerospace production scrap  
  – Secondary amount is cured production trim  
  – Some pre-preg scrap has to be oven cured prior to landfill  
  – Regulations vary based on constituents in resin system  
  – Adds cost/time burden on composite manufacturers

• It is difficult to estimate amount of end-of-life composite
Challenges

• Supply Chain, need to know where material comes from and what it contains (fire retardants, etc), and available in what format
  – Sorting, Classifying, labeling

• For value added products, higher fiber volume fraction preform, aligned fibers etc. which could be achieved by new methods of preforming

• Development of standard for products will give confidence to designers and end users.

• Today Landfill fee/tax is not a driver for C-fiber recycling in US. However further legislation or banning landfill will drive recycling

• Life Cycle Assessment studies for recycling processes is needed.
Recycling Proposals Received

Automotive component and 3D printed tool both use reclaimed CF

Approved

Recycling aircraft components into 3D printed automobiles

In contracting

Profitably recycling glass and carbon composites

In review cycle

Automotive component uses CF reclaimed from scrap prepreg

In review cycle
Thank You!

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Big Area Additive Manufacturing
Composite Materials Recyclability, Challenges and Opportunities

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IACMI- The Composites Institute
09/014/2016, JEC- Knoxville TN
Our Vision and Mission

Vision:

- Our collaboration of industry, research institutions and state partners is committed to accelerating development and adoption of cutting-edge technologies in recycling and re-manufacturing of composites

Mission:

- To lead and grow a composite recycling industry that fully diverts fiber scrap and end-of life composite products into value-added products
  - **Economic**: Grow manufacturing and create jobs across the composite industry
  - **Education**: Support the training of a workforce prepared for and accomplished in the skills required by the composite recycling industry.
  - **Environment**: Reduce the amount of composite landfill through re-use in new applications with reduced energy and environmental footprints.
Increasing volume of materials to be recycled in aeronautics

Increasing volumes of materials to be recycled

- In the mid-term, end-of-life products will need to be recycled
- In the short term, most of the composite waste will come from production scraps

Data: Clean Sky
Recycled Carbon Fiber and Value
Composite Recycling Activities

- Vartega
- Adherent Technology
- CHZ Tech
- Materials Innovation Tech

The Institute for Advanced Composites Manufacturing Innovation

IACMI Overview 32
Driving Forces for Sustainable Materials & Manufacturing

- Growing public concern about environmental issues
- Corporate social responsibility
- Economical viability
Concluding Remarks

• Well recognized that composite recycling needs “market pull” to elevate demand and value, and improve reclamation business case. It is so critical to develop supply chain.

• Achieving Technological barriers in manufacturing technologies yielding product sales, creating confidence in using reclaimed fibers and, most importantly, fund increased R&D into new product areas

• Early manufacturing and development efforts will generate standardization and also process knowledge that feeds new applications/opportunities
**Big Area Additive Manufacturing (BAAM)**

**Conventional AM**
- Small (< 1 cubic ft)
- Slow (< 5 ci/hr)
- Expensive (~$100/lb)
- Takes days to go through 1 kg spool
  - Not exciting for material manufacturers

**Big Area Additive Manufacturing**
- Large (> 1000 cubic ft)
- Fast (>2500 ci/hr)
- Cheap (<$5/lb)
- One machine can go through a gaylord in a day