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COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

SUBCOMMITTEE ON RESEARCH AND TECHNOLOGY

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Chairwoman Stevens, and the members of the subcommittee:

Thank you for the opportunity to participate in this seminal discussion today.

The Troy University Board of Trustees approved the creation of a new School of Science and Technology on December 13, 2012. This school, which is comprised of five departments, Biological and Environmental Sciences; Chemistry and Physics; Mathematics; Geospatial Informatics and Computer Science is housed within the College of Arts and Sciences. The mission of the School of Science and Technology is to bring agency to the teaching of sciences, research in pure and applied sciences, and in its relevance to industry.

I am currently a Professor of Physics in the Department of Chemistry and Physics at Troy University. In my 19th year of service, in 2015, I was appointed as the founding director of the School of Science and Technology at Troy University. The desire to establish an academic center related to the recycling of plastics was already brought to my attention during my interview for the position of Director.

I am happy to report that Troy University's School of Science and Technology has recently established a Center for Materials and Manufacturing Sciences (CMMS)[1] at Troy University in Troy, Alabama. The establishment of the Center was made possible by a successful 3.2 million dollar grant awarded by the National Institute of Science and Technology (NIST). This Center will serve as a fully integrated multi-disciplinary research facility that will bridge various majors and academic ranks. Undergraduate students will be encouraged to enter into research early on in their academic career to develop a sustained and deeper understanding of the field. Faculty researchers and students will form the mainstay for the Center.

[1] Hereafter referred to as Center.

During the initial phase of establishing the Center, one of the primary focuses will be on developing a state-of-the-art laboratory for polymer/plastics recycling. This major emphasis will aid to advance capabilities, and offer support structure for local and national industries involved in the rapidly growing market sector of polymer recycling. In the long term, the Center will help address plastics recycling from a holistic perspective with complex issues of collecting, sorting, and cleaning with characterization—with processing and product development as core competencies. Moreover, the Center will assist to engender a well-equipped next generation workforce to these industries through appropriate course and program offerings. Students trained at the Center will participate and be engaged in real life/real time industry projects. As part of this initiative, Troy University will collaborate with the University of Alabama at Birmingham (UAB) to offer innovative programs in Materials Science and Engineering to Physics and Chemistry students at Troy.

1. Scope

Responding to requests from a local industry, KW Plastics, the School of Science and Technology faculty at Troy University has previously partnered in research concerning core aspects of the recycling of plastics[2]. One of the current issues facing the polymer and recycling industry is the practical limitations on the large scale recyclability of the existing types of plastic containers currently available in the market. Simple factors like color, odor, strength and malleability determine the value of recycled plastics. Additionally, environmental concerns behind the breaking down of plastic products loom the industry. Together with the immediacy to adopt a green lifestyle and the rapidly increasing standards for environmentally friendly materials, the present-day plastic recycling industry has a large demand to fill. Currently, over three hundred million tons of plastics are manufactured across the globe[3]. This provides for a potential market of over two hundred billion pounds of new material that can be shaped, extruded, or otherwise transformed into new plastic products. However, according to

[2] Preliminary research was conducted by our resident Analytical Chemist Dr. Shaoyang Liu on the odors of recycled samples provided by KW Plastics in 2017-2018.
[3] "Earth Day 2018: End Plastic Pollution" www.earthday.org, 2018.

the most recent Municipal Solid Waste Report from the Environmental Protection Agency, at present, the recovery rate for all plastics in the United States is only nine percent [4]. Of the two main plastics, Polyethylene terephthalate (PET) and High-density polyethelene (HDPE), the United States has a recovery rate of only 31 percent and 28 percent respectively[5]. Consequently, KW Plastics, the world's largest plastics recycler, headquartered in Troy, Alabama, has experienced a phenomenal growth in recent years. This is due to proprietary research that has expanded the recovery rate of the stated two plastics that dominate the marketplace. However, this opportunity also comes with challenges to the industry. To expand the application of the recycled materials, customers not only require good mechanical properties, but also demand superior sensory qualities for the recycled plastics. To expand, one of the major concerns of recycled resin is its odor. Due to the microstructure of the feedstock, some recycled materials would hold unpleasant smells. These odors prevent them from being used in products that come in close contact with people, such as food trays, inner parts of vehicles, etc. Thus, even if all the other requirements have been met by the material, the odor will restrict its applicability and hence it's utility.

