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MMEA D4.5.1.5

Potential, possibilities and technical solutions for particle charge measurement system

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12. Summary A novel technology is developed for aerosol particle bipolar electrical charge measurement. The technology can be applied to various applications, but currently the main interest is in pharmaceutical industry inhalable drug development. This report summarizes the technology, system components and preliminary results for the developed system.		
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1 Introduction

Electrical charge of aerosol particles is known to influence on particle behaviour in various applications. Some typical areas where the charge plays an important role are nanotechnology (particle generation and usage), filtration (e.g. flue gas cleaning in electrostatic precipitators) and pharmaceutical industry (inhalable drug development).

The traditional methods for electrical charge measurement are based on either total or size-classified net charge measurement with a faraday cup electrometer. Electrical Low Pressure Impactor ELPI is a commercial device that can be used for size-classified net charge measurements.

However the recent studies in pharmaceutical industry are showing that the particle charge levels are not constant and single polarity but the charging state is typically bipolar, in other words some of the particles are carrying negative charge while other can have positive electrical charge.

In CLEEN MMEA Task 4.5.1 Dekati and TUT have been developing the ELPI+ net charge measurement technology. Developed ELPI+ instrument contains fully automated feature for this purpose.

After the net charge measurement methodology development task 4.5.1 has been expanding the charge measurement capabilities towards size-classified bipolar charge measurement. This deliverable describes the current status of this work.

2 Technology

2.1 Measurement principle

The basic idea of the technology is to use electrical field to separate positively and negatively charged particles, and use sensitive electrometers for charge detection. To have also size classified charge information several measurement channels which ideally have the same input aerosol size distribution are used in parallel. In each measurement channel particles larger than a predetermined size are removed with inertial impactors. The remaining aerosol is led to an electrical collection tube where electrical field is used to separate negative and positive particles to different electrodes. These charges (both positive and negative) are measured separately with electrometers. The impactor stages of different measurement tubes have different cut points. Therefore the currents measured by collection units derive from different particle size range. As a result the bipolar charge distribution of the input aerosol can be calculated from the results of the separate measurement channels. Operating principle of the detector tube is seen in figure 1:

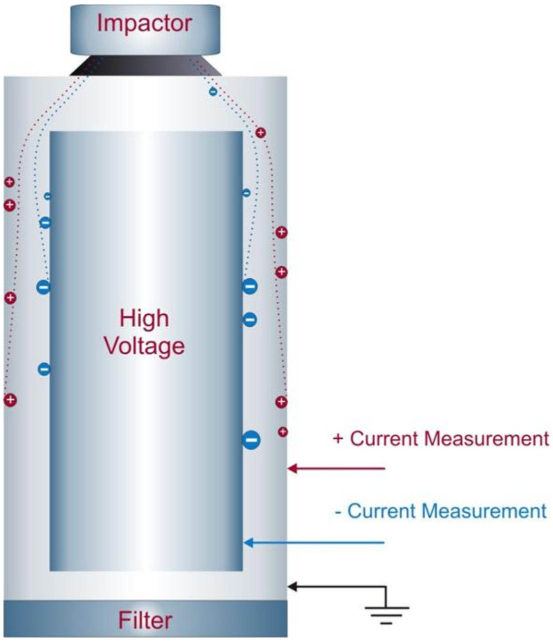

Figure 1: Principle of the charge detector tube

2.2 System components

The complete charge measurement system consists of the following four main components:

1) Flow divider
2) Pre-separator impactors for detectors
3) Detectors for positive and negative particles (electrical collection tubes)
4) Electrometers for charge detection

The following chapters describe the components in more detail.

2.2.1 Flow divider

The flow divider (Figure 2) stabilizes the sample and divides the aerosol evenly between 5 electrical collection tubes and a filter stage in the 6th branch of a flow divider. .

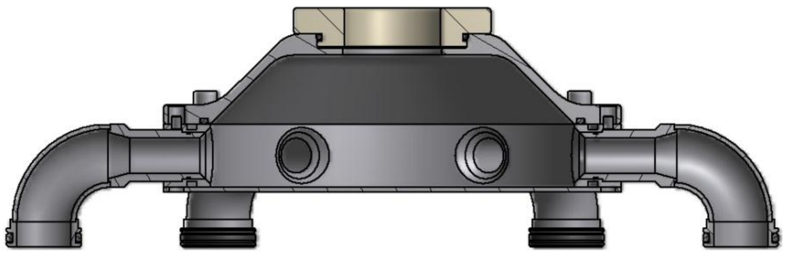

Figure 2: Cross-section of the flow divider

Flow divider acts also as a pre-separator for particles larger than approximately 15 microns.

2.2.2 Pre-separator impactors,

Tube pre-separator impactors are used for particle size fractionating. The cut points are about 0.9, 2.8, 4.4, 8 and 12.8 um, meaning that the particles smaller than those cutpoints go through the impactors to corresponding collection tubes.

