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Project Title: **Real-Time Identification and Characterization of Asbestos and Concrete Materials with Radioactive Contamination**

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Annual Report

REAL-TIME IDENTIFICATION AND CHARACTERIZATION OF ASBESTOS AND CONCRETE MATERIALS WITH RADIOACTIVE CONTAMINATION

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RESEARCH OBJECTIVE

Concrete and asbestos-containing materials were widely used in U.S. Department of Energy (DOE) building construction in the 1940s and 1950s. Over the years, many of these porous building materials have been contaminated with radioactive sources, on and below the surface. This intractable radioactive-and-hazardous-asbestos mixed-waste-stream has created a tremendous challenge to DOE decontamination and decommissioning (D&D) project managers. The current practice to identify asbestos and to characterize radioactive contamination depth profiles is based solely on bore sampling, which is inefficient, costly, and unsafe. A three-year research project was started 1998 at Rensselaer with the following ultimate goals: (1) development of novel non-destructive methods for identifying the hazardous asbestos in real-time and in-situ, and (2) development of new algorithms and apparatus for characterizing the radioactive contamination depth profile in real-time and in-situ.

RESEARCH PROGRESS AND IMPLICATIONS:

This report summarizes the present status as of June 17, 2000:

1. Asbestos Identification

Electro-optic Terahertz Time-domain Spectroscopy (EO THz-TDS) is a new technology being developed at Rensselaer's Ultrafast Optoelectronics Laboratory and elsewhere. As one of the major goals of this project, basic research to develop THz-TDS has helped shape brand new research effort in this scientifically and technologically important, but long inaccessible spectroscopic region. We have demonstrated that the ultra-wide bandwidth, coherence and sensitivity of the newly developed technique can be used to characterize the electronic, vibronic, and compositional properties of solid, liquid and gas phase materials, flames and flows. Many researchers now believe that basic research in this area could lead to a breakthrough that may eventually become as significant as ultrasound and X-ray technologies. The grant support from DOE allows us to propose

innovative approaches to test that: each asbestos-containing sample has unique signatures which can be identified and characterized with the new THz time-domain spectroscopy method, and a unique electro-optic, far-infrared (FIR), electromagnetic (EM) field sampling and imaging system can be developed for real-time and *in-situ* applications. So far, our efforts have been devoted to the development of an adequate system with an ultrahigh sensitive and broad bandwidth for initial asbestos testing. Progress in this area can be summarized as four different tasks:

a) Time domain spectroscopy of sands and soils in THz range

To identify and characterize asbestos in the concrete, it is crucial to obtain the proper THz transmission parameter for different conditions. So far, we have performed the experiments of time-domain spectroscopy for sands and soils in THz range. A large amount of standard environmental samples were obtained from various national laboratories. These samples, which were specially prepared and handled, were placed into the THz beam path, alternatively. So far, the measurements have been performed using two kinds of THz emitters.

b) Real-Time, Two-Dimensional Terahertz Wave Imaging

We are continuing to develop an advanced technology of the THz bandwidth electro-optic sensor and we have applied it on the imaging of pulsed electromagnetic radiation. One of our major technical achievements is the development of dynamic aperture to improve spatial resolution for THz imaging. This development significantly improves the imaging spatial resolution.

c) THz Transceivers

For THz spectroscopy and imaging applications, it is important to develop a transceiver. We were able to develop the first experiment on photoconductive THz transceiver that combines both generation and detection into one device. This transceiver alternately transmits pulsed electromagnetic radiation at THz frequency and receives the returned signal. Because only one element is involved, the system complexity is greatly reduced. Parallel to the development of photoconductive THz transceiver, we also developed electro-optic THz transceivers, since electro-optic detection promises real-time 2D THz imaging.

d) Spectroscopy measurement of asbestos

The spectral data of asbestos in infrared range have been reported by others. However, data in THz range are lacking. We have applied THz time-domain spectroscopy to a large number of asbestos-containing-materials, including Chrysotile, Grunerite, and Riebeckite. Our experiments show that it is possible to use this THz technique for the dielectric constant measurement of asbestos. Two THz systems have been used: a Coherent RegA 9000 laser with a pulse duration of 250 fs for test in 0.1 ~ 2 THz range; and a ultrashort pulsed laser with 12 fs pulse duration for test in higher frequency range (up to 40 THz). However, further experiments are needed to obtain spectral signatures of asbestos in GHz to THz range. Fig. 1 shows a typical example of the time-domain spectroscopy measurement of the Chrysotile. More absorption is observed in high frequency. Fig. 1(a) plots the temporal waveform of a THz beam transmitted through the asbestos (Chrysotile), and it is reference waveform (free space). Sharp dips in Fig. 1(b) are due to the water vapor absorption.

