Electrostatic Detection of Stainless Steel Dust Particles for Fusion Applications

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Motivation
Dust is a safety concern for fusion devices.
- Dust accumulates in fusion devices from the erosion of plasma facing components, mechanical abrasion during maintenance, and other sources.
- This dust may be chemically reactive, activated, tritiated, and toxic. It also may pose an explosion hazard.

A remote dust detection device is needed.

Diagnostic tools will be needed for managing dust in fusion devices.

Pulse height analysis for carbon, stainless steel, and C/SS mixtures will be used.

Trials with the larger "PF 0.5F" stainless steel particles showed significant differences in behavior compared to the "PF 1.5F" stainless steel particles.

Challenges of stainless steel particles:
- Past results suggest that metal particles may melt or burn up on the detector, causing permanent short circuits or damage.
- This work aims to characterize the response of the detector to stainless steel particles.

Electronics
Voltage pulses from impinging dust particles were detected using counting electronics.

Dust Particle Size Analysis
Carbon and stainless steel dust particles were observed in the experiments.

Challenges included:
- Difficulty in differentiating between carbon and steel particles.
- Some particles formed clumps up to 100 µm.
- Stainless steel counts vs. areal mass density did not follow a linear trend, unlike carbon.

Carbon sensitivity, determined from a linear fit including the previous result of 239 counts/µg/cm².

Stainless steel particle behavior showed promise for future work.

Carbon and stainless mixture produces waveforms representative of both materials.

Some isolated voltage spikes were detected exceeding 5 V mimic stainless steel behavior.

Numerical analysis of waveforms may yield counts for individual particle types.

Experimental Setup
Dust is detected when it creates short circuits between biased copper traces.

Dust was dropped onto the detector through a mesh-bottomed tray with 86 µm openings.

- A Sartorius ME 5F Balance with 1 µm precision was used to measure the dust lost from the tray.
- The tray was tapped to release dust onto the detector.
- The detector grid was mounted on a 6" flange, that was bolted to the bottom of a metal tube.

Waveform Comparison
Carbon and Stainless

- 0.5 to > 2.5 V pulse heights
- Small negative amplitudes
- Large negative amplitudes

Similarities:
- For both particle types, isolated pulses and chaotic oscillatory behavior observed
- Duration of isolated pulses between 100 and 500 µs

Discussion/Conclusions
Detector produces counts for mass fluxes as low as several micrograms/cm².

Current limit successfully prevented grid damage.
- The grid sustains no observable damage from repeated stainless steel trials at a bias of 50V and current limits from 2 to 47 mA.

Data collected to date shows no observable correlation between counts and stainless steel areal mass density.
- Stainless steel counts vs. areal mass density did not follow a linear trend, unlike carbon. Approximate sensitivity was about 100 times lower than that for carbon.
- Many recorded waveforms reveal chaotic, oscillating waveforms, accompanied by numerous SCA pulses. These could be caused by bouncing particles or clumps breaking up, as observed in past work.

Results from tilting grid and analyzing waveforms show promise for future work.
- Angled grid mount enables detection of relatively large particles.
- Pulse height analysis for carbon, stainless steel, and C/SS mixture trials could allow dust particles to be differentiated.

References
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10 Image J Image Processing and Analysis Software, NIH.
12 J. Provost, J. Holoman, G. Smalley, and D. LaBrie for their assistance with this research.
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Detection of Stainless Steel Dust for Fusion Safety Applications

Dust accumulation in large-scale fusion devices such as ITER (International Thermonuclear Experimental Reactor) will pose significant safety concerns. Dust in ITER will be radioactive and toxic, and a maximum quantity of 1000 kg of dust will be allowed inside the device as a safety precaution. A remote dust detection device is needed to monitor dust levels inside both ITER and other fusion devices. An existing dust detector design has been tested with carbon dust particles inside the NSTX (National Spherical Torus Experiment) and Tore Supra fusion devices, but to date has not been evaluated with stainless steel dust. Planned dust detection experiments in the Large Helical Device in Japan will involve stainless steel dust particles. Work done during the summer 2013 SULI internship characterized the response of the detector to different varieties of stainless steel dust, in order to help prepare for dust detection experiments in LHD. It was found that the detector, when used with specific parameters, responds to both carbon and stainless steel dust particles with promising sensitivities. Working on this project strengthened skills in data analysis, oral and written communication, and project planning. It also enforced knowledge of oscilloscopes and multi-meters, amongst other lab equipment. Completing this project not only allowed for the invaluable experiences of documenting and presenting a complete research project, but enabled legitimate student contribution to fusion, one of society’s most promising potential advancements in energy generation.