2.2.3 Bipolar collection tubes

The electrical collection tube's operation is based on electrical charge separation caused by electric field. As the aerosol leaves the flow divider and after removal of large particles in the pre-separator impactor it enters one of the five bipolar cells. In the detector there are two concentric metal tubes. Inner cylinder is at high positive voltage while the outer is at ground potential. Due to the electric field the positively and negatively charged particles are collected separately either to the outer cylinder (positively charged particles) or the inner cylinder (negatively charged particles. Electrometers are connected to both inner and outer cylinders to detect the current (electrical charge) carried by the particles. Both the negative and positive charges from particles are measured from each of the five detector tubes; each one of them having a different size class for particles.

2.2.4 Electrometers

Electrometers are similar in design than those used in the ELPI+ instrument. Five normal electrometers are connected to outer cylinders, detecting the positively charged particles collected there. Five electrometers connected to the inner cylinders are floating in high voltage (1000V) to be able to detect the negatively charged particles.

Additional electrometers are used to measure the net charge from the sixth flow divider outlet (faraday cup electrometer), as well as from the pre-separator impactors. This measurement is used for data validity purposes: the net charge from the sixth outlet must be the same than the net charge (sum of impactor, positive and negative collection tubes) from all other five detector branches.

3 Intended application

Due to large interest in pharmaceutical industry the first application where the technology is applied is inhaled drug delivery to lungs with inhaler. These devices are typically used for asthma or COPD (Chronic obstructive pulmonary disease) treatment. In the first phase the developed technology is then applied to inhaler testing and the particle size range, sensitivity and usage are optimized for this application. The target is the ability to measure particles in the size range between 0 and 15 microns, high concentrations and charge levels that are typical in this application.

4 Results

Since the beginning it has been clear that some of the particles are positively charged, some of them are negative. A successful measurement result (electrical currents from detector tubes) is seen in figure 3:

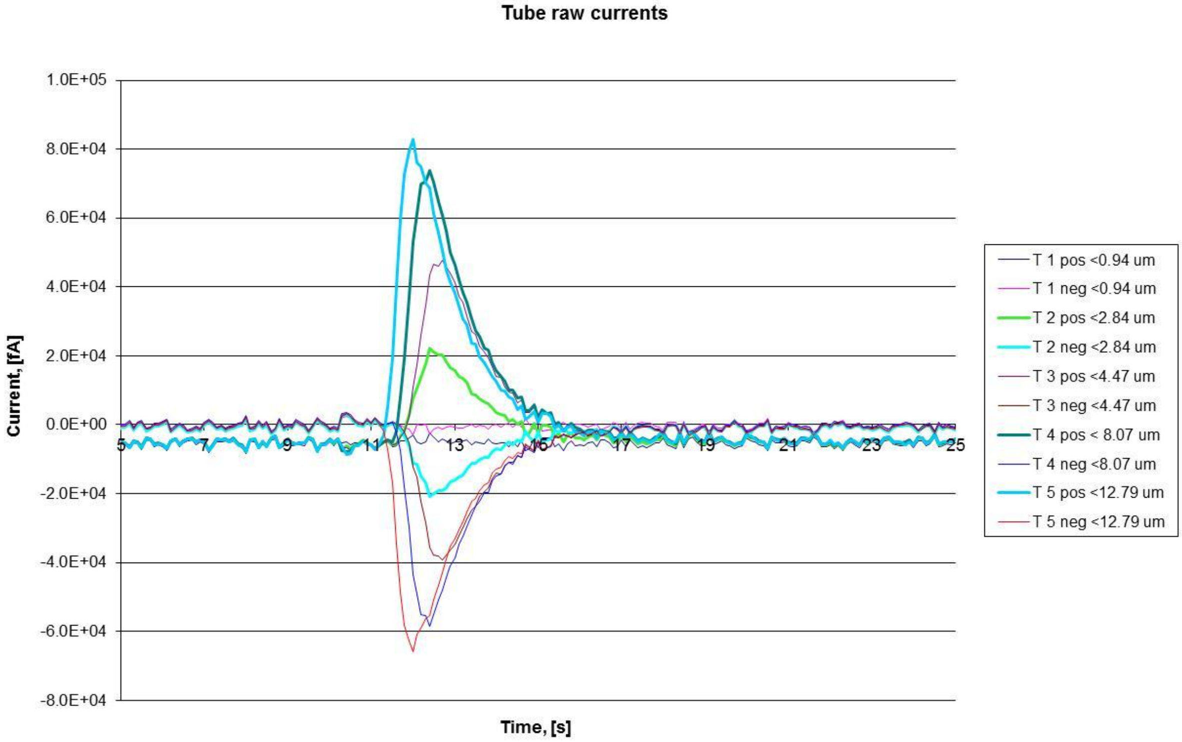

Figure 3: Measurement result: Electrical currents from inhaler particles; positively charged particles generate positive current signals, negatively charged particles cause negative current signals

It should be noted that the tube 1 is measuring all particles smaller than about 0.9 microns, tube 2 measuring all particles smaller than 2.8 microns, tube 3 measuring all particles smaller than 4.4 microns and so on. This also means that the tube 5 collects most particles and therefore it must have the largest signal levels. Respectively; tube 1 must have the smallest signal levels.

