Mermigkas, A. C. and Timoshkin, I. V. and MacGregor, S. J. (2012) Micro electrostatic precipitation for air treatment. In: 6th Environmental and Clean Technology Conference, 2012-06-21, Grand Central Hotel. ,

Micro-electrostatic precipitation for air treatment

A. C. Mermigkas, I. V. Timoshkin, S. J. MacGregor

Department of Electronic and Electrical Engineering
University of Strathclyde, 204 George Street, Glasgow, G1 1XW,

athanasios.mermigkas @strath.ac.uk

2nd year PhD student

University of Strathclyde Engineering

Problem Statement

Exposure to particulate matter less than 2.5μm in diameter (PM2.5) can cause health problems [1,2].

There is no evident safe level found for PM2.5 [2]

Attempts are made to reduce overall levels of exposure.

Electrostatic precipitation

Charge airborne particles using non-thermal plasma (corona) discharges

Typically 50 Hz AC or DC stress is used

Precipitate charged particles using electrostatic forces on collection electrode

Electrostatic precipitation can be used for PM control.

Minimum in ESP efficiency for 0.1-2.5μm particles [3].

New approach: the use superposition of ns impulses and DC voltage to charge and remove

Micro-Electrostatic precipitation

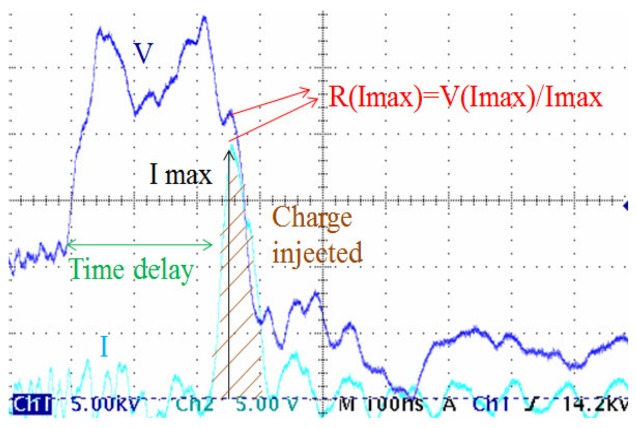
Uses combining impulses and dc voltage in order to charge and remove fine, sub-micron particles efficiently.

Short impulses are expected to increase the precipitation efficiency and to reduce power consumption.

Types of impulses used

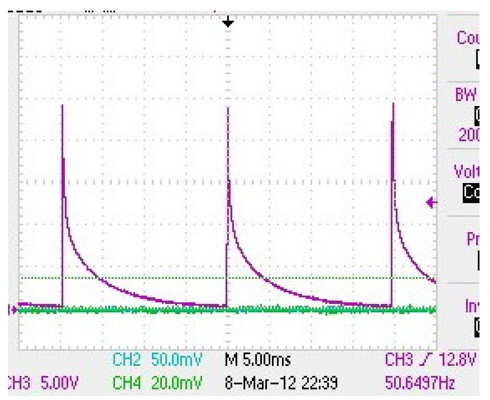
1) Sub-μs impulses:

- One way transient time - 125ns
- System is designed to generate 250ns impulses.



2) μs impulses:

- ~ 25 kV amplitude
- ~ 175 μs wide



✓ At 50 pps and with the use of an HV diode to avoid negative overshoot, they take the form as shown in the oscillogram:

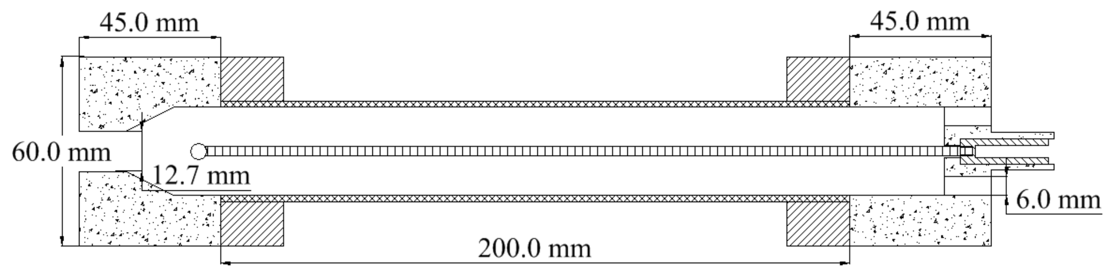
Reactor design

Cylindrical topology : compact design of small-scale indoor air-cleaning applications.

