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**ELECTROSTATIC STUDIES ON
PHARMACEUTICAL POWDERS AND AEROSOLS**

by

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ABSTRACT

This thesis concentrates on various problems and phenomena associated with electrostatic charging of pharmaceutical powders and aerosols. The main objective of this study is to enlighten some factors which have an effect on the generated charge. These factors involve, for example, charging of powder mixtures, effect of small particles in the powder mixture, surface amorphicity, and detergent contamination on pharmaceutical production equipment. All these things are present to some extent in pharmaceutical production. Also, new measurement techniques for electrostatic charging experiments are presented. These methods give valuable information on particle-particle charging, charging of powder when fluidized in a miniaturized fluidized bed, and complex bipolar charging of an aerosol when emitted from a dry powder inhaler.

Resistivity of a powder mixture which contained lactose and glucose was found to follow a linear relationship with the concentration but although frictional charge is often related to the resistivity, the nature of the charge transfer process between the mixture and a glass pipe changed considerably. Both pure materials charged positively in contact with the glass but some mixtures became negatively charged due to powder-powder contacts within the flow and near the pipe surface. It was noticed that in contact with each other, lactose charged positively and glucose negatively.

Observed behavior was studied with closer detail and also by different materials. The role of adhered powder to the pipe surface was found to have a significant effect on the generated charge. Small particles which stick on the pipe surface change the charging process from powder-pipe contacts to powder-adhered powder -contacts. It was noticed that a very small concentration of small particles may change the sign of the total charge of the powder mixture. By adjusting the small particle concentration, a neutral total charge can be obtained which could have a clear industrial importance.

It was also found that a typical procedure such as washing the process equipment might have a significant effect on the generated charge. Several typical

detergents were used to "contaminate" the surface of a steel pipe. Measured charges varied from positive to negative depending on the detergent used and these detergents were arranged in triboelectric series.

Surface amorphicity has a significant role on the properties of the materials including charging. It was noticed that the frictional charge between lactose and polypropylene increased with increasing amorphicity. A sample with less than 1 % of amorphicity increased the generated charge more than 3 times compared to crystalline lactose. It was suggested that triboelectric measurements could be used in studying samples with small surface amorphicities.

The morphology, amorphicity and following recrystallization of the lactose powder had a measurable effect on the charge of the lactose aerosol when it was emitted from two different dry powder inhalers. It was shown that different preparation parameters of the spray dried lactose also changed the total charge of the aerosol.

Electrostatic charge carried by an aerosol has an effect on the function of an inhaler. To study the complex bipolar charging, a novel grid-probe was designed. It was found out that the grid-probe can be used to study whether the drug and additive particles are emitted separately from the dry powder inhaler.

Electrostatic forces may deteriorate the quality of a fluidized material due to sticking on the walls of a fluidized bed device. These effects are emphasized in a miniaturized fluidized bed. A novel measurement technique based on charge induction was developed to study the complex charging process without disturbing the sensitive flow. This system allowed charge scanning across the fluidized bed, or real-time monitoring of generated charge at a chosen location. The probe was modeled and the experimental data was simulated using an advanced field solving software.

LIST OF ORIGINAL PAPERS:

This thesis is based on the following publications which will hereafter be denoted as papers I-VII:

- I M. Murtomaa, and E. Laine:
Electrostatic measurements on lactose-glucose mixtures
J. Electrostat. **48**, 155 (2000).
- II M. Murtomaa, K. Ojanen and E. Laine:
Effect of surface coverage of a glass pipe by small particles on the triboelectrification of glucose powder
J. Electrostat. **54**, 311 (2002).
- III M. Murtomaa, K. Ojanen, E. Laine and J. Poutanen:
Effect of detergent on powder triboelectrification
Eur. J. Pharm. Sci. **17**, 195 (2002).
- IV M. Murtomaa, P. Harjunen, V. Mellin, V-P. Lehto and E. Laine:
Effect of amorphicity on the triboelectrification of lactose powder
J. Electrostat. **56**, 103 (2002).
- V M. Murtomaa, V. Mellin, T. Lankinen, E. Laine and V-P. Lehto:
Triboelectrification of lactose by dry powder inhalers: Effect of feed solution of the spray drying
J. Aerosol Sci. (submitted).
- VI M. Murtomaa, S. Strengell, E. Laine and A. Bailey:
Measurement of electrostatic charge of an aerosol using a grid-probe
Proc. 30th Ann. Conf. ESA (2002).
- VII M. Murtomaa, E. Räsänen, J. Rantanen, A. Bailey, E. Laine, J-P. Mannermaa and J. Yliruusi:
Electrostatic measurements on a miniaturized fluidized bed
J. Electrostat. **57**, 91 (2002).