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Nanoparticles as Lubricant Additives

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CHEMICAL AND LIFE SCIENCE

Nanoparticles As Lubricant Additives

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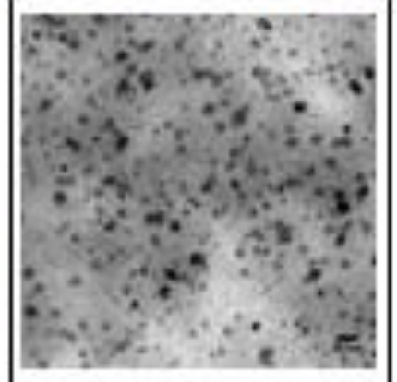
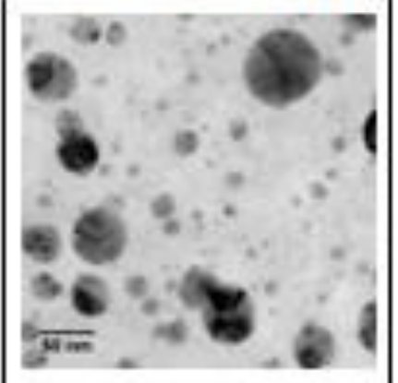
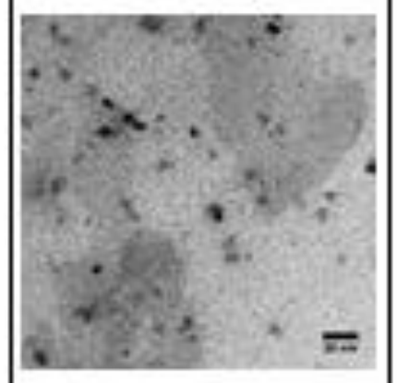
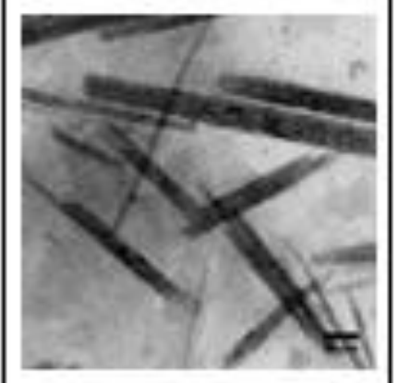
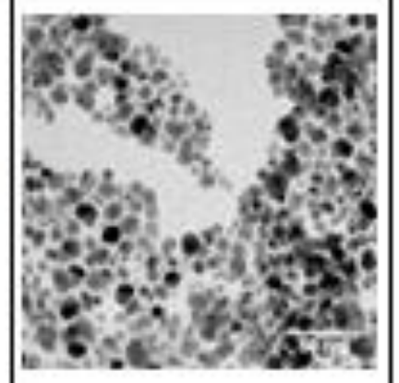
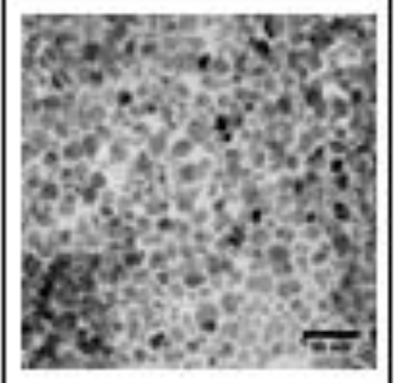
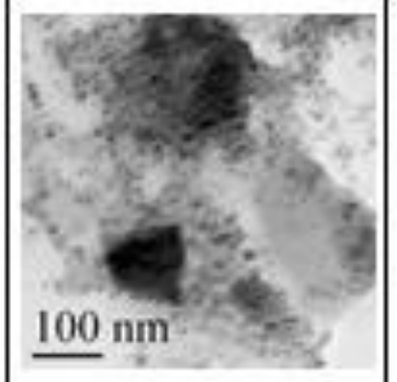
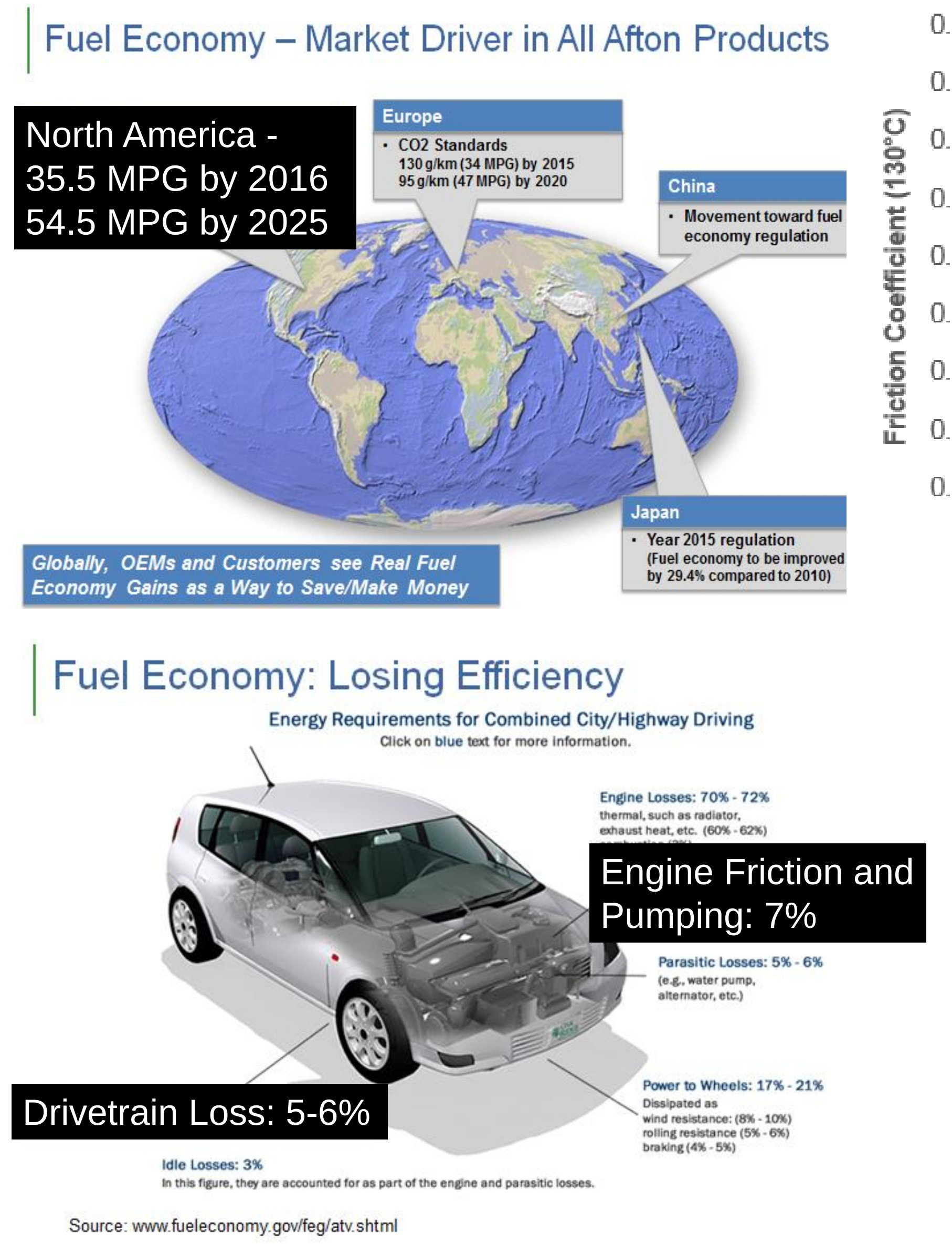
Presentation of the Problem