Positive energisation is used in micro-ESP process in order to avoid excessive ozone and nitrogen oxides production.

Air flow of 16 L / min used

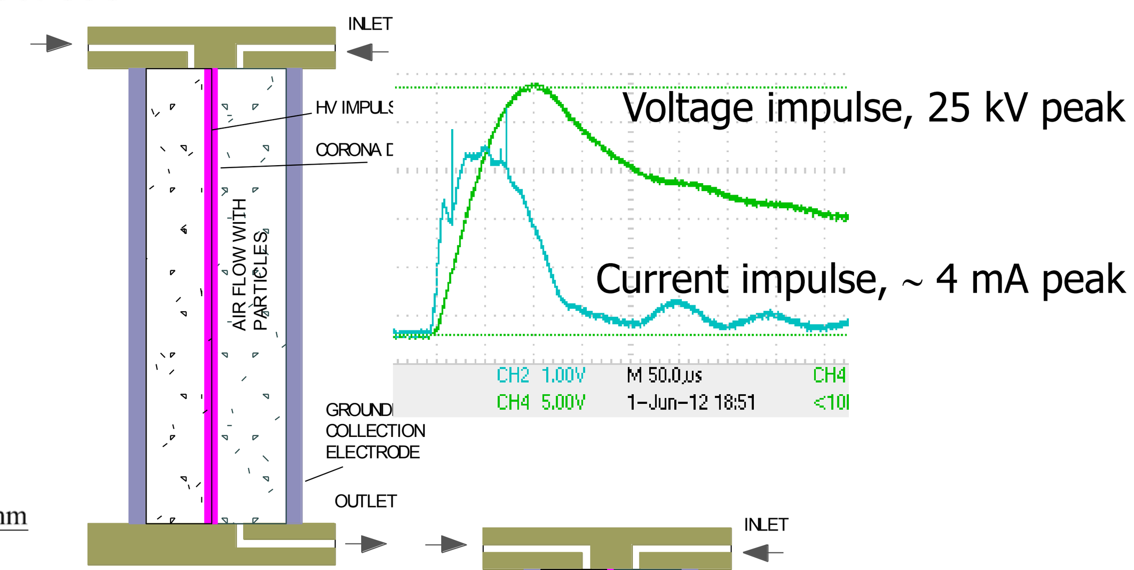
Sub – Microsecond impulses were used on top on DC voltage in a single stage reactor.