Clearly, innovation and implementation of new technologies lead to successful manufacturing, and are the key to support long-term competitiveness. To obtain necessary knowledge and appropriate instrumentation to solve this problem, chemists at KW Plastics teamed up with the faculty of School of Science and Technology at Troy University in Troy, Alabama[6]. At present, Troy's faculty have been successful at tackling some of the simpler issues in this field. For instance, one of the research outcomes from the joint study predicted that the unpleasant odors from recycled resin could be caused by a large variety of volatile compounds released from the material[7]. In addition, they observed that due to the huge variation of the feedstock, the odorous volatile compounds changed significantly from batch to batch. To detect these volatile compounds, an advanced chemical analysis technique, gas

[4] "Plastics: Material-Specific Data", *Facts and Figures about Materials, Figures and Recycling*, EPA, 2018.
[5] Doug Clauson, "Modernizing the Resin Identification Code", *ASTM International,*2016.

[6] KW Plastics representative joined the School of Science and Technology advisory council in Fall 2016,
[7] Preliminary research was conducted by our resident Analytical Chemist Dr. Shaoyang Liu on the odors of recycled samples provided by KW Plastics in 2017-2018.

chromatography-mass spectrometry (GC-MS), was employed. By coupling this with an advanced extraction technology, viz. solid phase microextraction (SPME), a sensitive and rapid analysis method was successfully established to monitor the large number of volatile compounds in the recycled resin. This method of analysis provided a critical tool to control/eliminate the odor and improve the product quality. As a result, presently, the chemists at KW Plastics are able to monitor the odorous compounds in every batch of production while implementing strategies to control, and subsequently, regulate the odor inherent in these products. It has also become evident that existing resin chemistry and labeling technology in the field needs improvement[8]. This is a small but relevant example that demonstrates the effectiveness of researchers of School of Science and Technology teaming with local industry to solve pertinent problems in the field, thereby validating the potential of the newly established Center in being a crucial force in addressing demanding issues in the field of polymer recycling.

In order to glean the larger issues at stake, at its inception, the Center hosted a road mapping conference session at the recent annual *Plastics Recycling Conference* held in Washington D.C. I will briefly recapitulate three salient points raised by the nearly 200 attendees of the conference workshop. In the coming years, the Center will focus on tackling these poignant issues. The primary issue facing the recycling industry is the supply of feedstock. If the plastics recycling industry depended on the various states to supply their plant with recyclable feedstock, most plants could only run their facilities for a few days each year. Recycling plants purchase material from municipalities and material recovery facilities (MRFs) throughout North America and continue to explore global possibilities. Studies have proven that U.S. has both the supply and the demand, yet lack of infrastructure limits collection. We are filling American landfills with materials that have proven to have value with domestic markets and demand with domestic manufacturers. Development process that ensure a sustainable recycling practice can divert millions of tons of waste while generating large monetary rewards in revenue (per state) and save private businesses and local

[8] Alexander Tullo, "Innovation is Still Alive in Plastics", *Chemical and Engineering News*, 2018.

governments money in hauling and disposal costs. To a large extent, the collection of recyclable plastics is an issue of awareness. The Center has the advantage of being situated within an academic institution. Awareness begins with education. While Communities and municipalities will have to do their due diligence, the Center will help develop a viable plan that can be deployed at various levels to facilitate the collection of recyclable plastics. Further, the Center will work alongside the numerous plastics recycling organizations in the United States to educate and assist in the recycling process.

