Mechanische Verfahrenstechnik und Mechanik
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Investigations on the precipitation of particles charged by thermionic emission

The objective of this study is to understand the charging process and the factors that influence the particle charge at high temperatures. Furthermore, the possibilities and limitations of the precipitation of charged particles are investigated.
Particles were classified in a DMA and afterwards passed through a Al_20_3-tube in a furnace. Above the furnace electrodes are mounted. Two different methods were used to determine the mean particle charge. Firstly, an adjustable electric DC field perpendicular to the gas flow is applied, to precipitate the charged particles. The resulting grade efficiency is measured by determining the particle concentration by a CPC (after cooling) with and without an electrical field. By comparing the precipitation with an electrostatic precipitator, we can relate the grade efficiency to a Deutsch number and thus to a migration velocity that is proportional to the particle charge. Secondly by applying AC instead of DC voltage, a mean particle charge can be measured directly with a combination of CPC and FCE.
The main results of our investigations are summarized in what follows:
Fig. 1 shows what was found with applying an AC voltage.
Although theory predicts thermionic emission of electrons from the pariticles and thus positively charged particles, the measured mean particle charge is negative for furnace temperatures above 800°C.

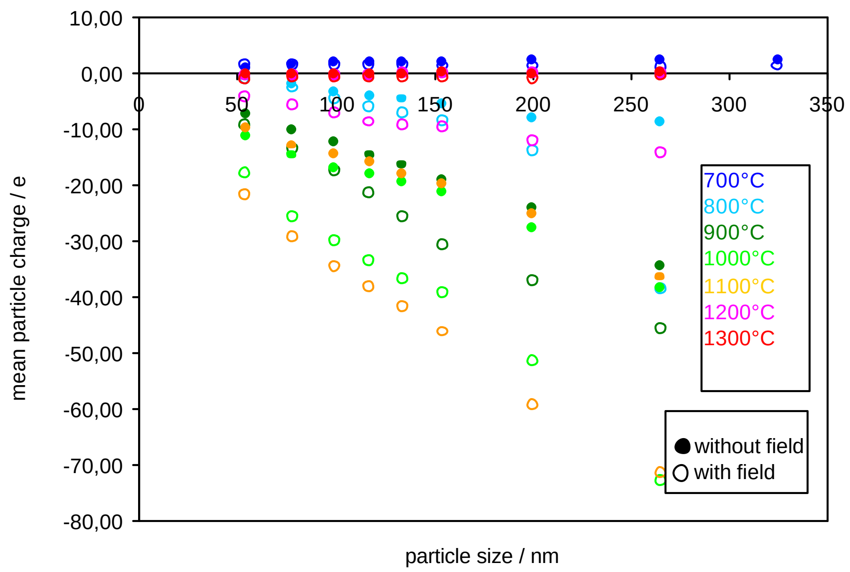

Fig 1. Linear dependence of the mean particle charge on particle size

Besides, the mean particle charge becomes even more negative when an electrical field is applied. (For furnace temperatures above 1200°C this rise in the particle charge begins at higher field strength, around one 10000 V/m and 20000V/m for 1200°C and 1300°C respectively.) This shift in the particle charge indicates a charging process of the particles caused by charges emitted from either the Al2O3-tube or the TiO2 particles that have already been deposited.

Our measurements with DC voltage to precipitate the particles show a threshold of the electric field strength that has to be exceeded for particle precipitation. This minimal electric field strength at which significant precipitation occurs is dependent on the furnace temperature, see Fig. 2

The needed field strength first decreases with increasing temperatures, until it seems to be constant at 50000V/m.