Concerns over fuel consumption and environmental impacts have increased the need for innovations in how we utilize oil. Previous studies have shown that nanoparticle additives can reduce friction and wear in various engines when added to oil. Friction and wear reduction produces better fuel economy and achieving a longer life for engines. Yet, there are almost an unlimited number of potential candidates and little is known about what mechanism drive these properties. **The objective of this project was to develop a predictive model which demonstrates the impact of factors such as size, concentration, and composition on the performance of nanoparticles as oil additives.**

Table 1. Nanoparticles tested.

Composition	5-15 nm	20-50 nm
Copper Phosphate		
Cerium Oxide		
Iron Oxide		
Zinc Oxide		



Source: www.fueleconomy.gov/feg/atv.shtml

Figure 1. Global emission standards and vehicle efficiency loss. Courtesy of Afton Chemical.

What to test?

One of the goals of this project was to limit the number of additives which needed to be tested. Through systemic analysis of the traits believed to control friction and wear, we were able to show with high confidence which samples should be discarded. The chart to the left illustrates the design space. Compositions of nanoparticles of varying hardness, size, and concentration were analyzed in order to provide a predictive model for potential additive candidates. The pictures to the right illustrate the instruments used to gather data.

Data

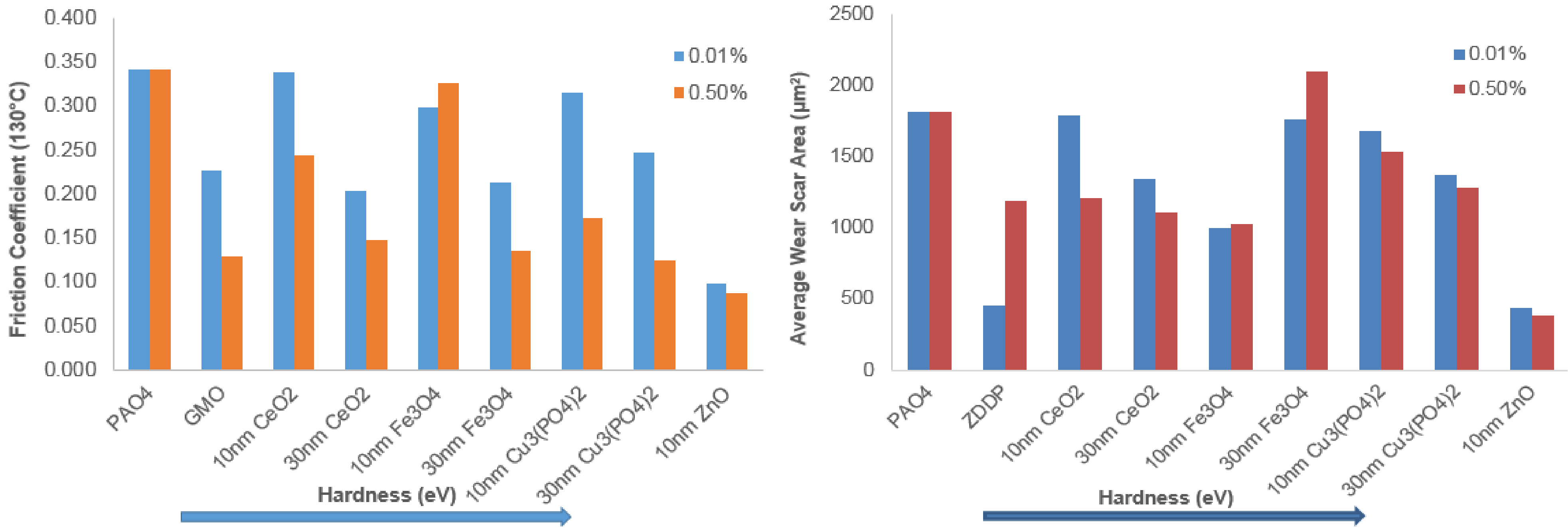


Figure 3. Friction coefficients at 130ºC (left) and wear scar areas (μm^2) (right)

- ❖As hardness, size, and concentration increase, better friction and wear performance is observed.
- ❖Fe_3O_4 behaves opposite to this trend in both friction and wear.
- ❖ZnO performed better than traditional additives: GMO for friction and ZDDP for wear.
- ❖DOE statistical analysis suggests that a large, hard particle at a high concentration would be the most optimal candidate, however this could change with replicate trials.

