Formulation of Molding Materials
From Recycled Printed Wiring Boards

Federal Manufacturing & Technologies

J. W. Lula and

G. W. Bohnert

KCP-613-6066

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Final Report/Project Accomplishments Summary

CRADA Number 96-KCP-1037

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AlliedSignal Inc.

Federal Manufacturing
& Technologies

P. O. Box 419159

Kansas City, Missouri

64141-6159

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Formulation of Molding Materials From

Recycled Printed Wiring BoardsProduct Formulations Using Recycled Tire Crumb
Rubber

Project Accomplishments Summary

CRADA Number 96-KCP-10378

Date: 3/30/989/30/97

Revision: 0

A. Parties

The project is a relationship between:

AlliedSignal FM&T

2000 E 95th Street

PO Box 419159

Kansas City, MO 64141-6159

Resource Concepts EnviroRecycled Rubber
ResourcesCompany Name

2940 Eisenhower

Suite 1001600 Blee Industrial DriveCompany
Address

Carrollton, TX 75007Macon, MO 63552City, State,
ZIP

B. Background

A rapidly growing environmental concern is the rapid obsolescence of electronic equipment, including, but not limited to, personal computers and related hardware. Such state-of-the-art equipment is obsolete within a matter of 18 months or less at the current rate of technological advancement. Once obsolete, the equipment has virtually no value

other than precious metal recovery. Resource Concepts Enviro (RCE) has developed a process to pulverize electronic assemblies and then concentrate the metal particles into a high metal content stream. This minimizes the amount of inert material that the smelter must handle and makes their recovery process more efficient. The remaining material from RCE's pulverizing process has little value for precious metal recovery and with conventional disposal technology would be landfilled, incinerated, or otherwise treated as a hazardous waste.

RCE has worked for the past several years to identify and develop applications that can use the secondary pulverized stream from this process. This stream consists primarily of plastic resins, ceramic particles, and glass fiber reinforcement and represents approximately two thirds of the total initial weight of the electronic assemblies. Without commercial applications, this material will end up in landfills or be incinerated. This project was implemented to develop high-value, environmentally friendly, commercially viable end uses for this material. Approximately 250 million automotive and truck tires are discarded each year in the U.S. The very properties that ensure a safe ride and long service life make the disposal of these scrap tires difficult. In spite of this, scrap tire recycling/reuse has rapidly grown from 10% in 1985 to over 90% today. The majority of scrap tires that are recycled/reused are burned for fuel in power plants and cement kilns. Since tires have somewhat higher heating value than coal, this would at first seem to be an acceptable option. But burning scrap tires recovers only 25% of the energy originally used to manufacture the rubber. An alternative is to use the scrap tires in the form of crumb rubber, by which 98% of the original energy is recovered. This project sought to explore potential formulations of crumb rubber with various thermoplastic binders, with one goal being developing a material for a low-cost, high-performance roofing composition. [What was the state-of-the-art of the product/process prior to initiation of the project? Why was the project needed (e.g., performance, quality, cost, time to market)? Describe the strengths and interests of each party and how they are complementary with respect to the project.]What KCP expertise was needed and how did it complement the partner's capabilities?]

C. Description

[What was the purpose / objective of the project? What were the roles of the KCP and the Participant Company? What were the technical results / accomplishments? Discuss the value of working together on the project from the point of view of each party. Where possible, provide positive comments from Participant regarding project & performance]The objective of this project was to takeformulate the pulverized electronic waste (PEW) stream derived from grinding obsolete electronic assemblies and combine this material with thermoplastic or thermosetting polymers into useful, high-value commercial productsmaterials. PEW consists primarily of various thermoset plastic materials and glass fibers from the printed wiring boards, along with ceramic pieces from chip carriers and other electronic components. Typically, the thermosetting materials have the same desirable properties as in the original electronic assembly, including relatively high temperature resistance, excellent chemical resistance, and flame retardancy. These properties combine to make PEW an inherently good inert filler material for plastic composites.

During this project, personnel at AlliedSignal Federal Manufacturing & Technologies

(FM&T) focused on developing formulations and preparing mechanical and thermal test specimens using the PEW blended with various thermosetting and thermoplastic binders. Resource Concepts Enviro personnel continued to develop their grinding/separation process, investigated potential applications, and supplied material to those manufacturers that were interested.