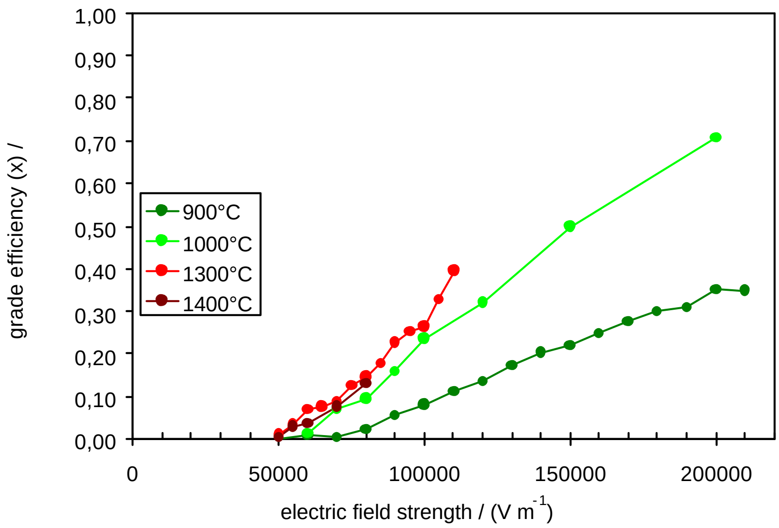

Fig 2. Percipitation threshold field strength

The precipitation threshold shows a strong dependence on the particle concentration. Measurements with a set-up where the particles are size classified (78nm) after the furnace and the precipitation zone result in a significantly lower threshold of 25000 V/m for precipitation at a furnace temperature of1300°C. This rises the question, if the difference in the precipitation behavior is caused by electrostatic dispersion of the particles after the electrode zone. Further investigations on the described phenomena are planned.

The focus will ly on the emitting behavior of the Al_20_3-tube.

Acknowledgement

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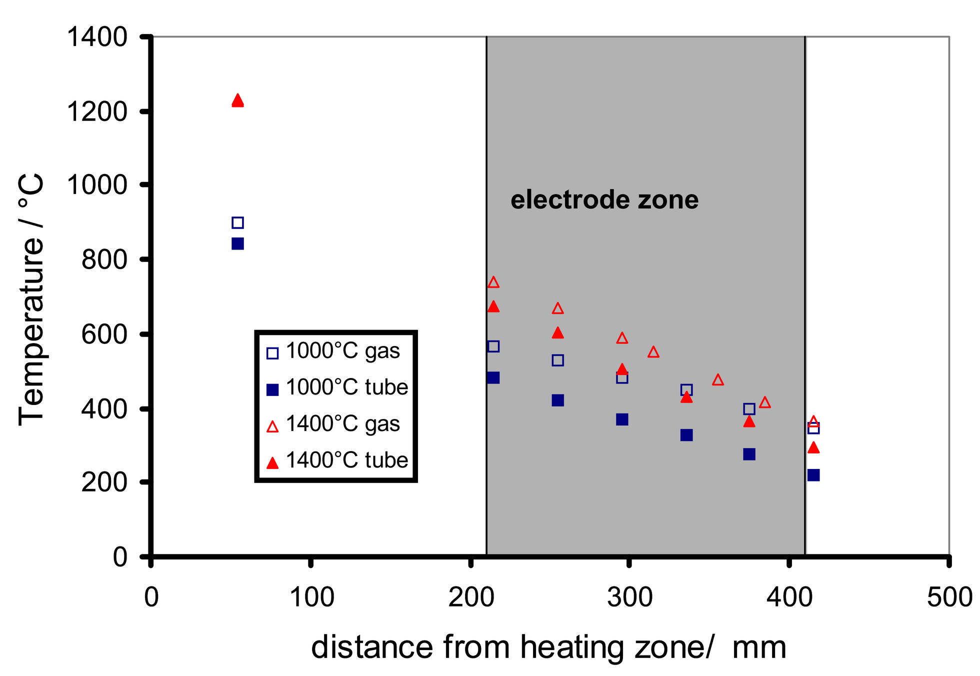
Introduction

The power industry has to face the call for more efficient coal fired power plants in order to decrease CO_2 emissions. New efforts to improve the combustion processes have been made, where pulverized coal is burned at a temperature of 1400 °C and a pressure of 16 bar. The hot flue gas then can be used for a combined gas and steam turbine process. Accordingly, the flue gas has to be cleaned at the operating temperature and pressure before entering the gas turbine. Granular bed filters were successfully tested for the removal of larger particles, but they are not sufficient for the separation of particles smaller than approximately 3 µm. The particles are significantly charged by thermionic emission of electrones. One option to clean the flue gas from the remaining particles is electrostatic precipitation of the - highly charged - particles.
The objective of this study is to understand the charging process, the factors that influence the particle charge at high temperatures and to investigate the possibilities and limitations of the precipitation of charged particles.

