NOTICE

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SCRAP TIRE UTILIZATION VIA SURFACE MODIFICATION

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Air Products and Chemicals, Inc. is developing a novel approach to reusing scrap tire rubber, which will be described in this presentation. In addition to consuming scrap tires, this technology represents a new approach to material engineering. Furthermore, this method of rubber recycle is most efficient in terms of energy recovery.

INTRODUCTION

The United States disposes approximately 270 million used automotive tires each year. The vast majority of these, estimated at 70-85%, are currently disposed of in ways which preclude further use, such as by landfilling. This method of disposal represents the loss of over 3 billion pounds of rubber each year, despite the fact that the used tire rubber still retains its original desirable physical properties.

While several approaches exist for recovering value from scrap tires, these are not having a significant impact at this time. Uses for scrap tires include burning them for energy; pyrolysis to form solid, liquid and gas products; using portions to form end products such as boat fenders, sandal soles, and fishing reefs. Technology also exists for incorporating ground tire rubber in asphalt highways to give more durable surfaces.

On obvious approach for recycling scrap tires, grinding them up and molding them into new products, is not feasible. Since rubber is a thermoset polymer, once it is cured it cannot be melted and reformed into new shapes as is the case for thermoplastics. Heating rubber above a critical temperature simply causes the rubber to decompose, as in pyrolysis.

Another obvious approach for reusing scrap tires is to grind them and combine the rubber particles with other "moldable" materials to be formed into new products. However, this approach is limited by the fact that tire rubber is quite inert, which precludes its bonding to other materials. Hence, adding ground scrap tire rubber to other materials amounts to adding an inert filler. Considering the costs associated with collecting, shredding, and grinding tires, this represents a rather expensive inert filler.

AIR PRODUCTS APPROACH

The Air Products concept for recovering value from scrap tires consists of grinding the tires, removing the steel and fabric, and chemically modifying the surface of each rubber particle. The chemical modification of the rubber particle surface layers significantly alters the inertness property and enables the rubber particles to be chemically combined with various materials, and to be subsequently molded into new and useful end products, figure 1. In the process of surface-treatment, which consists of exposure to reactive gas atmospheres, the interior of each rubber particle is unaffected, which enables one to take advantage of the inherently desirable properties of the rubber in post-tire composite applications. It should be noted that this process is non-polluting: all process gas streams are completely neutralized before venting to the atmosphere.

The efficacy of surface-modification in facilitating adhesion is demonstrated by comparing the bond strength of strips of rubber, figure 2. T-peel test results for polyurethane cast onto a non-treated strip of rubber gives adhesion values of 3 lb./in. In analogous tests with surface-modified strips of rubber, the bond is so strong that the rubber rips at 150 lb/in -- before the polyurethane/rubber bond fails.

It is easy to envision how such a dramatic adhesion enhancement between the continuous and discontinuous phase components in a composite will have significant impact on composite physical properties.

Two generic types of surface modifications for tire rubber are being developed. These are termed polar surface treatments and double-bond treatments. The nature of the polar surface modification is illusrated in figure 3. Two types of modified surfaces are needed to enable the scrap rubber particles to be incorporated in a broad range of materials. The polar surfaced particles are amenable to use in polyurethanes, epoxies, and several other polar matrices. The double-bond surfaced particles can be used in unsaturated polyesters, various free radical polymers, and in rubber formulations.

APPLICATIONS

In order for surface-modified rubber particles to have commerical usage, there must be cost/performance benefits. Anticipated composite property incentives which will drive commercial use have been identified.

From this, initial end-use applications for surface-modified rubber particles can be targeted by matching cost/performance benefits with material performance requirements for specific uses. Amenable markets for polar surfaced rubber particles in polyurethane systems (where we have greatest technical/commercial knowledge to-date) are listed in figure 4.

ECONOMICS

One of the most important determinants of commercial success -- economics -- is favorable for substitution of surface-modified rubber for virgin resin systems. In the case of polyurethanes, raw material costs range from $1.25 to $5.00/lb. With selling price projections for surface-treated rubber in the $.75 to $1.00/lb. range (with economy of scale), molders are offered a significant incentive in the form of cost savings.

ENERGY SAVINGS

Scrap tire recycle via this technology represents the greatest energy-savings potential of all known tire recycling methods, and hence explains the Department of Energy interest in this approach. The energy required to produce one pound of polyurethane resin is about 90,000 BTUs.

The estimated total energy requirements for collecting, grinding, and surface-modifying scrap tires is 9,000 BTU/lb. Hence, each pound of polyurethane substituted with one pound of surface-modified rubber will save about 81,000 BTUs. For comparison, the energy derived from burning tires is only 14,000 BTU/lb. which represents only 20% of the energy required to make the tires originally.