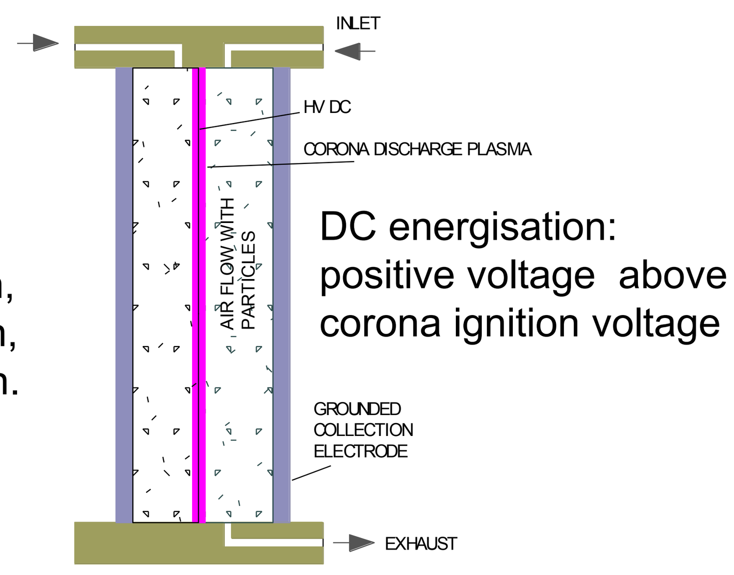


In the double – stage precipitator

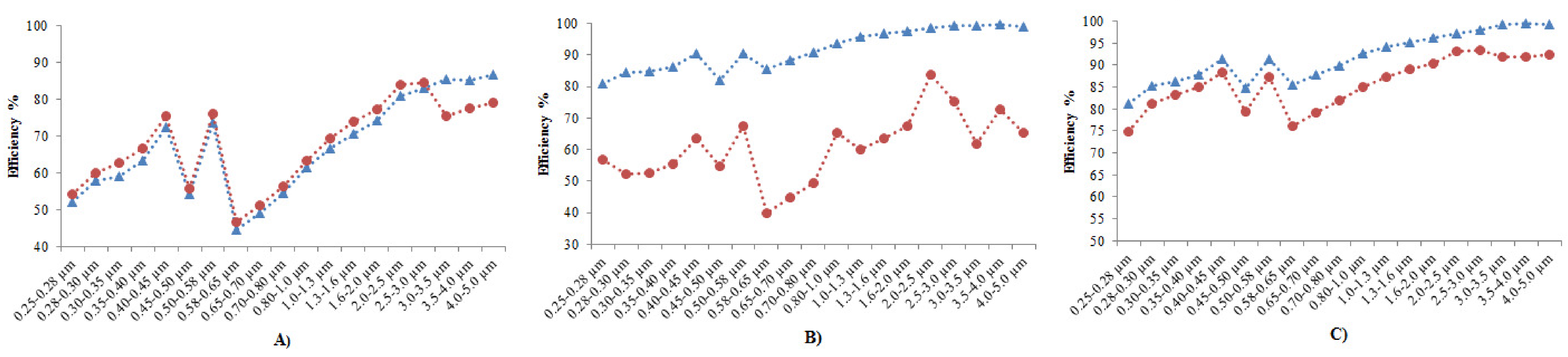
1st stage – Charging: μs impulses - wire acts as a HV electrode

2nd stage – Collecting: DC Voltage – smooth rod acts as HV electrode





Single Stage tests: H600 dolomite powder



Precipitation efficiency at

(A) +11 kV dc and +24-kV-impulse energization,
(B) +15 kV dc and +26-kV-impulse energization,
(C) +16 kV dc and +32-kV-impulse energization.

(Circles) DC energization only.
(Triangles) Superposition of dc voltage and HV impulses (50 pps)

✓ Particle spectrometer Grimm 1.109 is used for detection of fine particles.
✓ Spectrometer measures airborne particles in sizes ranging from 0.25 μm to >32 μm in 31 different size channels in real-time.

➢ It was established that the micro-ESP technology provides a high precipitation efficiencies for fine, less than 2.5 micrometer (PM2.5), airborne particles: up to 81-97%. Efficiencies of ~100% have been achieved for environmental particles larger than 2.5 μm.