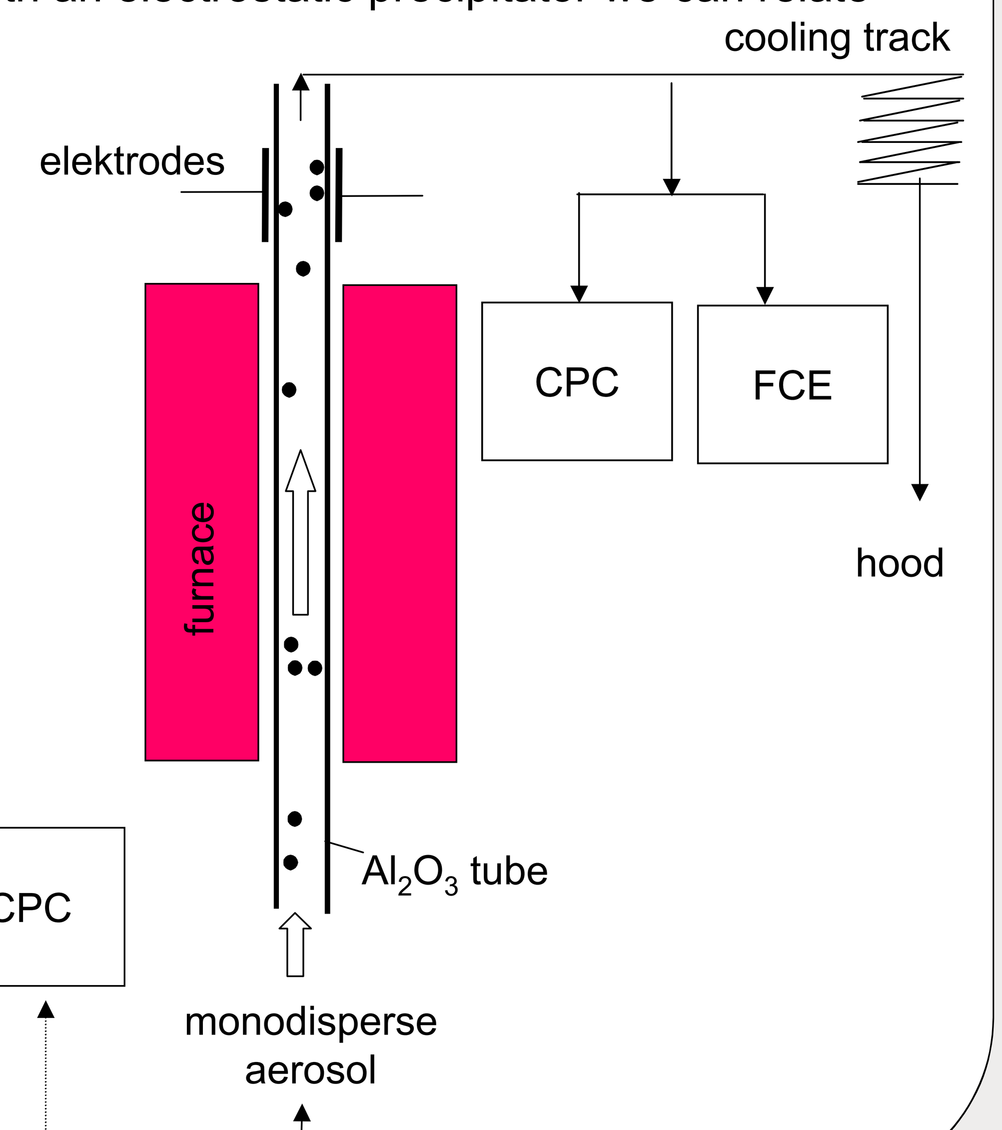
Temperature profile

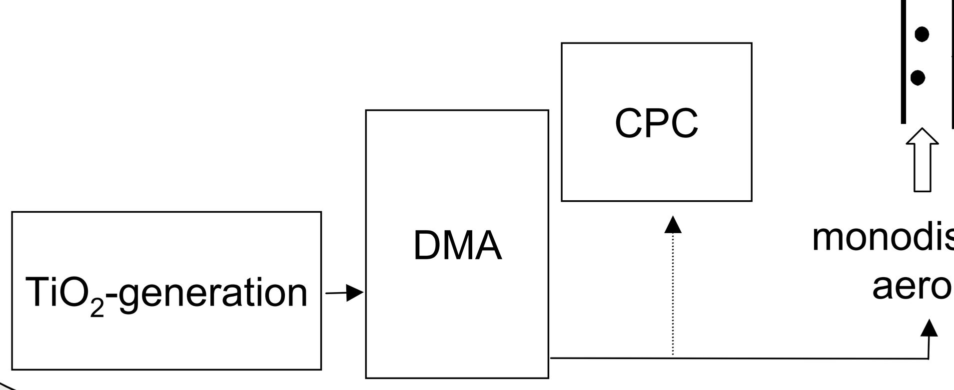


Assuming that the kinetic processes upstream are fast, the temperatures in the electrode zone must be known to determine a mean particle charge from the grade efficiency data.

Experimental Set-up

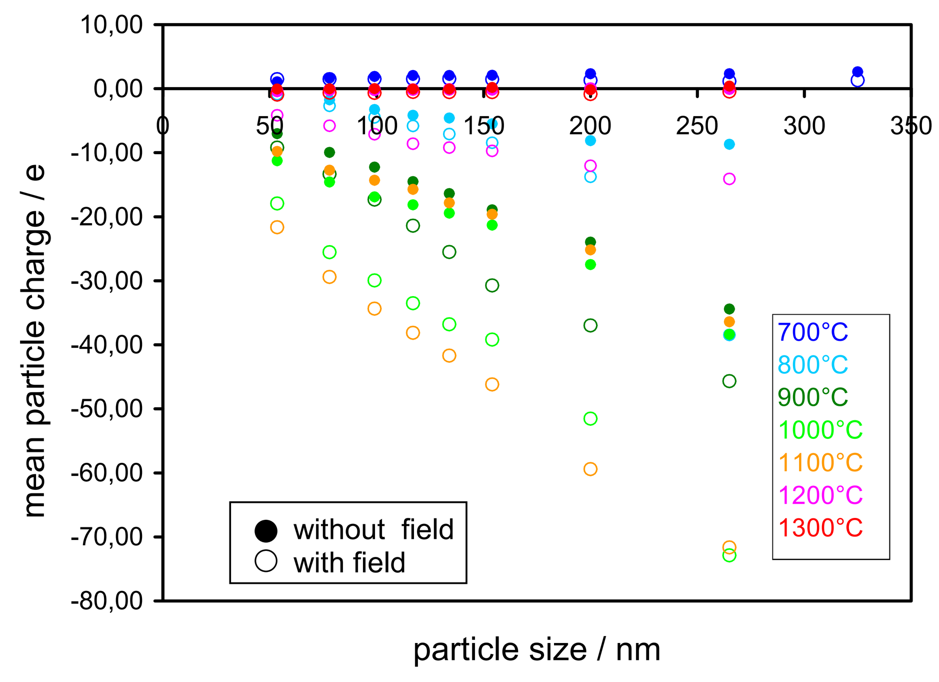
In a lab-scale experimental set-up TiO_2 -particles were generated in a hot wall reactor, by thermal decomposition of Titanium-tetraisopropoxide. The TiO2-particles were passed through a furnace. Above the furnace the electrodes are mounted. Two different methods were used to determine the mean particle charge.
Firstly, an adjustable electric DC field perpendicular to the gas flow is applied, and the resulting grade efficiency is measured by determining the particle concentration by a CPC (after cooling) with and without electrical field. With this setup the influence of particle losses caused by thermophoresis does not have to be considered.
By comparing the precipitation with an electrostatic precipitator we can relate the grade efficiency to a Deutsch number thus a migration velocity that is proportional to the particle charge. Secondly by applying an AC instead of a DC voltage a mean particle charge can be measured directly with a combination of CPC and FCE.



