2009 BFRL Project Description

Project Title: Sustainable Fire Safe Products

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Principal Investigator: Jeffrey W. Gilman

Co-Investigator(s): Barbara Lippiatt, Mauro Zammarano (GR), Joannie Chin

BFRL Program: Reduced Flammability of Materials

Objective: To design and implement measurement science tools which enable the development of sustainable fire safe products. The goal is to combine life-cycle, environmental health and safety, nanotechnology and flame retardant knowledge into one approach to enable fire safe products.

Problem:

What is the problem? The measurement science tools do not exist to enable the development of sustainable[1] flame retardants for less flammable products[2]. A number of issues contribute to this complex problem: 1- general chemophobia by society requires development of far more "green" or sustainable[3] chemicals used to manufacture all products[4] (the proposed bans on halogenated flame retardants in several states is one example of this trend) and new flammability and environmental regulations under consideration require levels of flame retardancy (FR) **and sustainability** which industry has yet to develop. For example, the Polyurethane Foam Association (PFA) recently asked the state of California to relax their flammability standards for a period of time to allow the industry to do the research required to meet the new requirements. Corporate responsibility programs across the chemical industry are also focusing on greener products, processes, operating procedures, and new formulations that minimize or eliminate emissions, and may reduce some of the nation's dependence on petroleum.[5,7] 2- although nano-based flame retardants offer a potential alternative for halogenated flame retardants, there is no **sustainability** (EH&S, service-life, etc) data on most nano-materials including nano-based flame retardants[6]. Without this critical data and the quantitative sustainability tools to compare and contrast different approaches it is difficult for industry to move forward to develop truly sustainable flame retardants.

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[1] National Research Council, "Sustainability in the Chemical Industry," 2005 also "Industrial Environmental Performance Metrics: Challenges and Opportunities," 1999, National Academy Press, Washington, DC,.
[2] Gary L. TerHaar, Fire Mater. 2004; 28:417–421, Product stewardship in the flame retardant industry.
[3] Sustainability – "Meeting the needs of the present without compromising the ability of future generations to meet their needs," G.H. Brundtland, et al, "Our Common Future: Report of the UN Commission on Environment and Development." 1987
[4] C&EN article "Sustainability" May 2008.
[5] http://www.pfa.org/Library/AEP_no_logo.pdf
[6] NNI, Strategy for EHS research 2008.

Why is it hard to solve? Development of the measurement science to enable evaluation of sustainable flame retardants is difficult because it requires combining the tools and expertise from disciplines that are not often brought together: i.e. environmental science, nanotechnology, flame retardancy, and economics. The tools developed and the data generated will assist government and industry with the difficult task of balancing environmental sustainability, economic sustainability and technical sustainability.

How is it solved today, and by whom? No organization is addressing all of the necessary issues associated with the development of sustainable flame retardants. Industry develops product stewardship analysis of their own products, usually for their own purposes and it is proprietary. However, an aggressive look for new advanced flame retardants which bear the majority of the important features of sustainable materials is lacking. For example, the Voluntary Emission Control Action Program[7] (VECAP) is a growing program initiated by the brominated chemicals industry. VECAP looks at reducing emissions of brominated flame retardants and other polymer additives during manufacturing from supplier to OEM. However, release of emissions during and after the products service-life are not yet addressed. A concerted program on developing sustainable flame retardants has been called for by VECAP participants.[7] Many groups focus on some subset of the issues, e.g., the flammability performance, material cost, halogen/environmental and nanotechnology aspects only. The majority of the programs that do focus on the environmental piece of the sustainability of flame retardants are in Europe (see PREDFIRE NNANO 13 member program) where sustainability funding is available from the government.[8] This type of program is only open to European industry; this puts US industry at a competitive disadvantage. A number of large chemical companies now offer "organic" material-derived chemicals for food and cosmetics applications. Very few have been evaluated for use in fire safe products or have been included in extensive LCA studies.

Why NIST? The objective of this project is aligned with the BFRL mission in terms of improving public safety and enhanced industrial competitiveness, specifically for the chemical, flame retardant, polymer and soft furnishings industries. This project is aligned with the BFRL strategic priority of Measurement Science for Sustainable Infrastructure Materials. It lies at the intersection of BFRL core competencies of fire protection and fire spread within buildings and communities and the performance, durability and service life prediction of building materials.