Electrical current signals are integrated over the whole measurement cycle and then converted to electrical charge units. 1 Coulomb is 1 Ampere in one second. Electrical currents measured here are in picoampere (10e-12A) range, and the charge carried by particles is therefore expressed in picocoulombs. When the current is converted top electrical charge we see the cumulative charge distribution:

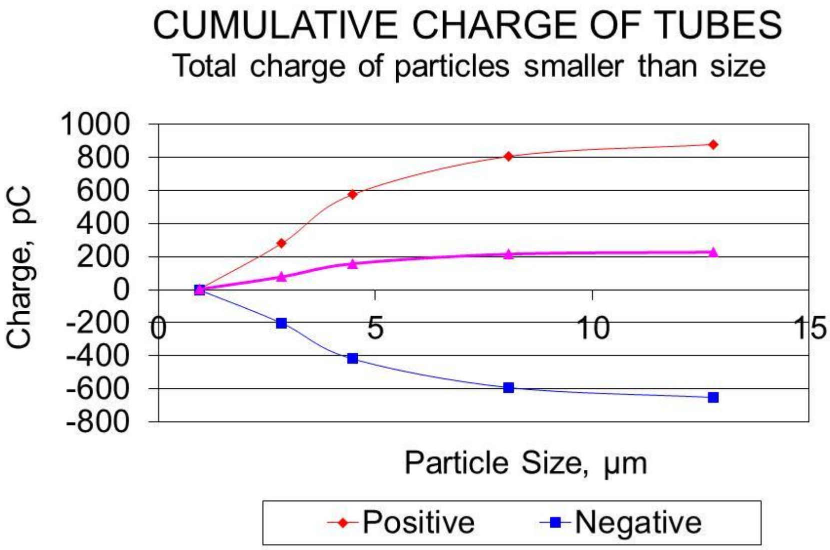

Figure 4:Example cumulative electrical charge distribution

From the cumulative charge distribution we see that the the amount ot positive charge in particles smaller than 13 microns is about 800 pC and the amount of negative charge is about -600 pC. Net charge (the sum of these) is + 200 pC.

By looking at the differences between tubes we can see the discrete electrical charge distribution:

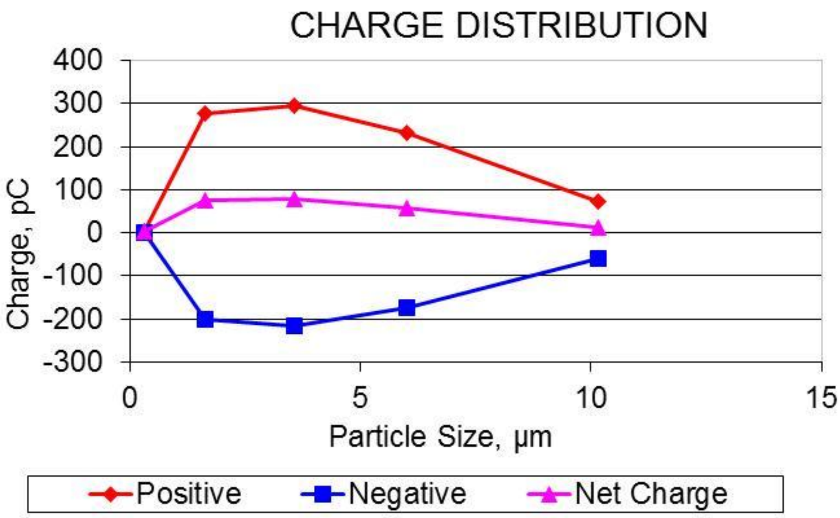

Figure 5: Measurement result: Discrete charge distribution

Here the electrical charge in each size class is taken from the cumulative charge distribution by subtracting the signals from each other. Channel 1 result is taken directly from the cumulative distribution, Channel 2 result is got by subtracting the channel 1 result from channel 2 result and so on.

5 Conclusions

A unique system has been developed for aerosol particle electrical charge measurements. The technology expands our know-how on electrical charge measurements and allows bipolar charge measurements for pharmaceutical drug particle analysis. The technology has been demonstrated successfully with inhaler powder measurements.

The data got from the system is unique; there is very little information about the bipolar electrostatic properties of aerosol particles. With this technology it is possible to gain new information about the particle behavior in different environments. Within pharmaceutical industry there is clear commercial interest on this technology.

Particle charge measurement system described and demonstrated here is built for the inhaler particle charge measurements. Particle size range is typically larger than 1 microns, one sample containing some 10 – 20 mg of powder. An investigation is started already to evaluate the interest on the charge measurement in other particle applications. Main focus at the moment is on nanotechnology, in filtration and in power plant ESP optimization.