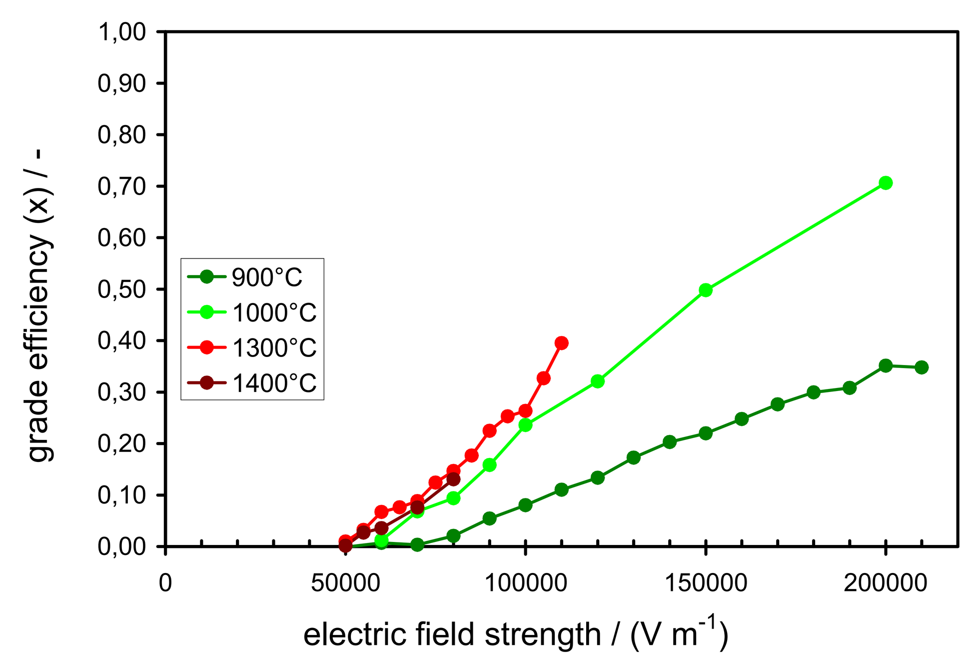


Results

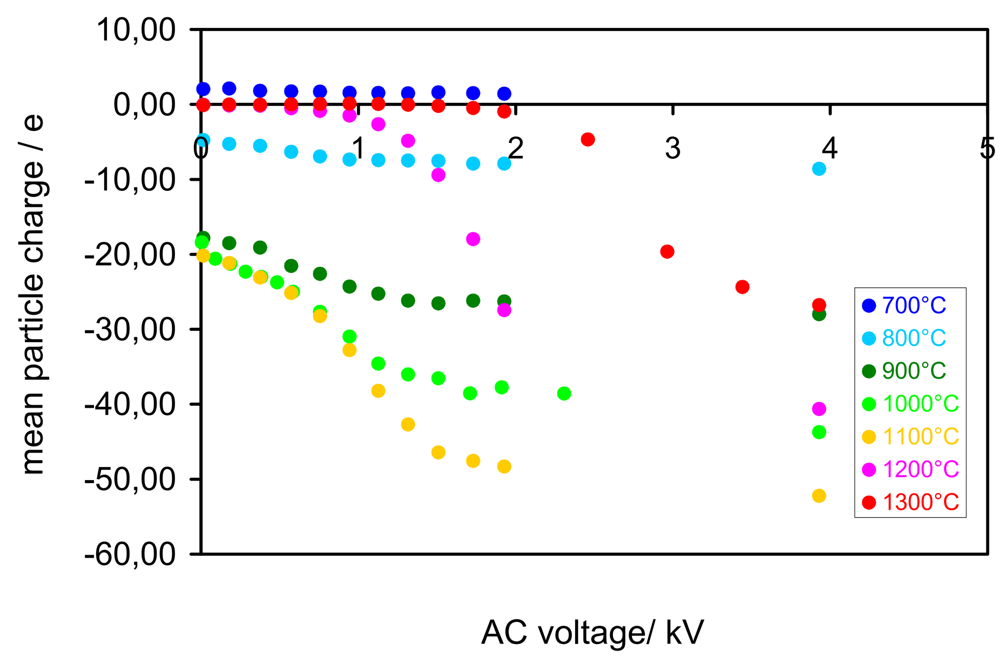
Influence of particle size



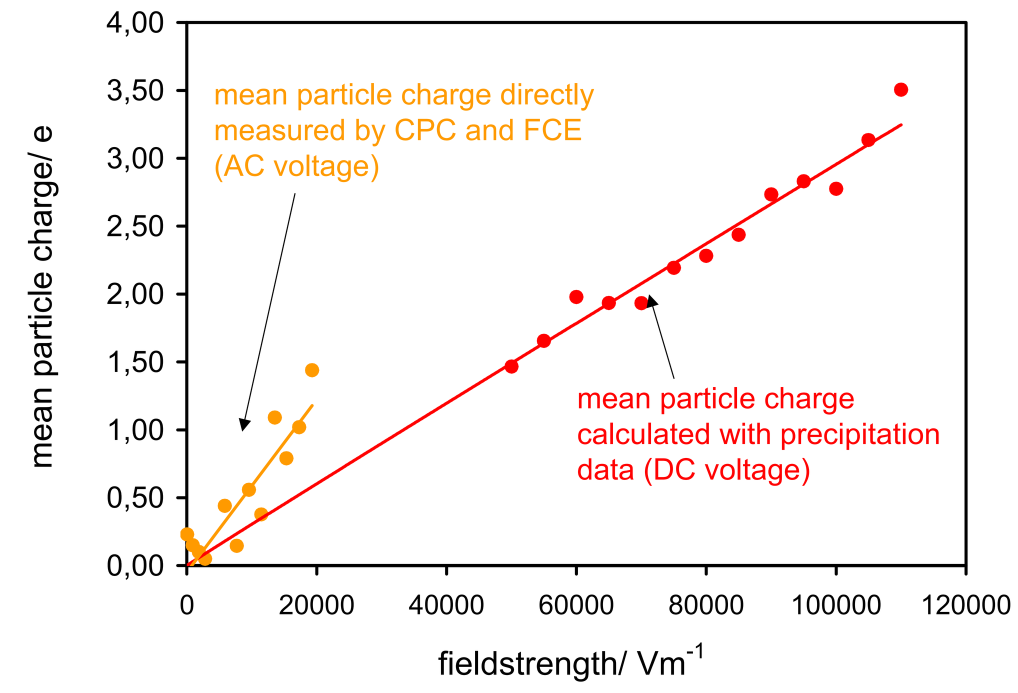
Minimal electric field strenght



Influence of electrical field strength



Comparability of both meathods



Conclusions

While the theory predicts positive particle charges caused by thermionic emission of electrones, above a furnace temperatures of 800°C the mean particle charge is negative. Applying an external electrical field shifts the mean particle charge to higher negative values, This indicates an external particle charging process by charges emitted from either the Al_2O_3-tube or the TiO_2 particles that have already been deposited.
In agreement with theoretical predictions the mean particle charge increases linear with the particle size.
Up to a temperature of 1100°C the particle charge is rising both with increasing temperature and increasing electrical field. For higher furnace temperatures, the particle charge is decreasing again. The mean charge at these temperatures can be increased by applying an electrical field, but the field has to overcome a minimum field strength achieve a rise. This threshold field strength is rising with the temperature.
To precipitate the particles, a minimum electric field strength must be overcome, as well.
Although this behavior shows a kind of similarity with the charging process of particles at temperatures above 1200°C, more investigations are necessary to understand the described phenoma.
For 1300°C the determined mean particle charges of both methods are comparable.

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