Approach:

What is the new technical idea? We will assemble a database of materials with promising sustainability attributes and evaluate these materials for their effectiveness as flame retardants in a series of polymer systems. The currently available environmental, health, and economic data will be used to select candidate sustainable materials. Example of new materials include: cellulose nanofibrils, graphene, and Halloysite. Each of these systems has revealed the potential for comparable flame retardant effectiveness as that found for carbon nanotubes, but they are either from renewable raw materials, biodegradable, or potentially less toxic. For new materials with incomplete data we will work with several outside organizations such as Prof. Kenneth

[7] www.vecap.info

[8] PREDFIRE NANO- Predicting Fire Behaviour of Nanocomposites from Intrinsic Properties, http://www.engj.ulst.ac.uk/predfire/project.php

Dawson, director of the Nanointeract program[9] at University College Dublin, who agrees that this is an important problem and is willing to collaborate with us by evaluating new nanoparticle flame retardants for toxicity. We have an MOU with the Consumer Products Safety Commission (CPSC) on release of nanoparticle flame retardants from foam. We will work with academia to fill documented LCA knowledge and data gaps related to the elementary flows and impacts that result from nanoscale production and use.[10] Uncertainty and sensitivity analyses, which are indispensable in the case of nanomaterials with incomplete and uncertain production characteristics, will be incorporated in the LCA. The key will be the careful integration of opportunities offered by new, potentially "green" nanomaterials with LCA, economic and fire performance data into user-friendly eco-design screening tools.

Why can we succeed now? Halogenated fire retardants have come under regulatory scrutiny creating an urgent need for new approaches to fire retardancy. BFRL has had extensive experience in LCA, nanotechnology, and novel flame retardant approaches; the combination of these efforts will produce the necessary tools for industry to develop sustainable fire safe products, and give them tools to innovate and compete in the markets where new domestic and foreign regulations mandate steps towards sustainability (e.g. REACH, RoHS, WEEE).[11]

What is the research plan? The first priority is to develop a database of potential new "green"flame retardants (FRs) and polymers. We will gather information on bio-derived cellulosic and fatty acid ester materials from wood, soy, corn, castor, and yucca, as well as less toxic nanomaterials such as graphene, and Halloysite. Our focus will be on one system each year. The candidate materials will be evaluated for their fire performance in polyurethane (PU) foams utilizing the foam melt-drip flammability test recently developed in BFRL. We will also evaluate the FR effectiveness of these materials using bio-derived polyols in PU foams. Several natural oil polyols (NOPs) have become commercial, but little is known about the FR requirements or performance of these polymers. Fire performance over the service-life of the materials will also be evaluated; i.e., the influence of environmental effects such as UV light, heat and humidity will be evaluated using the BFRL integrated sphere and "dark-side" facilities, and these data used as inputs in the sustainability models. In addition to fire performance and service-life data, the database will include inventories of environmental inputs and outputs across all life cycle stages—raw material acquisition, manufacture, transportation, use, and waste management—for these new flame retardants and polymers. By the end of the first year of the project we plan to provide new knowledge about one new promising sustainable fire safe material. To fill known data gaps, inventory data for semiconductor production, which has much in common with nanoprocessing (e.g., use of large, rapidly outdated equipment and clean rooms), will be adapted for similar manufacturing pathways and technologies (e.g., lithography, precipitation, depositions). To assess environmental sustainability, the life-cycle inventories will be scored against the 13 BEES environmental and health impacts, adapted as necessary for nanoscale

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[9] www.nanointeract.net, "Development of a platform and toolkit for understanding interactions between nanoparticles and the living world".

[10] U.S. Environmental Protection Agency, Woodrow Wilson International Center for Scholars, European Commission, *Nanotechnology and Life Cycle Assessment: Synthesis of Results Obtained at a Workshop*, March 2007, http://www.nanotechproject.org/file_download/files/NanoLCA_3.07.pdf .

[11] European Union, "Registration, Evaluation, Authorization and Restriction of Chemicals" (REACH), EC Reg. No 1907/2006 (2006), "Restriction of Hazardous Substances Directive (RoHS), Dir. 2002/95/EC (2003), "Waste Electrical and Electronic Equipment Directive" (WEEE) Dir. 2002/96/EC (2003).

application. These inventories and impacts will be developed in collaboration with toxicologists and other scientists who will review data, uncertainties, and scaling approaches. Finally, economic performance data will be added to the database for new flame retardants and polymers, and assessed using life cycle costing approaches, to incorporate the economic dimension of sustainability. At the conclusion of the project we envision delivery of new knowledge on new promising, sustainable fire safe materials, and a suite of tools and approaches that will apply the integrated fire, environmental, service-life, and economic performance database to guide the development of sustainable fire safe products.

Recent Results: new project

Standards and Codes: none expected