Methodology

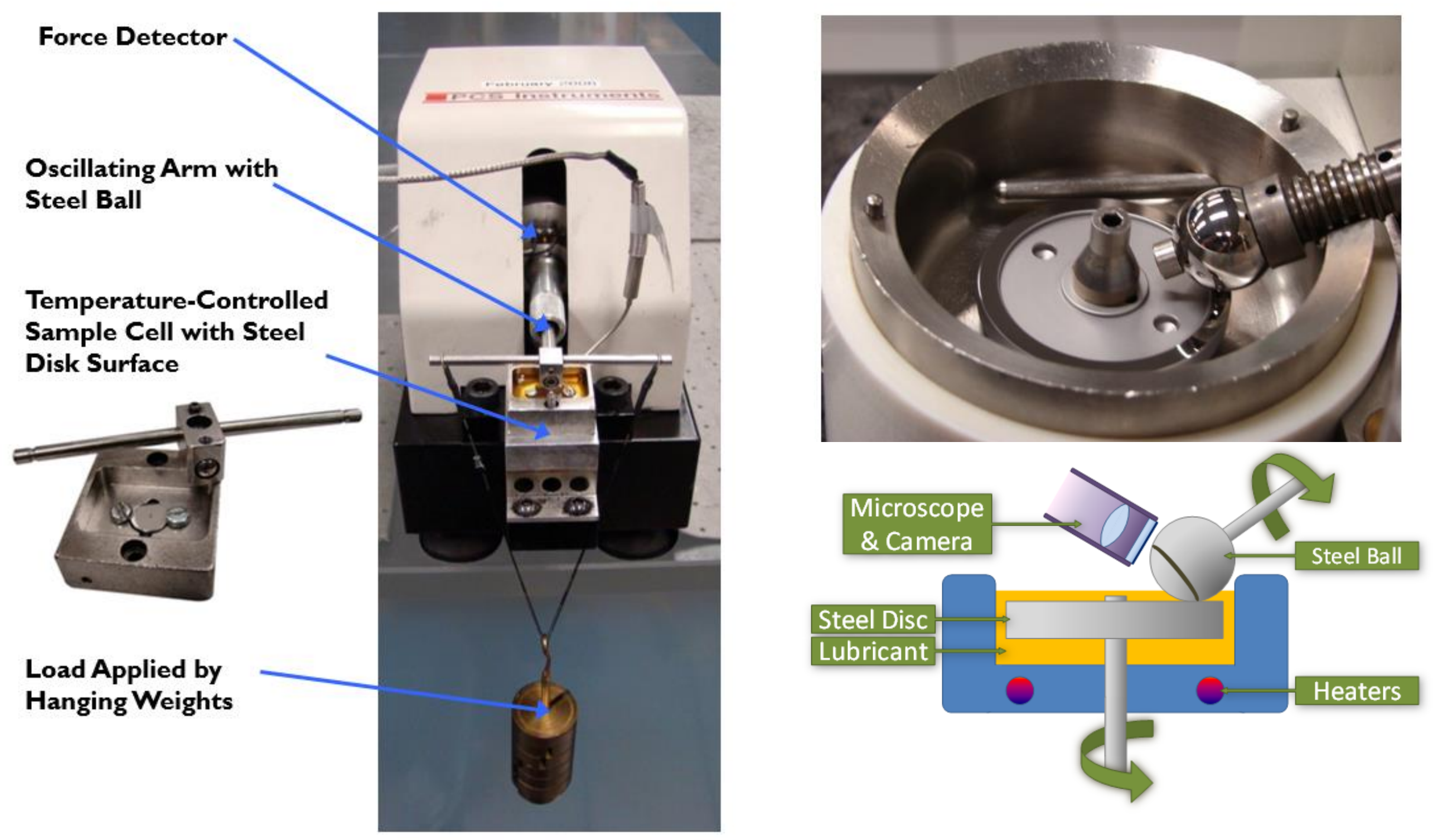