The thermosetting resins that were used included epoxy and polyester. Test samples made from the PEW and a standard two-part epoxy resin were prepared at FM&T and evaluated for tensile strength and modulus, flexural strength and modulus, and thermal expansion. In addition, a sample mold was made from silicone RTV to demonstrate the visually attractive attributes of a PEW-filled epoxy encapsulant. Because of its visual appearance and its recycled attributes, this material was chosen for the Department of Energy 1996 Pollution Prevention Awards.

Subsequently, RCE located a manufacturer of kitchen and bathroom countertops that accepted some of RCE's material and prepared some product samples with polyester thermosetting resin. Again, the visual appearance was such that they were chosen for DOE's 1997 Pollution Prevention Awards.

Another company that RCE contacted was Syntal, Inc., a recycler of high density polyethylene (HDPE) in Diboll, TX. Syntal extrudes ground-up scrap HDPE and molds the material into plastic lumber. A traditional problem with recycled HDPE plastic lumber is its low flexural strength. RCE supplied Syntal with a quantity of PEW for their evaluation and sample lumber planks were produced with good results. The samples were tested for heavy metals by TCLP (toxic characteristic leaching procedure) analysis. The TCLP performed on the material at AlliedSignal showed all metals were well under the maximum allowed.

AlliedSignal mixed some of the PEW and injection molded the material with various types of thermoplastics, including HDPE, polypropylene, and nylon. The PEW was mixed with the thermoplastics pellets (30% PEW/70% resin), then manually fed into the screw feed port of the injection molding equipment, and heated to the appropriate temperature for the particular thermoplastic resin in use. Thus the thermoplastic pellets were heated, melted, and uniformly ultimately mixed with the ground-up circuit boards. Injection molding proceeded without difficulty. The samples were tested for tensile, flexural, and thermal expansion properties.

Results

Samples made by adding PEW to epoxy or polyester resins were not tested for mechanical strength. The intent of adding these materials was from a visual perspective, such as might be used for countertops or plaques, or similar visual applications. Samples made in this manner were attractive and, as mentioned previously, were chosen as the material for Department of Energy Pollution Prevention Award plaques for 1996 and 1997.

Adding PEW to thermoplastics was made with the primary intention of enhancing the strength. In this regard, the tests were partially successful. Adding PEW to HDPE, polypropylene, or nylon resulted in a slight decrease in tensile strength, but not as much

as might be expected based on the loading percentage. However, the flexural strength increased in all three materials along with an increase in modulus. Overall, PEW displayed a measurable benefit to thermoplastics.

The coefficient of thermal expansion was also slightly affected, primarily when added to the HDPE. The following summary tabulates the results of testing for tensile, flexural, and thermal expansion.

