Venus, Volcanoes and Vacuum Cleaners: Understanding Triboelectric Charging in Aerosols

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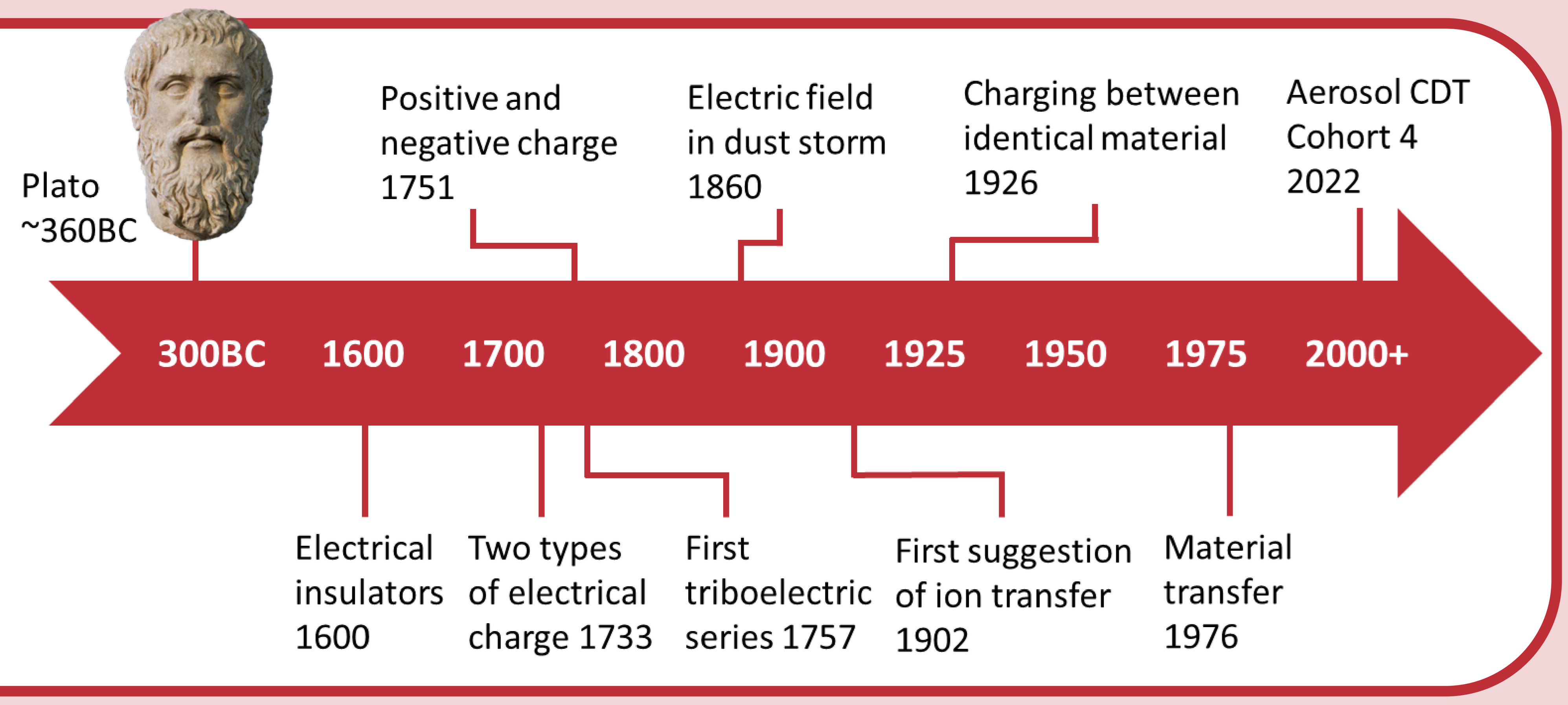
1. Introduction and Background