The second largest issue facing the private sector is access to current technology. As the demand has continued to grow, there is an immediate need for resins with *Letters of Non Objection* from FDA[9], and resins with technical specifications regarding color and smell. However, most recycling centers operate on very restricted budget. As a result most of the recycling centers cannot upgrade their infrastructure on a sufficiently regular basis. There is also a large need for additional technology surrounding sorting techniques in order to recover more material and supply a quality resin. Currently, there is an unprecedented demand from domestic markets for more types of plastics and a larger demand from end markets. Recyclability is less of an issue but collection infrastructure, sorting technology and resin chemistry is limited. Hence, these technologies offer a large opportunity with significant potential impact. Infrared technology does not read back-packaging and certain labels, which are in fact recyclable but unrecoverable if the product cannot get past the infrared readers. Investment in technology and chemistry could give a boost to more postconsumer resin being used in new applications. Naturally, research and development will play a significant role in the daily activities of the center. I fully expect the Center to extend the existing technologies beyond its current limitations.

The third and final issue that was raised during the workshop was related to the environmental impact of the recycling process. Recycling plastics conserve energy and natural

[9] George Sadler, "Recycling of Polymers for Food Use: A Current Perspective", *The Journal of Physical Chemistry*, 1995.

resources. Recycling is a sustainable solution from manufacturing to waste management. Plastics recycling has nearly a net zero carbon footprint comparable to virgin plastic production. Recycling saves significant energy in comparison with extracting virgin material. Recycling plastics reduces the amount of energy and natural resources (such as water, petroleum and natural) needed to create virgin plastic. According to the American Plastics Council, the production of plastics accounts for 4 percent of U.S. energy consumption, and 70 percent of plastics in the United States are made from domestic natural gas[10]. In addition to energy conservation, recycling plastics save landfill space. We know that plastics do not degrade in the landfill. According to U.S. EPA, recycling one ton of plastic material saves 7.4 cubic yards of landfill space[11].

There are many materials that are readily recyclable, but are not currently collectable in sufficient quantity to make recycling feasible. In those areas, development of additional *quantity-multiplying technologies* would be necessary to make the leap forward. Research is needed in *sorting technologies, cleaning technologies, and waste treatment science* to combat the highly variable and fluid conditions in the reclaimed marketspace. Improvements in cleaning, for example, would allow higher utilization of recycled products in markets where smell or color is a sensitive issue. These problems in recycling are similar to activation energy in the field of chemistry—there are certain obstacles that must be cleared for the reaction to go forward. The obstacles in recycling processing are the quantity of new resources and economical techniques in cleaning and treatment, and clearing either of those can drive the process forward toward higher recycling overall.

The point here is that the technologies developed must be flexible and incorporate universal utility— because the market for material changes rapidly, and materials available today may not be available next week. Technology must then be adaptable to new resources.

[10] "Recycling Plastics Also Reduces the Amount of Energy", *BUS 370, Ashford University*, 2015.
[11] "Volume-to-Weight Conversion Factors" *U.S. Environmental Protection Agency Office of Resource Conservation and Recovery,* April 2016.

In as much as possible, the Center will retain adaptability to feedstock as a core requirement for all the technologies developed.

2. Goals

The Center at Troy University will focus on the recycling of plastics with research considering not only the science involved in recycling plastics but also with the logistics in collecting a larger supply of used plastics. Additionally, it will develop and establish a well-defined standard for the quality of recycled plastics. As mentioned earlier, the use and need for recycling of plastics provide for a rapidly growing market that must be addressed through partnerships with industries, communities, academics, and municipalities. The Center at Troy University will help address this issue through education, training and research. The following are proposed:

2.1 Education and Training

- Develop course curricula that includes polymers and polymer recycling
- Introduce the importance of sustainability in materials in existing courses
- Introduce environmental impact of materials in course materials
- Provide short courses to industry and communities
- As part of this program Troy University will partner with UAB to offer Physics/Chemistry students the opportunity to earn a bachelor in Physics/Chemistry and a bachelor in Materials Science and Engineering through a 3 + 2 program and/or the potential for an accelerated MS degree in Materials Science and Engineering at UAB

2.2 Research and Development

- Establish laboratory capabilities for polymer characterization, testing and processing
- Develop research topics in partnership with industry and municipalities
- Provide equipment and expertise in polymer recycling to help industry solve complex problems
- Act as a one-stop resource for community, industry and academia interested in and involved in polymer recycling

The Center will engage faculty and students across all academic areas to work in an integrated problem-solving environment. Undergraduate students will especially be encouraged to conduct applied research to link theory to applications.