Mechanical Tests

Tensile Tensile

Strength Modulus

HDPE 2,990 psi 160,000 psi

HDPE/30% PEW filled 2,850 psi 240,000 psi

Polypropylene 4,620 psi 220,000 psi

Polypropylene/30% PEW filled 3,900 psi 320,000 psi

Nylon 6,750 psi 220,000 psi

Nylon/30% PEW filled 5,170 psi 330,000 psi

Flexural Flexural

Strength Modulus

HDPE 2,880 psi 150,000 psi

HDPE/30% PEW filled 3,400 psi 200,000 psi

Polypropylene 4,630 psi 170,000 psi

Polypropylene/30% PEW filled 5,550 psi 270,000 psi

Nylon 6,220 psi 220,000 psi

Nylon/30% PEW 8,280 psi 280,000 psi

Thermal Expansion Coefficients

CTE CTE CTE

-40 to 25°C 25 to 100°C 100 to 150°C

HDPE 156 ppm/°C - - - - -

HDPE/30% PEW 100 ppm/°C 170 ppm/°C 387 ppm/°C

Polypropylene 91 ppm/°C 159 ppm/°C 371 ppm/°C

Polypropylene/30% PEW 80 ppm/°C 137 ppm/°C 336 ppm/°C

Nylon 90 ppm/°C 154 ppm/°C 220 ppm/°C

Nylon/30% PEW 85 ppm/°C 145 ppm/°C 224 ppm/°C

D. Expected Economic Impact

This project has provided potential material formulations using recycled, ground-up electronic circuit assemblies and various thermoplastic and thermosetting resins. In the case of HDPE, not only the ground circuit boards but also the thermoplastic resin can be obtained from recycled sources. In the case of nylon, the resulting formulation will be more expensive because of the resin, but the combination may provide improved material properties in terms of strength and durability. [What were the direct benefits to the Participant? When, by Whom and to What extent will the results be applied? Discuss the impact to the company, industry, the economy in terms of jobs created, revenues, environmental benefits, etc. What are expected benefits to consumer/taxpayer? (See closeout manual)]

E. Benefits to DOE

This project has enhanced the skills of FM&T technical staff in areas of composite fabrication including particle separation, particle size analysis, plastic composite material compounding, extrusion, compression molding, and injection molding. Materials developed during this project have the potential for application in WR programs. Incorporating inert fillers in thermoplastics effectively toughens the plastic, similar to filled epoxies now used in many encapsulants for electronic assemblies. This work also complements FM&T's Quality policy goals of respecting the environment and reducing waste, gaining practical knowledge and additional expertise in this area. [What products or processes used in the manufacture of DP products were developed/improved as a result of this project. How does this project support strategic R&D goals, core competencies and plans at KCP? Discuss the value of the partnership. Was the technology developed faster/cheaper/better because of the partnership? Would FM&T have been involved in this type of project without a partnership? Why? Describe benefits that can be shared with the public (e.g. improved software codes that will allow weapons surety without the need for testing.)]

F. Industry Area

The industries benefiting from this project include the computer and electronics, and manufacturers of recycled composite plastic articles.[As appropriate, indicate industry(ies) benefiting from this project (i.e. automotive, aerospace, electronics, medical, software, etc.)]

G. Project Status

This project was completed as scheduled.[Indicate whether the project was completed as scheduled or terminated.]

H. Point of Contact for Project Information

Ken Bauer	James W. Lula
US Department of Energy	George W. Bohnert
Kansas City Area Office	AlliedSignal FM&T
PO Box 410202	PO Box 419159
Kansas City, MO 64141-0202	Kansas City, MO 64141-6159
Telephone: (816) 997-3917	Telephone: (816) 997-2417, 5069
Fax: (816) 997-5059	Fax: (816) 997-2049

I. Company Size and Point of Contact

Resource Concepts Enviro is a small business of approximately 20 employees. The point of contact at Resource Concepts Enviro is Ray Chapman [(972) 243-2588]. This small business has recently moved into larger quarters, enabling it to more efficiently process electronic circuitry and other components of obsolete computers.[Provide names of industrial partners, annual sales, number of employees and the name, phone and fax numbers of personnel responsible for the project. Indicate which participant personnel would be willing to provide feedback regarding project success.]

J. Project Examples

During the course of the project, test specimens have been molded using ground-up printed circuitry in combination with epoxy and polyester thermosetting resins. Specimens have also been injection molded by mixing ground-up material with polyethylene, polypropylene, and nylon thermoplastic resins. Since most of the specimens were destructively tested, a very limited number of these samples are available. Award

plaques containing ground-up circuitry material were made from polyester resin by a private commercial business and presented to the DOE Pollution Prevention winners for 1997. A successful trial run of plastic lumber was made from ground-up circuitry and scrap HDPE by a company in Diboll, Texas. [Are there tangible items related to the project which could be used in a "show & tell" situation (e.g. congressional testimony)? If there are photographs which help tell the story, please provide a copy.]

K. Technology Commercialization

Resource Concepts Enviro has continually sought outlets for their various grades of materials generated at their plant. Several potential outlets have been researched with promising results.[Is it expected that a product or process will be commercialized as a result of this project? If yes, provide a commercialization plan.]

L. Release of Information

I have reviewed the attached Project Accomplishment Summary prepared by AlliedSignal FM&T and agree that the information about our CRADA may be released for external distribution.

Original signed by Ray Chapman 4/15/98

Name: Ray Chapman Date

Organization: Resource Concepts

Title: CEO