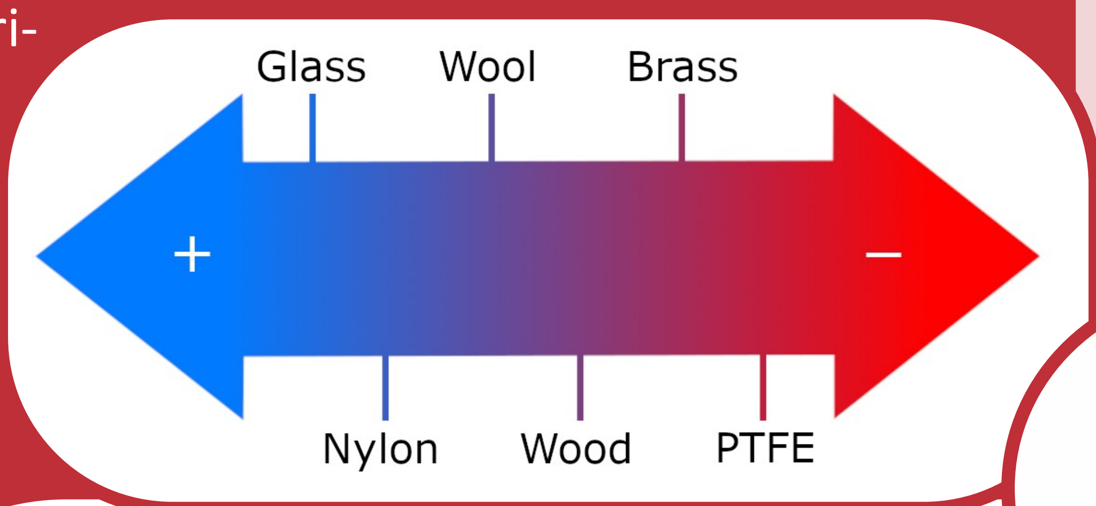
Triboelectric charging is a long-standing known phenomena that was discovered by the Ancient Greeks. The term "tribo-" comes from the Greek word for rubbing and "-electric" from electricity. The Greeks initially termed insulators as "electric" because they were able to **build up static charge**. Now we understand that this was directly due to the materials being unable to conduct electric current (insulators) as we understand today[1].

1) Daniel J. Lacks and Troy Shinbrot. Nature Reviews Chemistry, 3:465–476, 2019.



2. The Triboelectric Series

The triboelectric series dates back to 1757. Wilcke first proposed it as a **predictive tool** in understanding the phenomena by which one material becomes charged positively , such as glass, and another negatively, such as rubber.



3. Difficulty of Study

The nature of tribocharging is highly **system dependent**. The magnitude of charging and even the positions on the triboelectric series can vary greatly depending on the system in question. These problems are exacerbated by additional factors that must be considered when studying aerosols such as ash, which are often far from idealised systems.

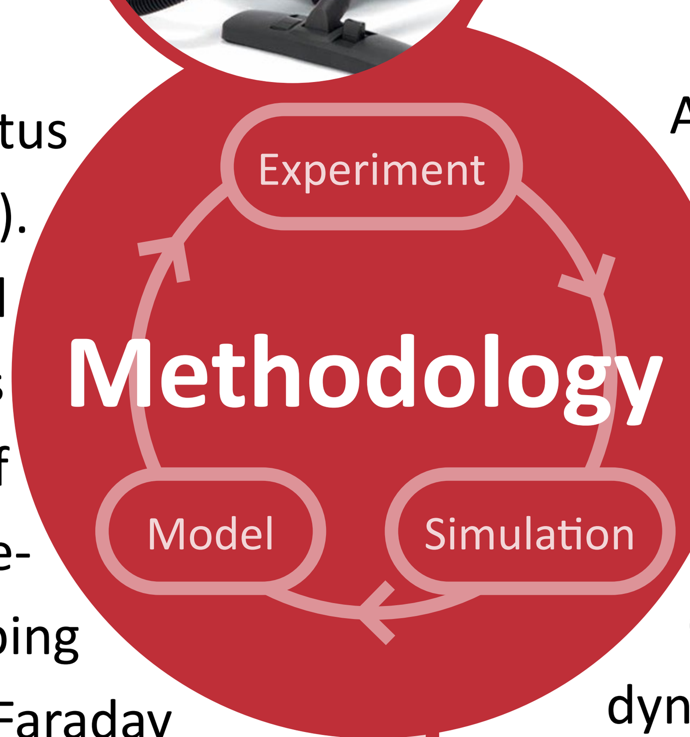
SEM image of an ash sample[2]

2) Isobel M. P. Houghton et al Physical Review Letters, 111, 2013.

