Microwave Technology for Waste Management Applications
Including Disposition of Electronic Circuitry

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DOE Contract No. DE-AC09-96SR18500
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MICROWAVE TECHNOLOGY FOR WASTE MANAGEMENT
APPLICATIONS INCLUDING DISPOSITION OF ELECTRONIC CIRCUITY

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ABSTRACT

Advanced microwave technology is being developed nationally and internationally for a variety of waste management and environmental remediation purposes. These efforts include treatment and destruction of a vast array of gaseous, liquid and solid hazardous wastes as well as subsequent immobilization of hazardous components into leach resistant forms. Microwave technology provides an important contribution to an arsenal of existing remediation methods that are designed to protect the public and environment from the undesirable consequences of hazardous materials. One application of special interest is the treatment of discarded electronic circuitry using a new hybrid microwave treatment process and subsequent reclamation of the precious metals within.

INTRODUCTION

Significant quantities of hazardous wastes are being generated from a multitude of processes and products in today's society. Microwave energy represents a unique heating source with the potential of providing a highly flexible means for a) minimizing generation of selected future wastes, b) reducing existing wastes and immobilizing hazardous components and c) reclaiming or recycling reusable and sometimes valuable materials in waste products. Some of the many wastes under study using microwave treatments include radioactive wastes and
sludges (high, low and intermediate level wastes, transuranic and mixed wastes), contaminated soils and sediments, incinerator ashes, industrial wastes, sludges, rubber products including tires, medical and infectious wastes, asbestos, groundwaters, volatile organic compounds (VOC's), discarded electronic circuitry and shipboard wastes.

POTENTIAL ADVANTAGES OF MICROWAVE PROCESSING

Microwave energy interacts with matter in a way different than other thermal treatment processes. As a result of this unique feature, the advantages of using microwave energy for treating a vast array of hazardous wastes can include some or all of the following:

- Waste volume reduction
- Rapid heating
- High temperature capabilities
- Selective heating
- Enhanced chemical reactivity
- Ability to treat wastes in-situ
- Treatment or immobilization of hazardous components to meet regulatory requirements for storage, transportation or disposal
- Rapid and flexible process that can also be made remote
- Ease of control
- Process equipment availability, compactness, cost, maintainability
- Portability of equipment and process
- Reduction in personnel radiation exposure for rad wastes (ALARA)
- Energy savings
- Cleaner energy source compared to some more conventional systems
- Overall cost effectiveness/savings

The advantages ultimately realized depend both on the type and characteristics of the wastes to be treated.

WSRC/UF MICROWAVE PROGRAMS

A team from the Westinghouse Savannah River Technology Center (DOE Laboratory) and the University of Florida has been active for about a decade in the development of microwave technology for a variety of waste management applications. This interaction has resulted in the development of some unique equipment and uses of microwave energy. The team has now joined forces with
industrial partners to tailor this technology for specific industrial needs. Some of these efforts and programs are depicted schematically in Figure 1.

ELECTRONIC CIRCUITRY AND RECLAMATION OF PRECIOUS METALS

Among the existing waste inventory in the United States and world-wide is millions of circuit boards from a vast array of discarded consumer products as well as from the DOE and DOD community. At present, these materials are most often disposed of by discarding them in landfills throughout our nation. This results in a number of concerns. First because of the large volume of waste material disposed of daily in landfills, many are reaching capacity, thus resulting in the need for new disposal sites causing increased costs both environmentally and economically. Next, there are a variety of hazardous materials that may be contained within electronic components. In landfills, these elements can leach from the waste and migrate into groundwater, which can produce undesirable environmental consequences. Finally, because the products are simply thrown away, the natural resources in the wastes, including precious metals such as gold, are discarded and cannot be reused or recycled. If one can develop a technology to not only treat the large volumes of electronic waste, reduce its volume and immobilize hazardous components into leach resistant forms, but also reclaim precious metals such as gold, an environmentally important contribution can be made with a significant potential return on investment.

Laboratory-scale studies have produced the following important results and have been documented in more detail in previous publications [5-11].

- A wide array of electronic components were able to be treated by a relatively simple and flexible, one-step, hybrid-heated microwave process.