COMMERCIAL SCALE PROCESSING

The conversion of scrap tires into surface-modified rubber particles require from three to five specific steps, depending in part on the type of surface being imparted. Economy of scale can be appreciated from tire processing plants with capacity of 10-20 million pounds/year. These plants, estimated to cost $3-5 million each, will probably utilize ground rubber supplied through the existing infrastructure of tire jockeys and rubber grinders. Since tire grinders currently sell the scrap steel for ultimate recycle and derive energy from burning the fabric, energy recovery from this process goes beyond rubber recycle.

Plant location is expected to be an important consideration. It is desirable to select sites near large sources of scrap tires -- major metropolitan centers. This will minimize shipping costs of tires and ground rubber.

STATUS AND CHALLENGE

Much work is still required to develop this appraoch into a commercial process having significant impact on the scrap tire situation. While effective reactive gas treatments have been developed and patented, much work is required concerning demonstration of specific applications for these new materials. In addition, process development is required to scale up these treatments from the current one lb/hour laboratory rate to the over 2,000 lb./hr required for maximum economy of scale.

CONCLUSIONS

In conclusion, the Air Products' approach to scrap tire recycle is very attractive in that it 1) renders scrap rubber reactive, which allows use in higher value applications; 2) is non-polluting; 3) has the potential to save (recover) significant quantities of energy; and 4) is economically attractive.

ACKNOWLEDGEMENT

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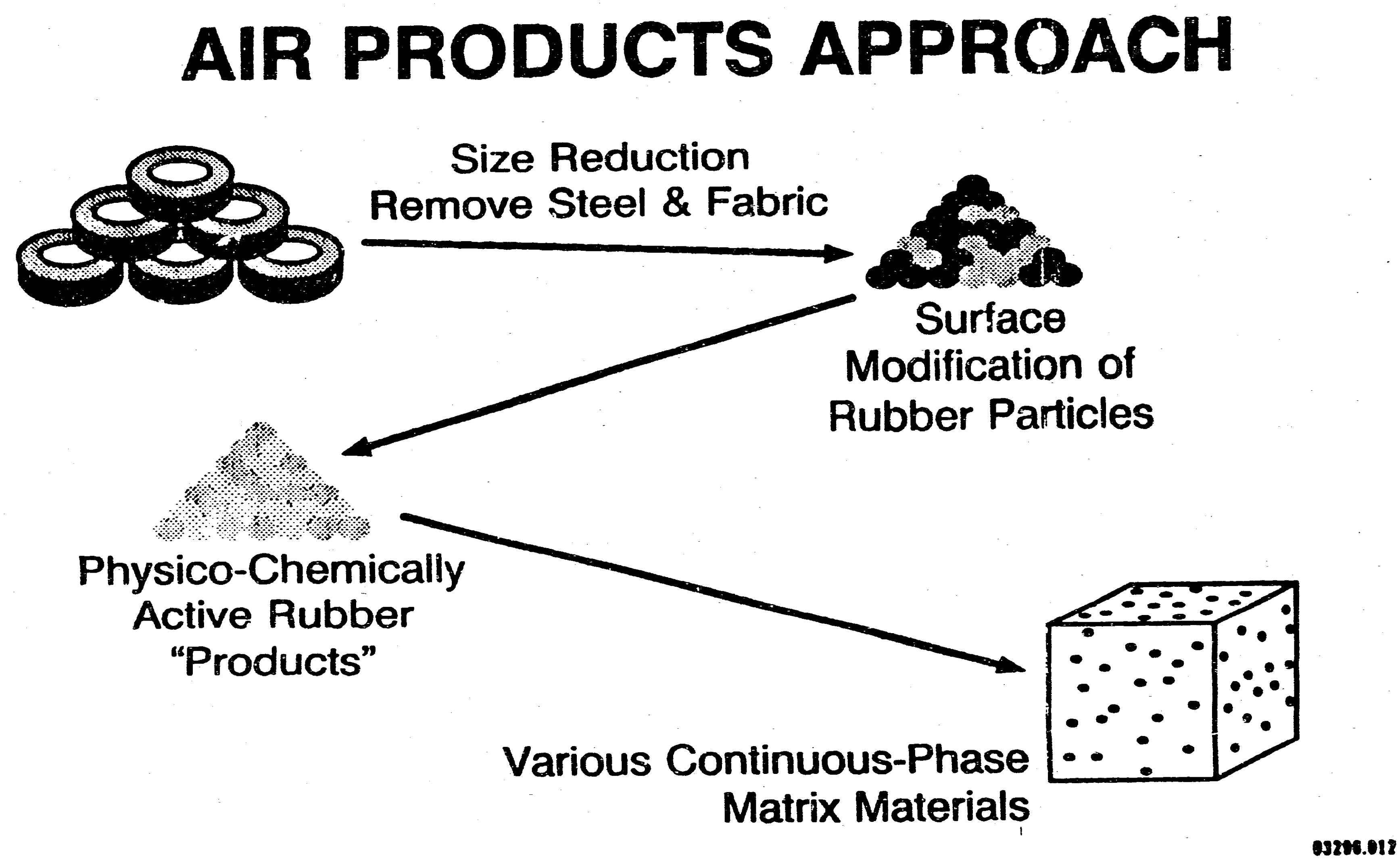
AIR PRODUCTS APPROACH
Size Reduction
Remove Steel & Fabric
Surface
Modification of
Rubber Particles
Physico-Chemically
Active Rubber
"Products"
Various Continuous-Phase
Matrix Materials
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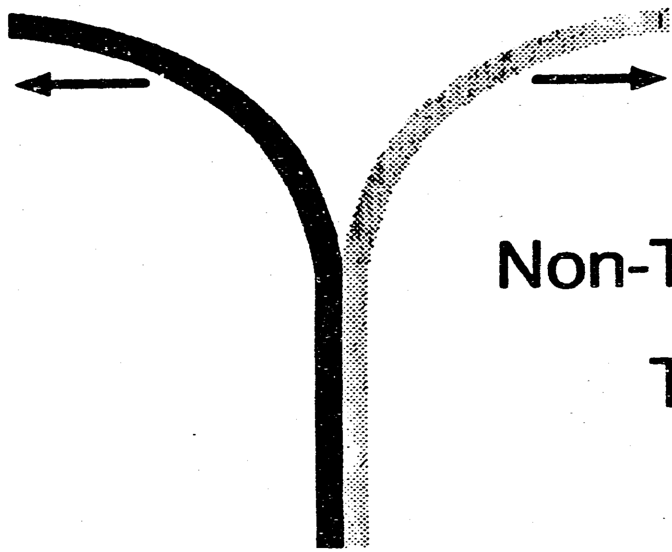
FIGURE 1

