Fiber Reinforced Polymer Composite Manufacturing RFI
DE-FOA-0000980
Summary of Responses

December 11, 2013

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RFI DE-FOA-0000980 - Overview

- AMO Released a Request for Information (RFI): Fiber Reinforced Polymer Composite Manufacturing DE-FOA-0000980 on 8/26/13

- Two topic areas
  - Topic Area 1: Fiber Reinforced Polymer Composite Manufacturing
  - Topic Area 2: Fiber Reinforced Polymer (FRP) Composite Supply Chain and Markets

- Initial close date 9/26/13; extended to 10/1/13

- 37 Responses representing 59+ respondents
  - Not all respondents answered every question.
1. What do you think are the three most important R&D areas with technology development needs in the Technology Readiness Level/Manufacturing Readiness Level (TRL/MRL) 4-7 for fiber reinforced polymer composites to achieve the goals of reducing life-cycle energy consumption and greenhouse gas emissions by 50% over a ten year period?

2. What do you think are the three most important R&D areas with technology development needs in the TRL/MRL 4-7 for fiber reinforced polymer composites to achieve the goal of increasing U.S. manufacturing competitiveness?

3. For the technology areas you identified as the most important in your response for questions 1 and 2, which would be more effectively addressed through a shared R&D facility capable of precompetitive and protected work? Which would be more effectively addressed through individual, independent R&D projects?

4. What do you consider the most important training and workforce development needs (skills, certifications, etc.) to increase U.S. competitiveness in fiber reinforced composite manufacturing?

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Q1-1: R&D Areas for Reducing Energy Consumption and GHG

What do you think are the three most important R&D areas with technology development needs in the Technology Readiness Level/Manufacturing Readiness Level (TRL/MRL) 4-7 for fiber reinforced polymer composites to achieve the goals of reducing life-cycle energy consumption and greenhouse gas emissions (GHG) by 50% over a ten year period?

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Q1-2: R&D Areas for Manufacturing Competitiveness

What do you think are the **three** most important R&D areas with technology development needs in the TRL/MRL 4-7 for fiber reinforced polymer composites to achieve the **goal of increasing U.S. manufacturing competitiveness**?

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Most Important R&D Areas (Combined Q1-1 and Q1-2)

Legend:

<table>
<thead>
<tr>
<th>R&amp;D Area</th>
<th>Number of Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>High speed production</td>
<td>46</td>
</tr>
<tr>
<td>Low cost production</td>
<td>41</td>
</tr>
<tr>
<td>Energy efficient manufacturing</td>
<td>37</td>
</tr>
<tr>
<td>Recycling/Down-cycling</td>
<td>35</td>
</tr>
<tr>
<td>Innovative design concepts</td>
<td>25</td>
</tr>
<tr>
<td>Modeling and simulation (ICME)</td>
<td>22</td>
</tr>
<tr>
<td>Dissimilar materials joining</td>
<td>14</td>
</tr>
<tr>
<td>Other</td>
<td>22</td>
</tr>
<tr>
<td>Multi-functional materials</td>
<td>13</td>
</tr>
<tr>
<td>Use of nanomaterials</td>
<td>12</td>
</tr>
<tr>
<td>Defect detection</td>
<td>10</td>
</tr>
<tr>
<td>Validation/Qualification</td>
<td>8</td>
</tr>
<tr>
<td>Reduced part count concepts</td>
<td>1</td>
</tr>
</tbody>
</table>

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Q1-3: Type of R&D Activity

For the technology areas you identified as the most important in your response for questions 1 and 2, which would be more effectively addressed through a shared R&D facility capable of precompetitive and protected work? Which would be more effectively addressed through individual, independent R&D projects?

Legend:
Response
Number of Responses

- Shared R&D Facility: 46
- R&D Projects: 18
- Either: 20

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What do you consider the most important training and workforce development needs (skills, certifications, etc.) to increase U.S. competitiveness in fiber reinforced composite manufacturing?

