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DEVELOPMENT AND CHARACTERISATION OF AN ELECTRO-HYDRODYNAMIC AEROSOL SPRAY SYSTEM

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INTRODUCTION

The application of a high electric field to a conducting liquid resulting in its break-up into a spray of fine droplets has been utilized for the development of Electrohydrodynamic (EHD) sprays for generating nanoparticles for various applications such as production of metallic particles (*Salata 2005*), aerosol standards (*Meesters et.al. 1992)*, polymer films (*Rietveld et.al., 2005*); medical inhalation therapy and air cleaning (*Tang and Gomez, 1994; Balchandran et.al. 2003*) etc. The distinctive features of this technique are monodispersity of generated particles, their highly charge and controllable droplet size by varying flow rate or electrical conductivity of the liquid. EHD atomization comprises of pumping the liquid through a capillary maintained under a high potential with respect to a plate kept at a distance from the capillary tip. As a result of the electric stress, a liquid cone is formed at the tip of the capillary. The highly charged tip of this cone develops into a fine jet which breaks up in to a number of primary and secondary droplets (*Hartman et.al., 1999*). This paper presents initial experimental results of various operating characteristics of a prototype EHDA system developed in our laboratory.

EXPERIMENTAL SET-UP

The schematic of the EHDA system is as shown in Fig.1. It consists of a metal capillary (hypodermic needle of OD 1.5 mm and ID 0.5 mm) placed vertically to which a positive dc voltage (*V*) in the range of 2-8 KV is applied. A circular brass electrode of diameter 160 mm, placed at a distance of approx. 10 mm from the capillary tip, serves as the ground for this system. This entire assembly is housed in a perspex cylindrical chamber of height 250 mm and diameter of about 90 mm and has 3-4 ports for aerosol sampling. The flow of the liquid (ethylene glycol) is controlled using a syringe pump. The ambient particles are deterred from entering the chamber by a flow of Nitrogen gas at 2 l min^{-1}. The highly charged droplets produced are neutralized using a Sr-90 radioactive source placed in the lower half of the chamber. The current (*I*) carried by the droplets was measured using an electrometer (Keithley make) connected between the brass plate and the ground. The particle size distribution after neutralization was measured using Scanning Mobility Particle Sizer (SMPS) which measures the sizes in the range of 10 nm to 1 μm in about 50 channels and Optical Particle Counter (OPC) which has the particle measuring range of 0.3 to 30 μm.

RESULTS AND DISCUSSIONS

a) Size Distribution Measurements

The typical size distribution of the droplets for a flow rate, *Q*, of 1 ml/h and for an applied voltage of 5.38 KV after neutralization is shown in Fig.2. The consistency of mean droplet size as shown in Fig.2 is indicative of the stability of the EHDA. The average geometric mean diameter over a period of about 30 minutes was 23.6 nm and the associated geometric standard deviation (σ_g) was 1.9. The main cause of the deviation from monodispersity may be inadequate neutralization, onset of instabilities and space charge due to corona.