- Geometric waste reductions of more than 50% were observed along with "landfill" volume reductions of many hundreds of percent.

- In this process, circuitry was converted into two waste form products; a glass and a metal form.

- The glass waste form retained hazardous components and met important environmental leaching standards. Furthermore, for most cases, the glass could be produced without the need of any additives.

- The metal form produced was subsequently processed to effectively reclaim precious and valuable metals, including gold and silver.
Figure 1. Flowsheet illustrating WSRC/UF's current and potential microwave waste remediation efforts.
A new "tandem microwave" system was developed which handled both primary as well as secondary wastes in an integrated unit, i.e., the off-gases produced were simultaneously treated along with the electronic circuitry.

The entire hybrid microwave process and specialized equipment (now being patented) can also be mocked-up to a larger scale and made mobile. The system is particularly suited to treatment of proprietary and/or very hazardous or radioactive materials. One of the many unique features of this treatment system is that since most of the electronics and controls can be made external to the treatment chamber, entire components can be destroyed and/or treated remotely by microwaves, which can be transported via waveguides, to controlled or contained areas.

The microwave studies conducted by SRTC and UF have been applied not only to treatment of primary waste streams, but also to the off-gases produced, using a new tandem microwave treatment concept designed to treat both primary as well as secondary wastes simultaneously.

The tandem microwave unit is shown in Figure 2 and consists of two microwave chambers interfaced together. First, the lower chamber is the combustion chamber that is used to ash or vitrify various solid and liquid waste streams. This unit may be "hybridized" by the use of a susceptor which allows processing of wastes normally not receptive to microwave heating. While the waste is being reduced in volume and transformed in this chamber, the off-gases produced pass into the upper microwave unit which contains a special series of filters. The material is also heated by microwaves which assist in the decomposition of the off-gases produced. Gas chromatography has shown that the amount of hazardous components found in the off gases are significantly reduced by the microwave treatment.

Laboratory scale data of microwave treatment of emissions are shown in Table 1. While only laboratory scale studies have been performed to date, it is believed that the overall concept and process can be mocked-up to a larger scale and even made mobile, if desired.

CONCLUSIONS

Microwave technology provides important advantages for remediation of a wide range of radioactive and non-radioactive hazardous wastes (solids, liquids and gases) and provides an important contribution to the growing arsenal of waste remediation tools.
Figure 2. Schematic and digital photograph of microwave waste treatment system.
Table 1. Microwave Treatment of Emissions Produced from Combustion of Electronic Circuit Boards.

<table>
<thead>
<tr>
<th>COMPOUND</th>
<th>SR-8 (ng) A</th>
<th>B</th>
<th>SR-9 (ng) A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzene*</td>
<td>5838.9</td>
<td>22.2</td>
<td>1415.6</td>
<td>139.5</td>
</tr>
<tr>
<td>Toluene*</td>
<td>8146.6</td>
<td>15.7</td>
<td>4215.9</td>
<td>158.7</td>
</tr>
<tr>
<td>Ethylbenzene*</td>
<td>1147.4</td>
<td>nd**</td>
<td>4557.0</td>
<td>5.2</td>
</tr>
<tr>
<td>Styrene*</td>
<td>1666.9</td>
<td>6.2</td>
<td>20012.0</td>
<td>38.4</td>
</tr>
<tr>
<td>Napthalene*</td>
<td>355.5</td>
<td>nd</td>
<td>2403.6</td>
<td>27.9</td>
</tr>
<tr>
<td>m/p Xylenes*</td>
<td>2259.0</td>
<td>nd</td>
<td>510.6</td>
<td>nd</td>
</tr>
<tr>
<td>1,3,5 Trimethylbenzene</td>
<td>1564.0</td>
<td>nd</td>
<td>378.7</td>
<td>64.3</td>
</tr>
<tr>
<td>1,2,4 Trimethylbenzene</td>
<td>904.7</td>
<td>nd</td>
<td>171.8</td>
<td>nd</td>
</tr>
</tbody>
</table>

A = Before microwave off-gas treatment; B= After microwave off-gas treatment
*Listed as hazardous air pollutants in the Clean Air Act, as amended, 1990
** nd= not detected (< 1ppb)

REFERENCES