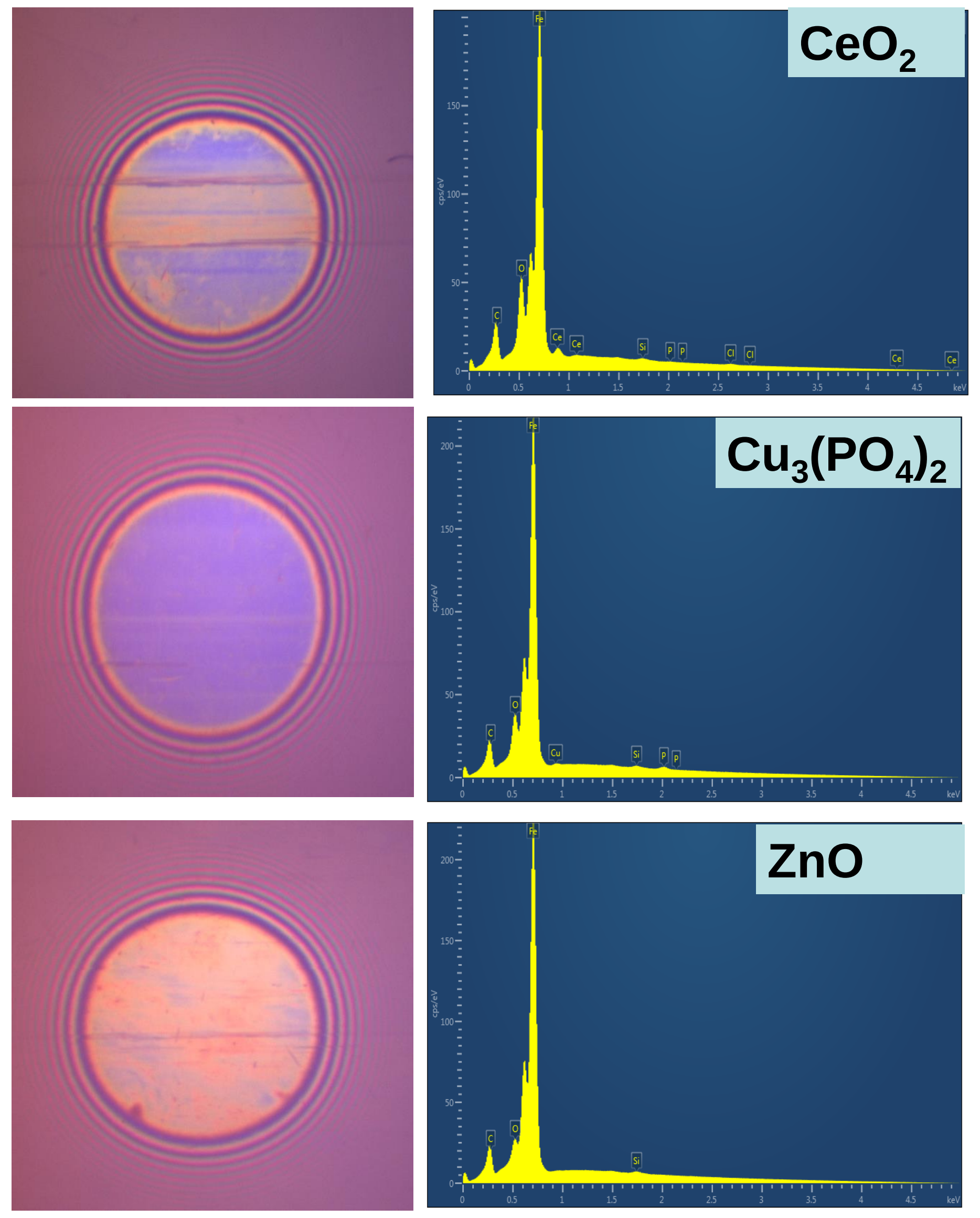


