Electrostatic charging of flowing granular materials

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On my way here...

Arrested in Dubai for riding in “Women and Children Only” train car
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Arrested in Dubai for riding in “Women and Children Only” train car

Attacked in Finland by crazed woman with sword
Industrial powders

Industrial powders

Negative electric field implies smaller particles charge negatively

Iceland, 2010
Volcanic plumes are generally composed of three parts: an upper part with positively charged gas and aerosol, a middle part with negatively charged fine ash particles, and a lower part with positively charged coarse ash particles.
Niger, 2010
Dust devils

Smaller particles lofted higher above surface

Negative electric field implies smaller particles charge negatively

Electrostatic charging occurs whenever surfaces contact – thus difficult to study granular systems!

In granular systems can occur in 2 ways:
• particle - wall interactions
• particle - particle interactions

We developed a methodology to disentangle the particle - wall and particle - particle effects
To get reproducible results...

All experiments done in formal attire!
Collaborators

Prof. Mohan Sankaran
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Collaborators

Dr. Mamadou Sow
Collaborators

Dr. Mihai Bilici
Only particle-particle interactions

Use a single hole distribution plate that results in fountain-like flow
Results

Charged particle will be lifted in electric field


PTFE particle:
• 2 mm particle
• Charged negative by triboelectric charging
• Placed on lower plate
• E-field increased. Above $E_{th}$ particle jumps
... but so can neutral *conducting* particle


**Aluminum particle:**
- 2 mm particle
- Charge state doesn’t matter as conducting particle neutralizes when on grounded plate
- Placed on lower (grounded) plate
- E-field increased. Above $E_{th}$ particle jumps

![Diagram showing electric field and particle behavior](image)

Positive voltage
Negative voltage
Insulating particles can act as conducting


Soda-lime glass particle:
- 2 mm particle
- Charged negative by triboelectric charging
- Placed on lower plate
- E-field increased. Above $E_{th}$ particle jumps

Low humidity (<10%): particle jumps only with negative voltage on upper plate → acts like insulator

High humidity (>35%): particle jumps equally well with either polarity voltage → acts like conductor
Particle-particle charging – new method
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Particle-particle charging – new method
Results – new method

- Large particles (%)
- Time (s)

- Positive
- Negative

- Smaller particles charge negative
Experiments at University of Chicago
Waitukaitis and Jaeger, PRL, 2014

Smaller particles charge negative
Smaller particles charge negative
Electric-field direction with gravity implies small particles tend to be negative

Industrial powders

Dust storms

Volcanic plumes


Why particle-size dependent charging?

Lacks, Duff, Kumar, *PRL* (2008)

We adapt non-equilibrium model for asymmetric rubbing (Lowell and Truscott, J. Phys. D, 1986) to particle systems

‘Money-exchange game’
- bring 1% of savings in $1 bills, in left pocket
- everyone blindfolded
- when collide with someone, give them $1 from left pocket
- put money you get into right pocket
Particle dynamics simulations

Lacks, Duff, Kumar, PRL (2008)

Simulation methodology
- 864 particles of different sizes
- Newtonian dynamics
- Transfer electrons at each collision according to trapped electron model
- Run simulation for 10 million collisions

Results for different densities

Blue: positive
Red: negative
Particle dynamics simulations

Lacks, Duff, Kumar, *PRL* (2008)

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