2.3 Equipment, Methods, Infrastructure Development

The intent on the first phase of development will be to primarily develop existing labs to include capabilities in polymer characterization, testing and processing. The bulk of the grant funded by the NIST will be used for the purchase and installation of equipment. The following equipment will be acquired to augment existing capabilities:

2.3.a Thermal Analysis Equipment: Thermal analysis equipment is needed to understand the thermal characteristics on the material for processing and utilizations. The following have already been ordered:

- *Differential Scanning Calorimetry (DSC):* Thermal transitions of a polymer play a major role in how the polymer can be processed and utilized. Glass transition temperature and melt temperature are the starting points for understanding polymers.
- *Thermogravimetric Analyzer (TGA):* A TGA provides analysis of a polymer over a range of temperature up to degradation. The mass loss over time provides understanding on the polymers reaction to temperatures, during processing it is vital to understand thermal limits and degradation of polymers.
- *Rheometer:* Understanding the rheological behavior of a polymer is paramount in understanding processing parameters and methodologies to shape and form the polymer into products.
- *Melt Flow Index (MFI):* Whereas most academics and scientists prefer rheological data, plant processing personnel need the MFI to set processing parameters on their equipment.

The key methods of analysis here include measuring heat capacity, melting point, and transition temperature of polymers. Additionally, investigating the boiling point, thermal stability, oxidation process of recycled plastics will help us gain an understanding of it durability.

2.3.b Mechanical Testing: Mechanical testing equipment is needed to understand the mechanical characteristics of the material for processing and utilizations. The following will be ordered in the current academic year:

- *Universal Testing Frame:* A servo-hydraulic test frame (MTS/Instron or comparable) with environmental capability is needed to provide mechanical properties (tensile, flexure, fatigue, etc.) of processed polymers. An environment chamber will help understand the material behavior under different environmental conditions of heat, etc. This is especially needed to understand limitations of recycled polymers
- *Instrumented impact test machine:* One of the major issues with the recycling of polymers is the degradation of impact properties. There is a need to understand the reduction and how this reduction in properties could be eliminated or minimized.

Measuring material physical properties, including strength, peel force, tear force, springiness, elongation, distension, adhesiveness, and hardness will help understand the range of applicability.

2.3.c Processing Equipment: Processing equipment is needed for machining, compression molding, casting, extrusion and forging. The following are proposed[12]:

- *Shredder:* Plastic products, consumer goods, industrial trim offs, etc. will be in bulk form and size reduction equipment will be needed to re-process the material into flake and/or powder form. The mechanical reduction process is typically used in industry with little understanding on the effects of the polymer microstructure, this will provide an opportunity to further research the effects of mechanical size reduction.
- *Twin Screw Extruder (with cooling and pelletizing capabilities):* The extruder will provide opportunities to re-compound recycled material and add fillers and/or additives to restore desired properties. Segmented screws with options to change shear and mixing zones will be needed for different polymer types. Multiple loss-in-weight feeder systems will accurately dispense additives for compounding. Cooling systems

[12] *Equipment in this category will be prioritized and purchased when needed.*

will be needed for controlled air and/or water cooling depending on the polymer system. Puller and pelletizing unit will be variable speed for controlled extrusion speed and pellet profile.

- *Injection molding unit* (with basic tooling for samples): Injection molding is the most common and widely used method for plastics processing. Most recycled plastics will end up at injection molding plants to be reprocessed into products. It is important to use the same process to evaluate the material for research purposes.