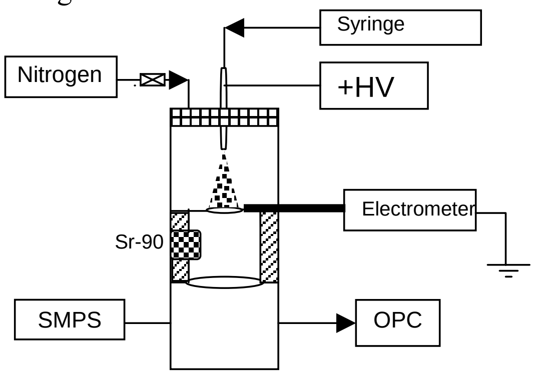


Fig.1: Schematic diagram of EHDA system

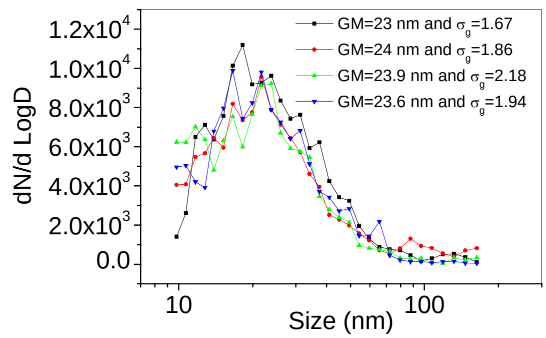


Fig.2: Size distribution of Ethylene Glycol droplets Q= 1ml/h and V= 5.38

b) I-Q Characteristics

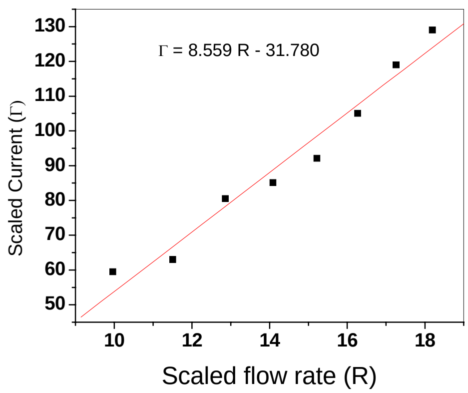
The electrospray current '*I*' is defined as the charge streaming from the cone tip per unit time in spray cone jet mode. For a given capillary electrode, the current-flow rate characteristics in the dimensionless form Γ versus *R* is given by:

$$\Gamma = \frac{I}{I_o} \text{ and } R = \left[\frac{Q}{(\beta-1)^{1/2} Q_o}\right]^{1/2} ; \; I_o = \left[\frac{\varepsilon_o \gamma^2}{\rho}\right]^{1/2} \text{ and } Q_0 = \frac{\gamma \varepsilon_0}{\rho K}$$

where *K* is the electrical conductivity, ρ the density, ε is the relative permittivity, γ is liquid surface tension. This is depicted in Fig. 3 for the present system. It is noteworthy that the experimental points lie close to a straight line with a slope of 8.559 which is in fair agreement with the reported value of 6.2 for ethylene glycol (*Ganon-Calvo at.al., 1997*). The deviation could be reduced by suppressing the corona current by covering the capillary with a gas having higher breakdown voltage (for e.g. CO_2, SF_6 etc.) and refining the sharpness of the capillary tip.

c) I-V Characteristics

The *I-V* characteristics of the EHD system for 1) dry capillary mode and 2) spray mode are presented in Fig.4. Overall comparison of *I-V* responses indicates that dry capillary current reduces when spray in cone jet mode starts. This is because fine droplets form space charge that reduces the electric field at the tip of capillary and prevents the corona discharge, and thus reduces the emitted current. From the I-V characteristics it also appears that the spray starts slightly earlier than the dry corona. Hence, one can operate the electrospray at lower voltage to eliminate corona component.



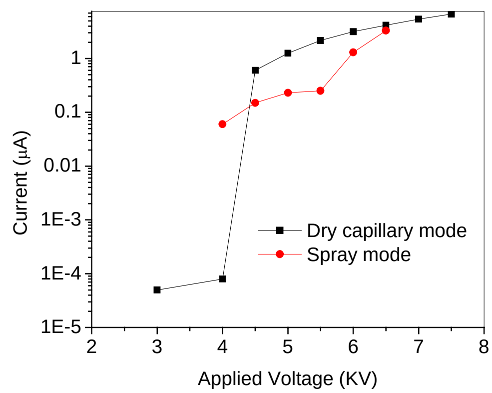


Fig. 3: I-Q characteristics of the EHDA system

Fig. 4: I-V Characteristics of EHDA system

CONCLUSIONS

A prototype EHDA Spray system has been designed and developed to generate charged or neutral, nano-aerosol particles from solutions and suspensions. The measurements made with SMPS using Ethylene Glycol show particles with 23.6 nm with σ_g=1.9. The *I-Q* characteristics conform to the linear law, although the slope and intercept are slightly different from that suggested in the literature. The I-V characteristics clearly show that onset of spray occurs at a voltage less than that for the onset of corona, which provides a useful operating information. Further work is in progress on the study of efficient neutralization and reduction of polydispersity of aerosols.

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