Fig. 1. (a) Temporal waveforms for free-space and 2.7 mm thick Chrysotile. (b) Corresponding spectral distributions.

2. RADIOLOGICAL CONTAMINATION DEPTH PROFILING

Current practice in characterizing radiologically contaminated concrete or asbestos-containing materials in DOE and nuclear industry facilities employ destructive approaches. The new approach being developed in this project provides a means to make the characterization of concrete and any material “better, faster, safer, and cheaper.” The task was accomplished with relatively mature technology-gamma spectroscopy and Monte Carlo simulations. Gamma spectroscopy had been widely used for isotope identification and quantification by measuring the energies of the gamma rays, which can easily penetrate thick samples. Despite these capabilities, gamma spectroscopy has not been demonstrated satisfactorily for determining the contamination depth profile *in-situ*. The major difficulty is that while gamma spectroscopy utilizes the photopeaks from the uncollided gamma rays to identify radioisotopes, there has been no sufficient unfolding algorithm to determine the depth to which the gamma rays have penetrated. There are also lacks of tools that can quickly estimate the contamination activity levels, and to assess the doses (risk) caused by the contamination. This information is crucial in deciding cleanup action and to demonstrate compliance with regulations on releasing a facility.

Monte Carlo Verification

For far, we have developed a non-destructive method based on *in-situ* gamma spectroscopy to determine the depth of radiological contamination in any media. The key to our development is the Gamma Penetration Depth Unfolding Algorithm (GPDUA), which uses point kernel techniques to predict the depth of contamination from uncollided peak information. The GPDUA is designed and verified through extensive Monte Carlo simulations and validated through laboratory experiments. The method requires the a priori knowledge of the contaminant source distribution, which may be obtained from limited number of traditional bore sampling. The non-invasive method is extremely useful for quick scanning of large areas with deep contamination. The applicable radiological contaminants of interest are any isotopes that emit two or more gamma rays per disintegration or isotopes that emit a single gamma ray but have gamma-emitting progeny in secular equilibrium with its parent (e.g., ^{60}Co , ^{235}U , and ^{137}Cs to name a few). The predicted depths from the GPDUA algorithm using Monte Carlo N-Particle Transport

Code (MCNP) simulations using ^{60}Co have consistently produced predicted depths within 5 % of the actual or known depth for a point-shaped contaminant. MCNP represents the state-of-the-art in terms of radiation physics, cross-section data, and mathematical models necessary for neutron, photon, and electron Monte Carlo simulations. The MCNP simulations verify that GPDUA for the point source prediction models yields very good predictions for the depth of point contaminants. For the MCNP simulations, the collimator radius was 1.27 cm with a length of 20.32 cm, and the distance from the detector to the surface of the contaminated material remained at 50.00 cm.

Experiment Verification

The experiment setup was as shown in Fig. 2. Varying thickness of aluminum and polyethylene were placed in front of a NIST standard 100 μCi ^{60}Co reference point source. The collimator radius was 1.27 ± 0.05 cm and the collimator length was 20.7 ± 0.2 cm. The distance from the surface of the collimator to the point source was 58.2 ± 0.2 cm. The detector has a known surface radius of 2.30 ± 0.05 cm. Comparison with predicted depths by GPDUA also show excellent agreement.

PLANNED ACTIVITIES

During the upcoming year, efforts will be focussed on:

- The use of new parameters (area density absorption coefficient α_g and refractive index n_g) to replace the conventional (thickness) absorption coefficient α and refractive index n for asbestos measurements.
- Measurement under a new laser system (Hurricane laser from Spectro-Physics).
- Further improvement of THz transceiver and the application for the THz reflection measurement.
- Complete “finger printing” for asbestos-containing-materials.
- More experimental and Monte Carlo verifications for realistic contamination geometries such as Disk Source and the Linearly Distributed Source.
- Purchase and integration of a new HPGe gamma spectrometer detector in the GPDUA system for the primary field testing.

INFORMATION ACCESS

Publications and Presentations

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- Jiang, Z.; Sun, F. G.; Chen, Q.; Zhang, X.-C. Electro-Optic Sampling near Zero Optical Transmission Point. CLEO'99, Baltimore, May, 1999.