CAAP Quarterly Report

Date of Report: *October 14, 2016*

Contract Number: *DTPH5615HCAP07*

Prepared for: *DOT*

Project Title: *Electromagnetic Strategies for Locatable Plastic Pipe*

Prepared by: *The University of Tulsa*

Contact Information: *Michael W. Keller, mwkeller@utulsa.edu, 918-631-3198*

For quarterly period ending: *October 10, 2016*

Business and Activity Section

(a) Generated Commitments –

Supplies	Cost
Lab supplies	75.92
Lab Supplies - Bolts/raw materials	46.30
Lab Supplies - Bolts/raw materials	127.79
Lab supplies	9.52
Lab Supplies - Bolts/raw materials	24.10
Lab Supplies - Bolts/raw materials	127.22
Lab supplies	40.32
Lab supplies	2.38

Students working on project: Laura Waldman (MS 2018) – Material compounding and testing
Jordan Trewitt (MS 2018) – Electronic modeling and detection
Ravi Venkata OSU Student – Assistance on extrusion and molding

(b) Status Update of Past Quarter Activities

In the past quarter, we have completed the following research planning activities

1. Analysis of compounding studies
2. Initial computational work on the RFID antennae and systems.
3. Design of lab-based EM test stand

Analysis of Initial Compounding Studies

Conduction testing of the initial compounding studies indicated that the resulting compression molded samples were not achieving conductivity levels that were expected. To understand the reasons behind this, we sectioned test samples and performed a microstructure analysis on the resulting plastic-metal compounds. Results of this study are shown in Figure 1. For the low weight percent composites (Figure 1 A&B) there appears to be insufficient flake content to ensure a continuous conductive path through the polymer material. At the highest weight percent (10 wt% Figure 1 C&D) there is enough material to ensure some continuity, but dispersion is an issue. To improve dispersion, we have tried two approaches or incorporating the metal flake material into the polymer, a pre-molding melt mixing and a direct-addition during compression molding. Figure 1C is a cross-section of a melt-mixed flake composite showing reasonably good dispersion of metal flake throughout the material, however this does not appear to translate to good conductivity in the composite. This is likely due to incomplete contact between the dispersed flake that reduces the availability of conduction paths within the composite. We also attempted an alternative mixing strategy of adding the flakes directly to the pelletized PE before compression molding. Figure 1D shows a cross section of a composite produced using this approach. As can be clearly seen the flake tends to congregate at the borders of the pellet material and does not penetrate into the bulk in the same way as in a pre-mixed material. Again, this morphology does not produce consistent conductivity across the entire specimen. Our current approach to address this performance gap is to begin compounding the metal flake into an already conductive UHMW material. This should allow for the production of a material with continuous conductive paths between aluminum flake. We expect that this should increase the conductivity of the material significantly above that of the base material.

In addition to the compression molding approach that we are taking, we will begin to perform some initial studies using the research extruder available at our collaborator at OSU. This should also improve dispersion, but we will have to balance damage to the flake or micro capsules induced by the high-shear extrusion process.

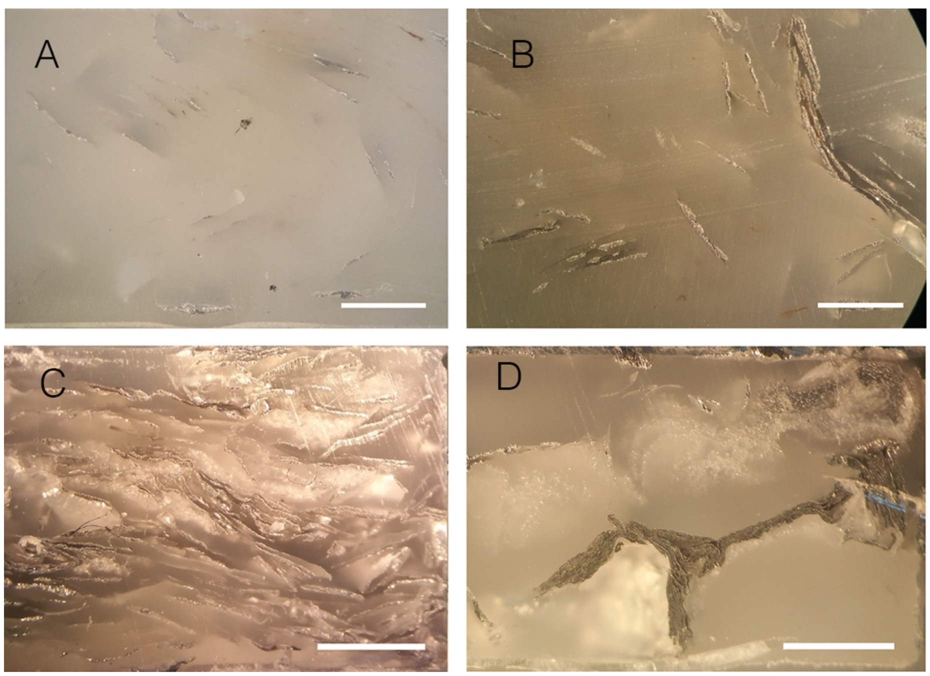

Figure 1: Cross sections of metal flake-polymer mixtures at different weight percent. A) 1.25 wt% of flake in PE, b) 2.5 wt% of flake in PE, C) 10 wt% of flake in PE mixed during melt, and D) 10 wt% of flake in PE added during pellet compression.

Initial Computational Studies and EM Test stand

We have begun our initial computation studies of the system to help home in on appropriate designs for EM-responsive antenna and potential RFID systems. We are interested in developing approaches that are responsive to a broad array of signaling devices that range from standard EM-field system to ground penetrating radar (GPR). We have access to several EM-shielded rooms on the campus of The University of Tulsa and so we have begun simulating the response of proposed designs within a test stand in these rooms.