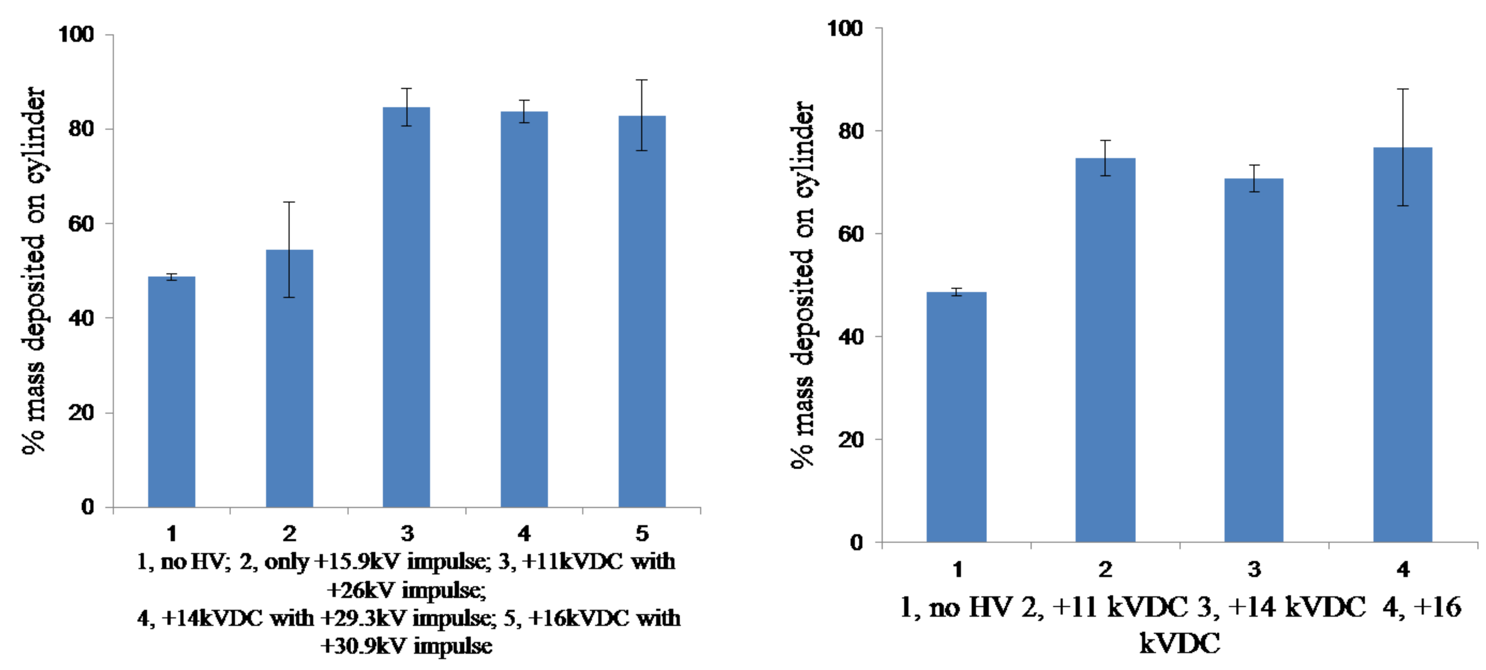
➢ Energy consumption: 6.95 μWh / pulse or 1.3 Wh / m³ of treated air.

➢ Charge injected: 1.81 μC / pulse

Single stage tests: Flour particles

Average % of particles collected on the grounded cylinder in the first histogram with DC + Impulse energisation (10 pps) and in the second one with DC only.

Each bar represents an average of 5 individual 2 min tests



➢ There is precipitation of particles without any voltage due electrostatic electrisation of particles (~50%).

➢ DC only voltage increase efficiency of precipitation at ~75%

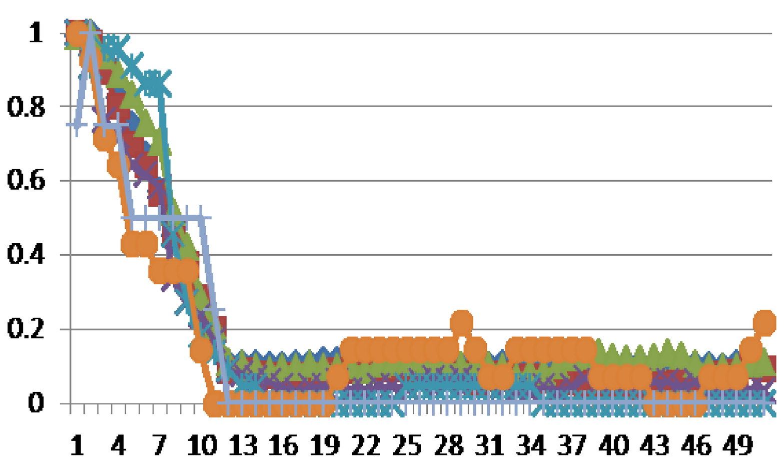
➢ Impulses superimposed on DC always improves efficiency increasing ~85% compared to the DC case.

➢ Energy consumption: 16.2 μWh / pulse or 0.6075 Wh / m³ of treated air.

