EPSC Abstracts
Vol. 6, EPSC-DPS2011-815, 2011
EPSC-DPS Joint Meeting 2011

Electrostatic accelerators for micrometer sized dust particles as a tool for planetary and impact physics research

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Abstract

Electrostatic accelerators, equipped with a dust particle source, provide micrometer-sized particles as projectiles for hypervelocity impact experiments [1]. Recently there has been some significant progress regarding materials that can be used for acceleration as well as concerning the detection, monitoring, and selection of the particles.

1. Introduction

In the past five decades various dust detection instruments on spacecrafts have been used successfully to investigate *in situ* the physical, dynamical, and chemical properties of cosmic dust in the Solar System. These instruments use the fact of the particle impinging onto a target and the physical processes which origin from this event. This can be for example the emerging of an impact ionisation plasma from a metal plane target or the track of the particle in an aerogel. To calibrate an instrument and to get an deeper understanding of the involved processes, hypervelocity impact measurements under similar and well defined conditions are required. For this, micrometer- and submicrometer sized particles are charged and passed into an homogenous accelerating field, and focused onto the investigating instrument.

2. Charging and acceleration

The dust beam originates from the dust source within the high voltage terminal of the accelerator.

After exiting the source, the dust particles are accelerated in the electrostatic field towards the experimental set-up. Before reaching the target, the particles are registered, characterised, and eventually selected while passing the beam line detectors of the Particle

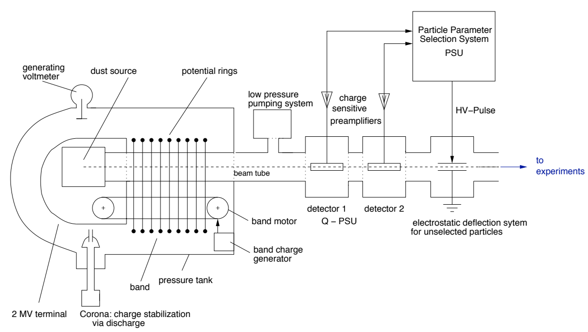

Figure 1: Schematic of a dust accelerator.

Selection Unit (PSU).
To reach high particle velocities, two requirements must be met. Both the accelerator potential and the charge-to-mass ratio (q/m) of the particles must be as high as possible. The charge of the particle is given by

$$q = \frac{\Phi}{4\pi\,\epsilon_0 r}, \quad (1)$$

with Φ being the surface potential of the particle and r its radius. The electrical field strength $F = \Phi/r$ at the surface is limited by ion field emission. Assuming the maximum field strength is constant for all particle sizes for one particular material, broad fundamental relationships for the dynamical parameters of homogeneous spherical particles can be found.

2.1 Dust materials

For the above described method of acceleration to work, the particles must therefore be capable of carrying charge and hence the range of materials used has been restricted to those which are either wholly conductive or those with a conductive coating. In the last

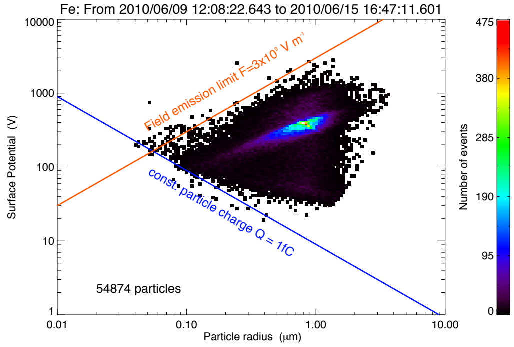

Figure 2: The surface potential $\Phi = q/4\pi\, R\, \epsilon_0\, r$ for iron particles in dependence on the particle size [4].

few years two techniques of coating underwent significant improvements.

- Coating of organic and silicate materials with conducting polymers (PPY-coated) [2].
- Coating of silicate particles with metals such as platinum [3].

This opens up a whole new range of material types to investigate.

3. Particle Selection

After their acceleration the particles can be selected due to their velocity, charge, and mass according to the requirements of the specific experiment. For this the particles are been detected by a chain of detectors measuring the particle's primary surface charge using an induction tube and a charge-sensitive amplifier (CSA). Due to a rising interest in measuring particles with very low primary charges a new low-noise detector has been developed for the beam-line of dust accelerators as shown in Fig. 3 [5].

The main component of the new particle selection unit (PSU) is a Field Programmable Gate Array (FPGA), capable of real time monitoring the particle's speed and charge. The selection of particles due to charge, speed and / or mass is possible.

4. Applications

The physical phenomena occurring during hypervelocity microparticle impact are manyfold and are the basis for the variety of applications. The processes of interest are particle fragmentation, impact ionisation, impact flashes, charge induction, microphony and

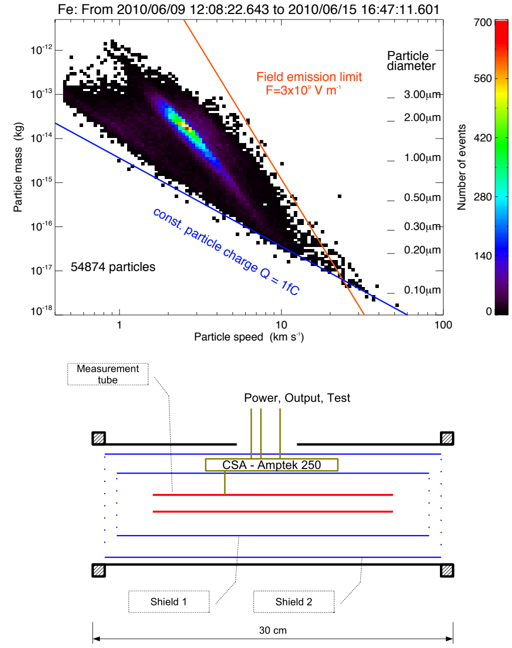

Figure 3: *(above)* Velocity mass distribution for iron particles The blue line at the bottom determines the detection threshold of 0.1 fC and indicates particles with a constant charge. The red line represents a field emission limit of the grains of $10^{10} V\, m^{-1}$ for grains with a constant field strength [4]. *(bottom)* Charge detector developed with multiple electrical shields for the reduction of noise and thus, lowering the threshold for particle detection [5].

mass spectrometry. Their detailed investigation using latest analysing techniques like high-speed cameras and sensitive high-resolution spectrometers promise new instrument concepts and insights into short-time high-pressure states of matter.

References

[1] J.F. Friichtenicht, Rev. Sci. Instrum., Vol. 33, pp. 209 - 212, 1962.

[2] M. J. Burchell et al., J. Appl. Phys. D, Vol. 32, pp. 1719-1728, 1999.

[3] J. K. Hillier et al., Planet. Space Sci., Vol. 57, pp. 2081 - 2086, 2009.

[4] A. Mocker et al., Rev. Sci. Instrum., subm. 2011

[5] R. Srama and S. Auer, Meas. Sci. Technol., Vol. 19, 2008.