- Most common responses are grouped and summarized as the need for:
  - **Certified manufacturing/technical workforce**
    - Professional level, re-education of designers and engineers
    - Community college and trade schools for technicians for manufacturing with hands on training
  - **Increased focus at universities** – undergraduate and graduate levels
    - Identified knowledge areas: materials science courses in general focused on composites (rather than metals), design and simulation for composites, robotics, automation, industrial controls, textiles, interfacial and surface science, nanomaterials

- Multiple responses also indicated a more general need to supporting K-12 STEM education and engagement with students at a young age to interest them in science and technical fields
“The combination of automation and information technology is the next wave of productivity…The acceleration of this trend in carbon fiber manufacturing will impact three workforce development trends. First is the need for more skilled technicians (with associate degrees from technical colleges) to build and maintain the IT-driven machinery. Second is the need for more engineers (with bachelor’s degrees in engineering and computer science) to design and develop these IT-driven factories. Third is the need for big data analytics experts to use high performance computing centers with advanced modeling and simulation programs to optimize IT-driven smart manufacturing (with master’s or doctoral degrees or IT entrepreneurs)."

“#1: certification of hands-on skills, not just ‘book learning,’ including for shop personnel, technicians, and entry level professionals.”

“The most important training and workforce development needs (skills, certifications, etc.) to increase U.S. competitiveness in fiber reinforced composite manufacturing are professional training for workers, technical training at high school level and high technology training at community college and college levels.”

“There are comparatively fewer trained engineers and other technical experts in composites engineering versus more mature material industries. This fact reinforces the need for multilevel curriculum and certification program for future composites workforce needs as reinforced composites technology becomes more widespread.”

“There are very few university level programs in the U.S. that educate engineers in the latest technologies in the field of composites, especially carbon fiber composites and design/simulation/CAE. Increased emphasis in this area is essential to increasing U.S. competitiveness for composites manufacturing. There is also a need for training in the areas of robotization and industrial controls, as evolving high speed processes for composites will increasingly rely on machinery to transform fibers into textiles, textiles into shaped preforms and preforms and resins into composites. These activities need to be automated to achieve high throughput and lower costs.”

“There is an important and essential need for plastic and composite university degree programs. There are very few such programs in the country currently. In addition, currently available engineering programs tend to focus, even today, on traditional material solutions. More options need to be available and encouraged now in order to meet the needs of the future workforce. A skills gap also exists in the current workforce. Trades and skilled workers should be required to have additional certification related to advanced materials, such as plastics and composites. This would not only serve to educate the skilled workforce, but also help demonstrate how to work with advanced materials within a current operational setting.”
1. Please identify the role of your institution or business in the supply chain: a) a material supplier (MS), b) component manufacturer (CM) includes tiered suppliers, c) original equipment manufacturer (OEM), d) end user or e) other (please identify)?

2. What composite material systems classes (i.e. continuous carbon fiber/epoxy resin) are most important to your business now? What composite material systems (i.e. discontinuous carbon fiber/thermoplastic resin) do you anticipate to be most important to your business 10 years from now?

3. What are the relevant targets for fiber reinforced polymer composites with respect to your industry for: (CM, OEM, End Users)
   – production volume (units per year)
   – process cycle time (time per unit)
   – percent cost reduction (relative to current)
   – percent weight reduction (relative to current) and
   – other important performance metrics?

4. What do you consider the three most significant obstacles you face to increase investment and/or adoption of this technology: a) high capital cost, b) high material cost, c) material supply chain insecurity, d) lack of customer demand, e) technical limitations, f) lack of knowledge, g) insufficient tools or h) other (please identify)?

5. Please describe how the value of high performance materials is reflected in the cost of the final product or value proposition for a new technology in your market.

6. What are the most significant opportunities for increased use of fiber reinforced polymer composites in industrial equipment (heat exchangers, membranes, piping, etc.)?
Q2-1: Role in the Supply Chain

Please identify the role of your institution or business in the supply chain: a) a material supplier (MS), b) component manufacturer (CM) includes tiered suppliers, c) original equipment manufacturer (OEM), d) end user or e) other (please identify)?