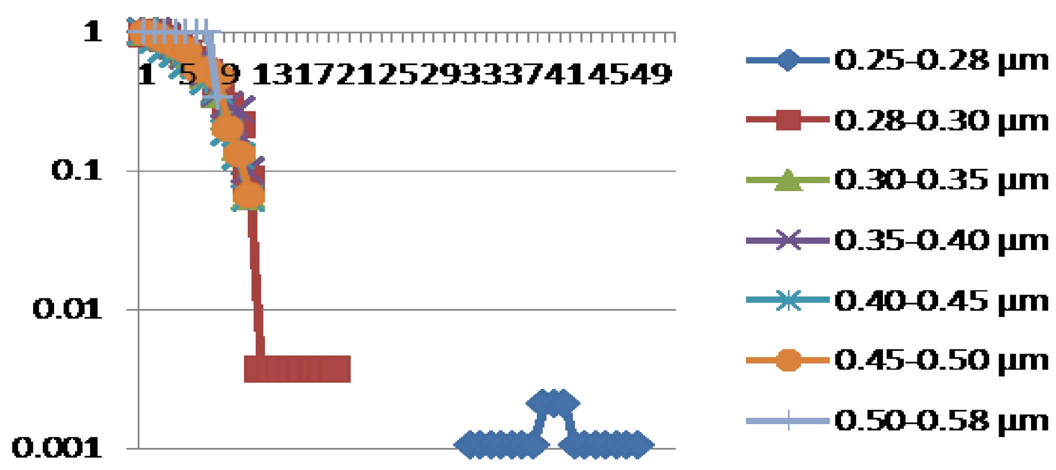
➢ Charge injected: 3.52 μC / pulse.

Environmental tests with double-stage precipitator

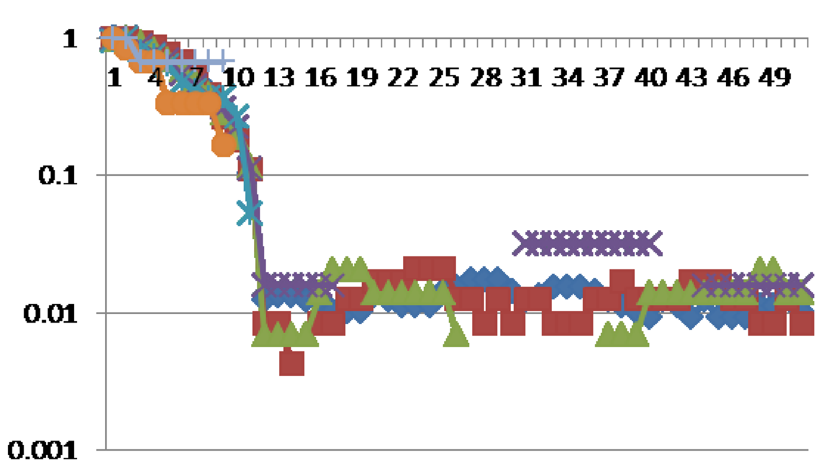
Vertical axis – normalised number of particles [$N(t)/N_{max}(t)$] Horizontal axis – time interval (interval = 6s)
Points that are 0 are not shown in logarithmic scale.



1st stage (25kV μs impulses @ 50 pps)



Both stages



2nd stage (17kV DC, 72.8 μA)

➢ With only the first stage energised ~ 10 % of the particles pass through, with only the second they fall to ~ 1 %, while with both stages only ~ 0.1 % of the particles passes through

➢ Impulse stage energy consumption: 2.6 μWh / pulse or 0.4875 Wh / m³ of treated air

➢ DC stage energy consumption: 1.2376 W

➢ Charge injected: 0.513 μC / pulse

Future work

❑ A powder resistivity measuring device has been designed in order to correlate ESP efficiency with resistivity of dusts.

❑ Smoke will also be used as it has all its particles inside the PM2.5 range and its distribution is more uniform during the measurement time.

❑ A scaled-up version of the reactor is intended to be tested later on.

[1] J. G. Ayres, "Long term exposure on air pollution: effect on mortality", Committee On the Medical Effects of Air Pollutants, 2009, COMEAP report, pp. 1-4, [Online]. Available: http://www.dh.gov.uk/ab/COMEAP/DH_108151
[2] D. Laxen, S. Moorcroft, B. Marner, K. Laxen, P. Boulter, T. Barlow, R. Harrison, M. Heal, "$PM_{2.5}$ in the UK", SNIFFER, Edinburgh, UK, Final report, Project ER12, Dec. 2010. [Online]. Available: http://www.sniffer.org.uk/Webcontrol/Secure/ClientSpecific/ResourceManagement/UploadedFiles/PM25%20Report%20Final%20%2820Dec10%29.pdf
[3] K. Parker, "Electrical operation of electrostatic precipitators", The Institution of Electrical Engineers, 2003, pp. 16.