Figure 2. The HFRR (left) was used to measure friction coefficients and wear performance. The MTM-SLIM (right) was used to observe tribofilm formation and structure.

Multiple mechanisms have been proposed:

- ❖ **Mending mechanism:** additives fill in natural defects as they are crushed; like butter on warm bread
- ❖ **Third body mechanism:** additives are ball-bearings which act like a conveyer belt
- ❖ **Tribological film mechanism:** a thin, solid film adhered to the surface that acts as a wear reducing layer



- ❖ Ce present in EDX spectra
- ❖ Very little observed film formation
- ❖ Possible tribofilm formation.
- ❖ Higher concentrations could affect observed film formation

- ❖ Cu and P present in EDX spectra
- ❖ No obvious film formation
- ❖ Possibly third-body or mending mechanism
- ❖ Higher concentrations could affect observed film formation

- ❖ No Zn in EDX spectra
- ❖ SLIM image suggests some film formation
- ❖ Possibly a transient film being formed then washed away during cleaning

Figure 4. MTM-SLIM and EDX measurements.

Final conclusions and remarks:

- ❖ Optimal conditions for friction reduction and wear are likely large, hard, and concentrated nanoparticles.
- ❖ Small, soft particles are largely ineffective at lower concentrations.
- ❖ Differences in EDX spectra and MTM-SLIM imaging suggests mechanism might not be consistent across different particles.
- ❖ Synthesis method is important due to the natural instability of the particles in oil. An organic coating is necessary to create a stable solution.
- ❖ Future work would consist of a wider spectrum of concentrations and more extensive MTM-SLIM testing.

VCU School of Engineering

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Make it real.

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