<table>
<thead>
<tr>
<th>Role in the supply chain</th>
<th>Number of Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material Supplier</td>
<td>16</td>
</tr>
<tr>
<td>Component Manufacturer</td>
<td>9</td>
</tr>
<tr>
<td>Original Equipment Manufacturer</td>
<td>2</td>
</tr>
<tr>
<td>End User</td>
<td>2</td>
</tr>
<tr>
<td>Other</td>
<td>14</td>
</tr>
</tbody>
</table>

“Other” identified as: Industry/Trade Association (3), University (7), Technical consulting firm (1), National laboratory (1), Major academic research institute (1), Private R&D company (1) and Non-profit consortium (1)
Q2-2: Important Material Systems Now and Future

What composite material systems classes (i.e. continuous carbon fiber/epoxy resin) are most important to your business now? What composite material systems (i.e. discontinuous carbon fiber/thermoplastic resin) do you anticipate to be most important to your business 10 years from now? (MS, CM, OEM, End Users)

- Common answers to the question for the composite material systems most important to business now include: glass (weaves, tape, continuous, chopped, pellet)/thermoplastics; carbon (continuous)/thermoset (epoxy, phenolic) and carbon (prepreg, woven)/thermoplastic.
- Common answers to composite materials systems anticipated to be most important 10 years from now include: bio-based/renewable materials, carbon (continuous/chopped)/thermoplastics and epoxy/thermoset resins.
- Additional comments about future materials include characteristics like: higher temperature, faster cure, multi-material systems/hybrids, and novel fibers.
• What are the relevant targets for fiber reinforced polymer composites with respect to your industry for: (CM, OEM, End Users)
  – production volume (units per year)
  – process cycle time (time per unit)
  – percent cost reduction (relative to current)
  – percent weight reduction (relative to current) and
  – other important performance metrics?

• Responses are grouped by associated market segment in the charts that follow.
• One response for Aerospace – provided only data on cost listed here:
  – Aerospace - cost equivalence to aluminum components for secondary structural components and >25% cost reduction relative to today’s composite components
### Q2-3: Automotive

<table>
<thead>
<tr>
<th>Production Volume (units per year)</th>
<th>Process cycle time</th>
<th>% cost reduction (relative to current)</th>
<th>% weight reduction</th>
<th>Other important Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>minimum 50,000 parts/year to be consider for use, more likely even 100,000 – 300,000 parts per year per model would be required before converting to composites.</td>
<td>1-2 minute per unit, more likely less 1 minute</td>
<td>cost neutral would be sufficient for the conversion to a composite part given a reduction in weight</td>
<td>50-75%</td>
<td>Mechanically suitable performance and relevant application making use of a composite system’s advantages, such as lighter weight or corrosion resistance.</td>
</tr>
<tr>
<td>15,000 to 75,000 per annum</td>
<td>5 minutes to 30 minutes, depending on volumes</td>
<td>greater than 50%</td>
<td>10% weight reduction compared to current carbon fiber parts, over 60% reduction versus steel and 40% versus aluminum</td>
<td>Class A surface finish straight from the mold without labor intensive rework</td>
</tr>
<tr>
<td>&gt;250,000</td>
<td>&lt;1 Min/part</td>
<td>$3-10/lb maximum value of weight savings. Cost of Carbon fiber $5-7/lb</td>
<td>&gt;50 reduction relative to steel</td>
<td></td>
</tr>
<tr>
<td>&gt;100,000 units/line/yr</td>
<td>&lt;2 min/unit</td>
<td>&gt;60% relative to current niche vehicle production</td>
<td>&gt;40% vs steel</td>
<td>$2-3 cost premium/lb weight saved for mass market</td>
</tr>
<tr>
<td>100,000 or more parts per year</td>
<td>5 minutes or less</td>
<td>10-15%</td>
<td>30-40%</td>
<td></td>
</tr>
</tbody>
</table>

