Graphene Filled Polymer Composites for Bipolar Plate Application

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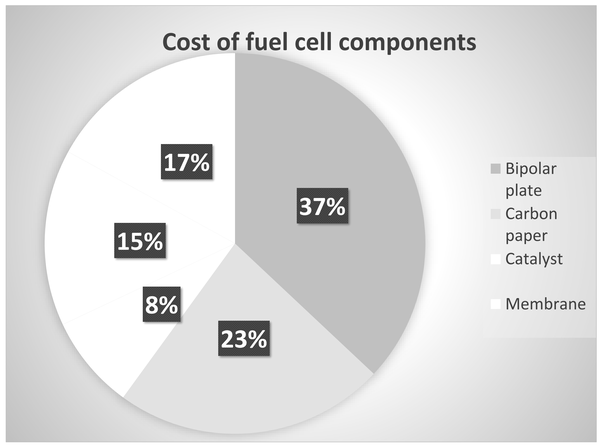
Objective

Develop material formula for graphene/polyester SMC and graphene/vinyl ester SMC that produces material that is:

- Moldable (that can fill parts of complex geometries with typical SMC processing parameters, including 1mm thickness)
- Electrically conductive (Transverse and in-plane)
- Mechanical properties that meet DOE automotive fuel cell requirements

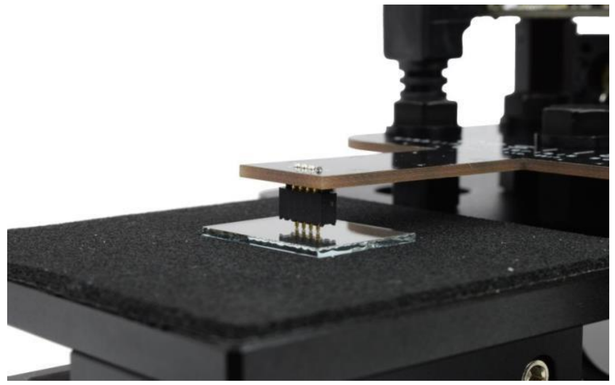
Motivation and Background

- Polymer nanocomposites combine the functionalities of polymer matrices, such as low cost, simple processing, with the distinctive features of the nanoparticles such as high electrical & thermal conductivities, high aspect ratio and excellent mechanical properties.
- An application of these polymer composite is proton membrane fuel cell and more specifically bipolar fuel cell plates which account for a sizeable portion of cost and weight of the modern fuel cell.
- And nowadays, graphene has entered the market as a carbon conductive filler because of its interesting properties due to its two-dimensional layer geometry.



Bipolar plays multiple roles in a fuel cell which includes:

- Connecting individual cells in series to get required voltage and current.
- Supply of oxygen to cathode and hydrogen to anode.
- Remove water and unreacted gases from the fuel cell.
- Better thermal management across the cell.



Four probe electrical conductivity setup

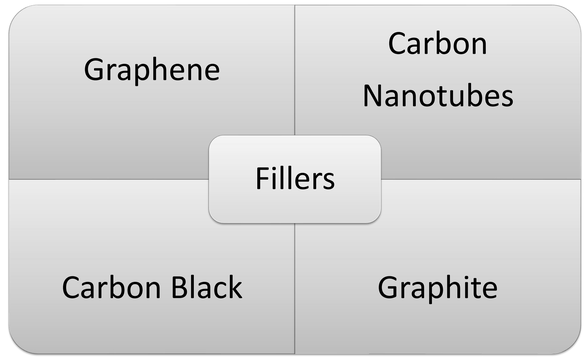
- Hydrograph Clean Power Inc, a Canadian company, has developed a novel gas phase, top-down process to create pure graphene that is very different from the more popular chemical, mechanical processing routes, or Liquid Phase Exfoliation (LPE). Graphene is synthesized by controlled detonation of acetylene and oxygen in a small chamber. This is a unique, one-step, highly efficient, gas-phase, catalyst-free process that is environment friendly, which yields graphene nanosheets. This eco-friendly process to produce graphene was first discovered by Kansas State University and then patented in 2016

US DOE targets for bipolar plate

Property	Units	2025 DOE Target	2020 DOE Target
Electrical conductivity	Scm^{-1}	>100	100
H2 permeability	$cm^3sec^{-1}cm^{-2}$	2×10^{-6}	1.3×10^{-14}
Thermal conductivity	Wm−1K−1	>10	>10
Plate weight	kg/kW	0.18	0.4
Cost	$\$kW^{-1}$	2	3
Flexural strength	MPa	>40	25
Tensile strength	Mpa	>25	>20

Research Methodology

- Developing material formula for graphene/polyester SMC and graphene/vinyl ester SMC that produces material that is:
- Moldable (can fill parts of complex geometries with typical SMC processing parameters, including 1mm thickness);
- The incorporation of graphene into the vinyl ester resin using various mixing protocols to disperse the graphene uniformly so that it doesn't cause any significant aggregation and damage to the graphene structure. The rheology of the mixture will be important to ensure that the resin composite can fill the test mold.
- Electrically conductive (Transverse and in-plane), using electrical conductivity measurements to do 2 point and 4-point conductivity measurements on samples produced of the graphene/vinyl ester compound.
- Improved mechanical properties when compared to standard SMC. ;using mechanical testing equipment following ASTM procedures to measure the key mechanical properties (compression, tensile, flex modulus, yield strength) at various temperatures.
- The project includes scaling up from a laboratory scale molding press to industrial scale compression molding machine to prepare test specimens. For better understanding, figure graphically depicts the ratios of the three different fillers system that can be incorporated to produce BPs.



Acknowledgments

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