Major processing methods include size reduction, extruding with cooling and pelletizing techniques and injection molding for application development.

3. Proposed Schedule[13]

Year I (current):

- Establish search committee to hire a chief scientist
- Polymer chemist begins collaboration with UAB material science department and formulates a research plan
- Polymer chemist gains familiarity with a large scale polymer lab and associated instrumentation
- Retrofit assigned lab space for thermal analysis instrumentation
- Procure instrumentation for thermal analysis
- Prepare and host a road mapping conference

Year II:

- Install and establish the analysis lab
- Retrofit assigned lab space for Mechanical Testing
- Procure instrumentation for Mechanical Testing
- Polymer chemist engages in active joint research with UAB
- Center engages student scholars in research

[13] Based on the duration of the grant, this is a three-year plan.

- Seek additional funds

Year III:

- Establish and advisory board that includes regional stakeholders
- Install and establish the processing lab
- Research students become an integral part of the Center
- Develop a joint program in material science with UAB
- Develop a clear long term vision
- Begin full scale research at CMMS
- Develop a national database of stakeholders
- Include the logistics of collection technologies into research
- Seek external funds
- Develop plans for long term sustainability for the Center

4. Projected Results

4.1 Resource to Industry, Municipalities and Communities

It is clear from our preliminary analysis that the plastic recycling industry has both environmental and economic benefits that are most often unrealized. On the technical end, the range of issues span from the inconsistency of feed stock to the limiting technology in the sorting process. However, a larger issue remains apropos a cost effective way of procuring feed stock. The need for outreach beyond the state of Alabama will also be a part of the central mission of the Center. The economic sway of a more comprehensive and systematic approach to the gathering and recycling of plastics is only exceeded in scope by its environmental impact.

The Center will be a resource for educating communities, through outreach programs on the economic and environmental benefits of plastics recycling. A more educated community will be a more enlightened partner in the collection and preliminary sorting process. Generally, most sorting facilities are owned and operated by municipalities or their contractors. Diverting plastic material from landfills will be a key result in securing a

continuous source of feedstock. Municipalities will realize the long-term economic benefits of the program through increased employment and cost savings in garbage disposal, not to mention the improved environmental impact. The key results of the program will be a facility that local and national industries would access to advance the field of recycled plastics. The Center will be resourced with equipment and expertise to help industry advance to a state-of-the-art facility in plastics recycling. Increasing and promoting the capacity of the recycling industry provides spin-off benefits in increased employment (which rivals the automotive industry in numbers), lower dependence on foreign oil (a precursor for polymers) and offers a valuable resource for other manufactured goods and products with the obvious benefit to the environment. Thus, the model developed by the Center with respect to education, research, industry engagement and the outputs thereof will extend these benefits locally and internationally.

5. Human Resource Development

Troy University is committed to human capital development. The teaching and training of the applied sciences will be an integral part of the mission for the Center. Students from all disciplines will be eligible to work on research projects along with individual faculty advisors. Troy University has already committed the necessary faculty lines to supplement the technical expertise. Also, potential physical space for new laboratories have been identified and assigned as the future location of the Center. By design, the proposed labs at the Center will support regional entrepreneurs and businesses with product development that foster long-term job creation and business expansion. The Center will leverage this engagement and will foster entrepreneurial education and provide opportunities for students interested in starting businesses aligned to the Center's mission.

An advisory board comprising of members from the plastics industry, recycling industry, trade organizations, municipalities, and other agencies together with key personnel from the Center will be formed to help manage, direct and provide oversight to the Center activities. The advisory board will meet semi-annually at Troy and provide direction to the

Center and new avenues for integration into industry and curricula. The advisory board will also guide the assessment plan, questionnaire and survey materials required to monitor the progress of the Center. The board will play a key role in directing the expansion of the Center and its facilities.