ADHESION PERFORMANCE



T-Peel Test

Non-Treated Rubber/PU	3 lb/in
Treated Rubber/PU	> 150 lb/in

FIGURE 2

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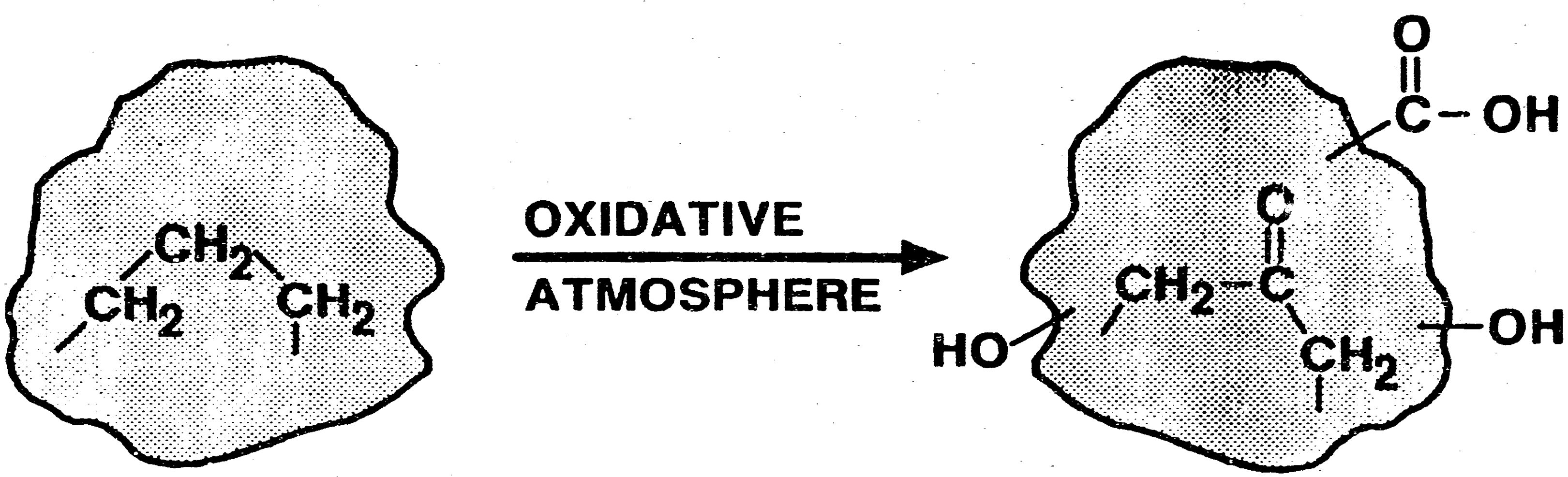
ENHANCED-ADHESION SURFACE MODIFICATION



- LOW SURFACE ENERGY
- BOUNDARY LAYER
- INERT

- ENHANCED WETTABILITY / COMPATIBILITY
- CROSS-LINKED BOUNDARY LAYER
- REACTIVE GRAFT SITES

02895.003

FIGURE 3

INITIAL TARGET MARKETS

- PU Shoe Soles
- Carpet Underlay
- Tires (Non-Pneumatic)
- Conveyor Belts
- Rubber Hosing
- Automotive Door & Window Seals
- Caulk, Adhesives, Sealants
- Sprayed-Up Roofing
- Flexible Foam
- Rollers
- Gaskets
- Pond Liners

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FIGURE 4

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