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## Q2-3: Other Markets

<table>
<thead>
<tr>
<th>Market</th>
<th>Production Volume (units per year)</th>
<th>Process cycle time (time per unit)</th>
<th>% cost reduction (relative to current)</th>
<th>% weight reduction</th>
<th>Other important Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind</td>
<td>&gt;10K blades/yr at &gt;60m length</td>
<td>&lt;2 days/blade</td>
<td>&gt;25% cost reduction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compressed Gas Storage Tanks</td>
<td>10 to 50 times our current production capabilities</td>
<td>1/10 to 1/40 of the time per unit</td>
<td>6% reduction in material cost; 30% reduction in total product cost</td>
<td>2%</td>
<td>Increased safety of high pressure composite storage vessels; Increased composite toughness; Increased ability to vent and relieve internal pressure during a fire situation; Increase the use of recyclable materials; Increased pressure vessel storage capacity; Eliminate and reduce the use of solvents and toxic materials</td>
</tr>
<tr>
<td>Oil and Gas</td>
<td>10K tonnes/yr</td>
<td>1m/min</td>
<td>&gt;25% cost reduction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nanocellulose fibers</td>
<td>10 million tons per year</td>
<td>10 tons per hour</td>
<td>30% cost reduction</td>
<td>50%</td>
<td>Life-cycle assessments – lower GHG emissions, made from sustainable renewable resource</td>
</tr>
</tbody>
</table>

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### Q2-3: Fiberglass Specific Responses

<table>
<thead>
<tr>
<th>Production Volume (units per year)</th>
<th>Process cycle time (time per unit)</th>
<th>% cost reduction (relative to current)</th>
<th>% weight reduction</th>
<th>Other important Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase Sales; there is enough manufacturing capacity</td>
<td>Increase line speed by 20%</td>
<td>3% per year</td>
<td>Not considered</td>
<td>Grow Sales 10% per year</td>
</tr>
<tr>
<td>N/A</td>
<td>N/A</td>
<td>5%</td>
<td>10%</td>
<td>N/A</td>
</tr>
<tr>
<td>750 million pounds of pultruded profiles</td>
<td>Totally varies based on part thickness</td>
<td>20%</td>
<td>10-15%</td>
<td>Scrap reduction of 10-15%</td>
</tr>
<tr>
<td>5000/yr</td>
<td>120hrs</td>
<td>15%</td>
<td>N/A</td>
<td></td>
</tr>
</tbody>
</table>

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Q2-4) Significant Obstacles

What do you consider the **three** most significant obstacles you face to increase investment and/or adoption of this technology: a) high capital cost, b) high material cost, c) material supply chain insecurity, d) lack of customer demand, e) technical limitations, f) lack of knowledge, g) insufficient tools or h) other (please identify)?

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Please describe how the value of high performance materials is reflected in the cost of the final product or value proposition for a new technology in your market.

Comments from respondents are summarized below:

– Lightweighting
– Performance – Strength
– Cost/Performance basis
– Support meeting Government regulations i.e. CAFÉ standards
– If it can’t be done, a composite may be able to do it.
– Quality must continue to rise to draw in new customers to the advantages of composite materials.
What are the most significant opportunities for increased use of fiber reinforced polymer composites in industrial equipment (heat exchangers, membranes, piping, etc.)?

- The FRPs such as glass/vinyl ester and glass/polyesters, SMCs, BMCs have high potential in piping as FRP for corrosion protection.
- Growth in corrosion applications in the chemical and power generation industries, fire resistant opportunities, and thermal break profiles to replace steel.
- Opportunities in chemical tanks and pipes will emerge as higher temperature resistant and more corrosion resistant composites are developed.
- Modifying the infrastructure within the facilities would represent the best opportunities. Increasing the lifetime and durability of piping and enhancing its chemical resistance.
- High pressure piping and structural load bearing components would be the top targeted areas replacing conventional monolithic materials.
- Deep sea risers, Pump impellers, Spoolable pipe & deep sea umbilicals, Gas Cylinders, Hydraulic pump components, Platform structural parts
- Cryogenic vessels and nano-tube reinforced "pre-pregs“
- Composite pressure vessels are the key enabling technology to alternate transportation fuels, reduced carbon gas emissions, and lowering the environmental impact of transportation.
- Automotive, aviation, tractor trailers, ship structures
- Housing/construction also mentioned by several respondents
- New features offered by new products, materials and processes such as higher temperature/corrosion resistant composites. Predictability of composites will also increase use.
- Anywhere where corrosion resistance, high strength/stiffness to weight, and design flexibility is required. If durability of FRP materials was more known, I think the materials would be seen in several industrial equipment applications.