The broad concepts of developing the Center, its function and interaction with industry is outlined and proposed above. However, input from industry experts, academics, municipalities, trade organizations, legislators, etc. is needed to ensure the success and viability of the Center.

6. Conclusion

Currently, the plastics recycling industry is operating below capacity with employment figures comparable with the U.S. automotive industry (according to U.S. EPA)[14]. Undoubtedly, an increase in supply will increase employment and capital investment. An increase in recycling will increase tax base, lower energy costs and decrease dependence on foreign sources for oil, manufacturing and consumer goods.

According to the Southeast Recycling Development Council, if Alabama increases its recycling by just 10% more each year, the potential economic impact would be over 1,400 new jobs, over $66 million in personal annual income, and $3 million in annual state tax revenue[15]. This equation could be duplicated throughout the nation. Additionally, the Tennessee Department of Environment and Conservation held a study in 2009 and discovered that Tennessee counties, cities and businesses disposed of approximately 7.6 million tons of solid waste at an average cost of $277 million. If Tennessee had recycled 75% of what was buried in landfills, the state could have captured $882 million in revenue, not including the additional savings in tip fees[16]. Besides, the Georgia Department of Community Affairs estimates that Georgians pay $100 million to landfill roughly $300 million worth of recyclables

[14] "Region 4: Municipal Government Toolkit", *archive.epa.gov*, 2016.
[15] Southeast Recycling Development Council (SERDC) study, 2016.
[16] Quoted by Managing Director of KW plastics during interview, 2016.

each year[17]. The need for plastics recycling is made evident in the above examples, and undeniably provides a case for a dedicated Center of research.

Overall, the above questions and responses make visible significant lacunae in contemporary research in plastic recycling that can be effectively translated to sustainable goals in the industry. The Center will focus on the short, medium and long term issues to be resolved to negate these existing gaps. The specific projects will be carefully selected, prioritized and undertaken in partnership with industry, community and other stakeholders.

Troy University is located in close proximity to KW Plastics—the world's largest plastics recycling company. In the recent years, owing to shortcomings in the private sector, KW Plastics has reached out to the faculty in the School of Science and Technology at Troy University for help in developing advanced capabilities in sorting technology and recycling chemistry. Additionally, the logistics involved in collecting a larger sample of used plastics also remains an open issue for the plastic industry in general. The nearly zero-carbon footprint technology of plastics recycling must be scaled up to meet the demands of global waste reduction. Ultimately, the Center for Materials and Manufacturing Sciences at Troy University will identify, develop and implement solutions to the problems in contemporary plastics industry by linking academia, industry, and community.

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[17] Recycling in Griffin Creates Jobs in Georgia", www.cityofgriffin.gov., 2015.

Govind Menon, Ph. D.
Brief Biography

After completing his schooling in India, Govind Menon moved to the United States in 1997 to pursue an undergraduate degree in Mathematics at Troy University. Subsequently, he joined the Physics Department at the University of Alabama in Birmingham for his master's and doctoral degrees in Physics to specialize in General Relativity. His Ph.D. dissertation focused on developing a non-axisymmetric spacetime that permitted gravitational repulsion. During the last year of his graduate training, Menon procured a lectureship at his alma mater—Troy University. Now, in his twenty third year at the university, he is professor of physics, and chair of the Department of Chemistry and Physics. Recently, Menon was appointed the founding director of the School of Science and Technology at Troy University.

Menon's summer sabbaticals at the Naval Research Lab in Washington D.C. have consumed a large portion of his research efforts in the recent years. He works on the active magnetospheres of supermassive black holes, and along with his collaborator Dr. Charles Dermer (Naval Research Lab), has produced the only known exact analytical solution to a stationary, axis-symmetric, force-free magnetosphere in a Kerr (rotating black hole) background. Their efforts have led to a manuscript entitled *High-Energy Radiation From Black Holes: Gamma Rays, Cosmic Rays and Neutrinos* published by Princeton University Press. When Menon is not working on Physics or spending time with his family, he can be found in his study playing classical guitar.