4. Experimentation

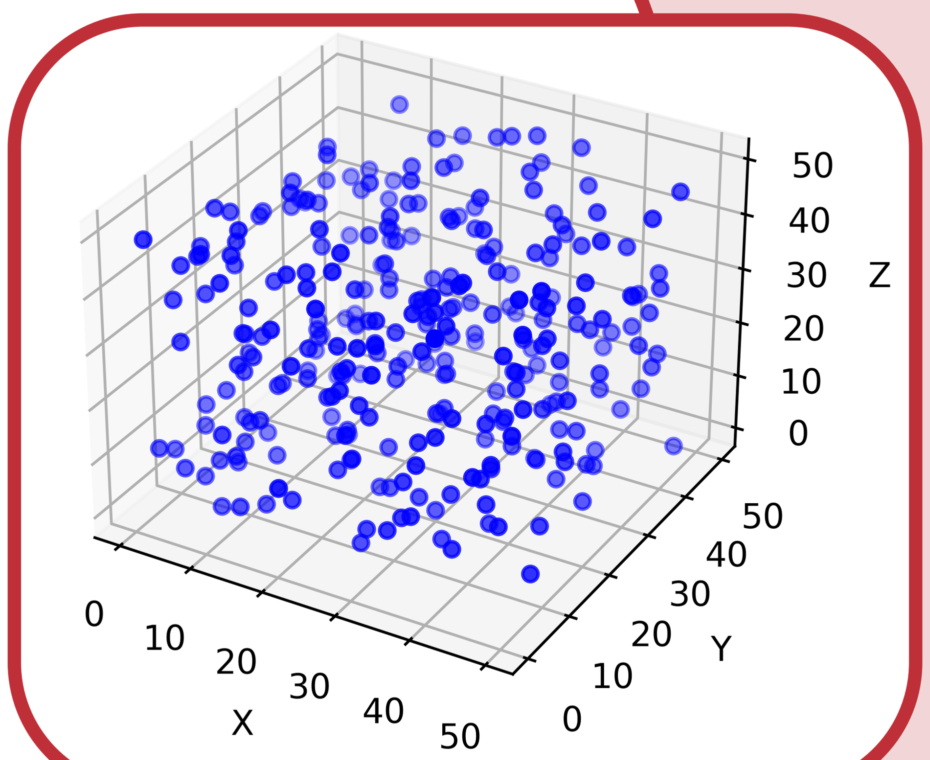
This work will utilise the charging apparatus created by Houghton et al. (pictured below). **Simplified materials**, such as glass beads will be used to reduce the number of variables under investigation. This apparatus consist of a turntable with multiple chambers for pre-loading samples to equilibrate above a dropping tube containing two Coulomb rings and a Faraday cup that are attached to a highly sensitive electrometer. This method of dropping of dust will be used to promote collisions that emulate the interactions taking place in larger clouds of solid aerosol, such as on Venus, in ash plumes, or inside vacuum cleaners.

Experimental dust-dropping apparatus



5. Simulation

As the transfer of charge is suspected to occur at the point of particle contact and separation, much work revolves around event-driven molecular dynamics (**EDMD**) simulations. Previous work has produced EDMD simulations that focus on the transfer of electrons from high-energy trapped states. There is now evidence that the magnitude of trapped electrons at the surface may not solely be able to account for triboelectric charging. Therefore, other modern simulation types could be explored in this work such as density functional theory (**DFT**), in addition to the more traditional EDMD to form a generalised model.



Plotted coordinates of an EDMD simulation

6. Policy and Innovation

This work has the potential to inform **policy** around the safety of **electrostatic ignition risks** within the process industry. The National Fire Protection Association (NFPA) produces the most highly adopted practices in this area, with the latest version being the NFPA-77[3]. Any change to policy within the process industry would lead to areas for **scientific innovation** that could increase the efficiencies of key processes.

3) NFPA 77, Recommended Practice on Static Electricity. 2019.

7. Research Objectives

Overall, this research aims to construct a **novel model** of aerosol triboelectric charging for a real world situation, such as an ash plume, through the use of more simplified experimentation and simulations of increasing complexity. A more moderate measure of success would be to **identify key factors** that affect the magnitude of triboelectric charging to inform policy around electrostatics.