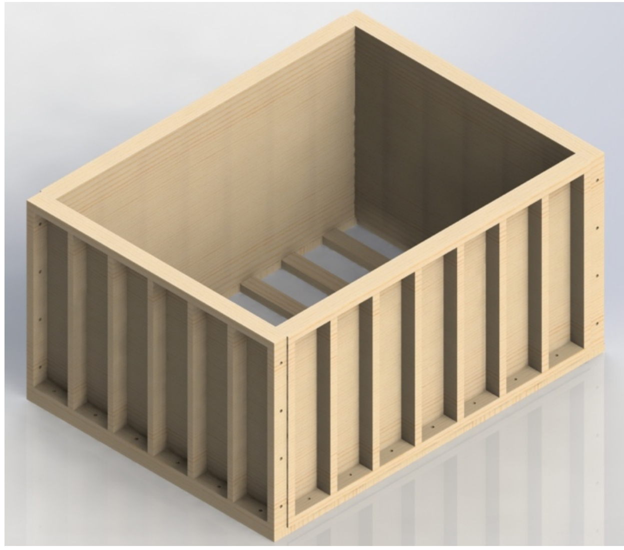

Figure 2: 3D rendering of test container for simulation of pipe response while buried.

Figure 2 shows a rendering of the test container that will contain either soil or water in order to mimic a desired burial depth. We will use this test approach to drive our initial studies and prepare for our eventual field testing of our developed systems. As an initial step, we have run some EM reflection studies to analyze the wave reflection on a model RFID antenna shown in Figure 3.

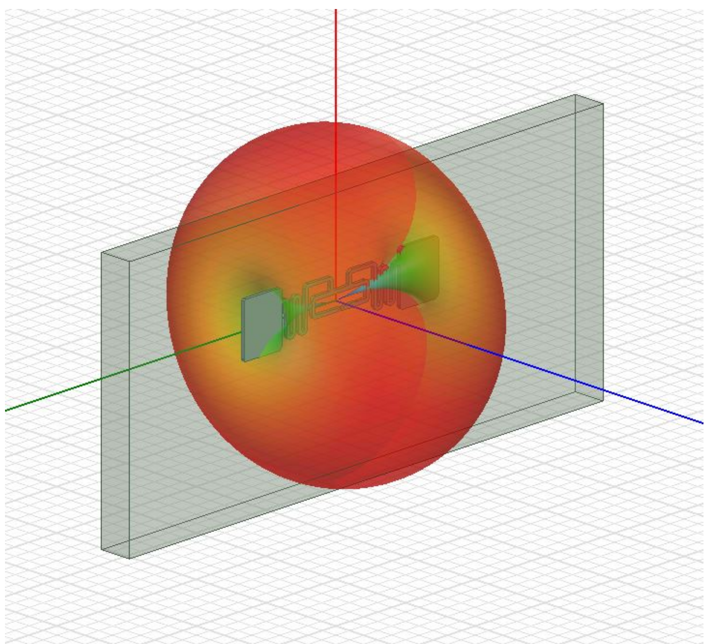

Figure 3: Model RFID antenna used for the initial computational studies of the test facility.

Figure 4 shows the wave reflection within our EM-shielded room, within the test container, and the initial sample. From this simulation we are also able to extract induced current vs. time at the sample surface. This will help us to optimize existing designs and provide information on appropriate development avenues for alternative antennas.

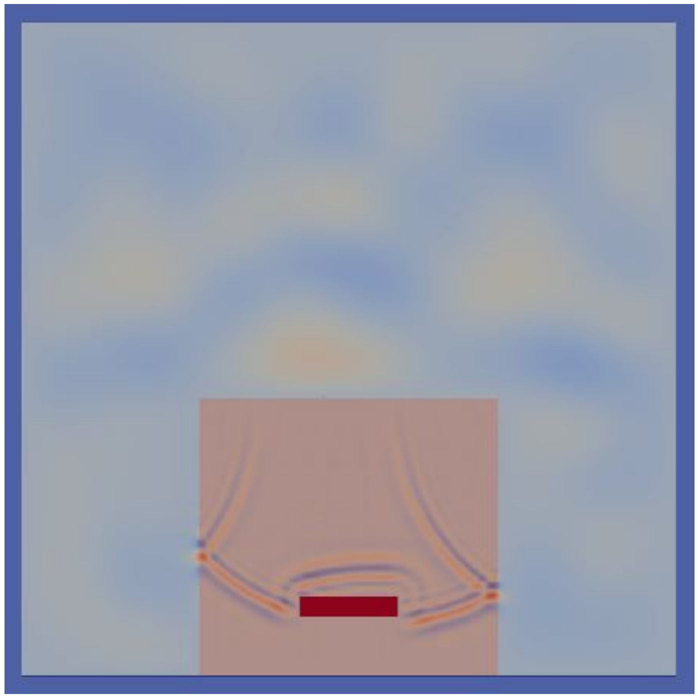

Figure 4: Simulation of EM waves reflecting off of a sample within a magnetically shielded room.

During the next quarter we will be continuing our simulation of the response of some initial antenna designs to a variety of EM inputs. Additionally, we will begin to experimentally characterize antennae structures composed of the conductive polymers that we are compounding as part of this study.

(c) Description of any Problems/Challenges –

There have been no significant delays, beyond the delays associated with student start days, or challenges at this particular moment.

(d) **Planned Activities for the Next Quarter** –

Planned activities for the next quarter include the following

1. Continue initial materials compounding
2. Compounding of microcapsule-polymer materials
3. Continuing of analytical and computation study of RFID designs for pipe.
4. Initial RFID studies using conductive polymers.