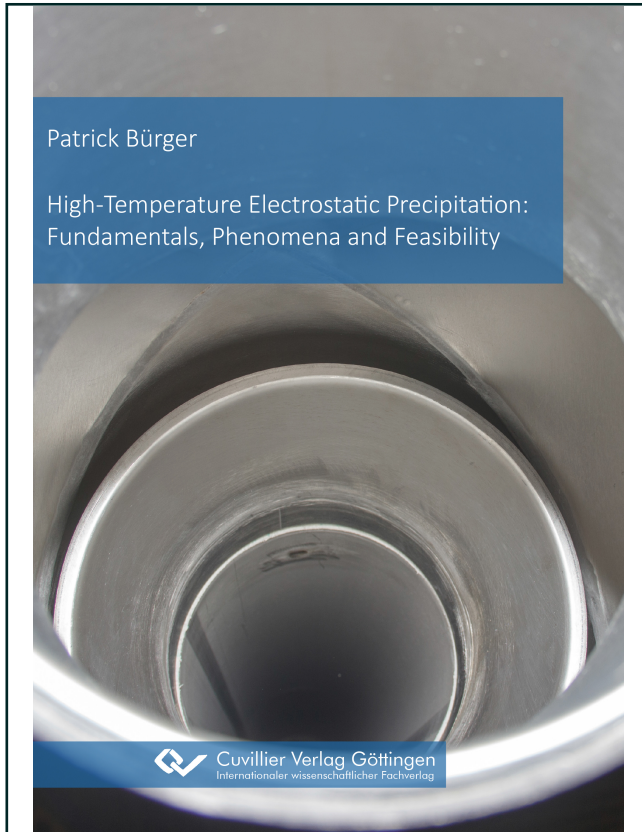




Patrick Bürger (Autor)
**High-Temperature Electrostatic Precipitation:
Fundamentals, Phenomena and Feasibility**



<https://cuvillier.de/de/shop/publications/8865>

Copyright:
Cuvillier Verlag, Inhaberin Annette Jentsch-Cuvillier, Nonnenstieg 8, 37075 Göttingen,
Germany
Telefon: +49 (0)551 54724-0, E-Mail: info@cuvillier.de, Website: <https://cuvillier.de>

Table of contents

| | |
|--|-------------|
| Abstract | I |
| Zusammenfassung | II |
| Acknowledgements | IV |
| Table of contents | V |
| List of abbreviations | VIII |
| List of symbols and constants | IX |
| List of indices | XI |
| 1 Introduction | 1 |
| 2 Fundamentals of electrostatic precipitation | 2 |
| 2.1 General working principle..... | 2 |
| 2.2 Corona discharge | 5 |
| 2.2.1 Onset criterion | 5 |
| 2.2.2 Polarity characteristics..... | 6 |
| 2.2.3 Sparkover | 9 |
| 2.3 Current-voltage characteristics..... | 10 |
| 2.4 Particle charging and precipitation | 12 |
| 2.4.1 Unipolar particle charging mechanisms..... | 12 |
| 2.4.2 Migration velocity and particle precipitation | 13 |
| 2.4.3 Corona quenching..... | 15 |
| 2.5 Dust resistivity and the phenomenon of back corona..... | 15 |
| 3 State of knowledge | 17 |
| 3.1 Research on high-temperature electrostatic precipitation | 17 |
| 3.2 Influence of pressure, temperature, and gas composition on ESPs | 21 |
| 3.2.1 Gas phase properties and charge carrier distribution | 21 |
| 3.2.2 Electric mobility of ions and electrons..... | 22 |
| 3.2.3 Current-voltage characteristics..... | 26 |
| 3.2.4 Ionic charging..... | 27 |
| 3.2.5 Electronic charging..... | 28 |
| 3.2.6 Bipolar charging | 30 |
| 3.2.7 Particle migration and deposition..... | 31 |
| 3.3 Thermionic emission of charge carriers..... | 31 |
| 3.4 Modelling of corona discharge, particle charging and ESP operation | 33 |
| 3.4.1 Corona discharge and charge carrier distribution | 33 |
| 3.4.2 Unipolar particle charging..... | 34 |
| 3.4.3 ESP operation, back corona and EHD effects..... | 35 |
| 4 Description of the HT-ESP modelling approaches | 37 |
| 4.1 Modelling approach – OD model with radius-averaged values | 38 |
| 4.1.1 Preparatory calculations | 39 |

| | | |
|----------|---|------------|
| 4.1.2 | Charging mechanisms and calculation of particle charge..... | 40 |
| 4.1.3 | Experimentally derived particle charge and hypothetical minimum particle charge..... | 44 |
| 4.2 | Modelling approach – 1D model with charge carrier distribution | 45 |
| 4.2.1 | Explanation of the 1D approach | 45 |
| 4.2.2 | Preparatory calculations and determination of relevant parameters..... | 47 |
| 4.2.3 | Charge carrier distribution model for negative corona discharges | 51 |
| 4.2.4 | ESP model and calculation routine | 54 |
| 5 | Preliminary experiments on electronic charging..... | 57 |
| 5.1 | Experimental setup and aerosol properties | 57 |
| 5.2 | Experimental results – current-voltage characteristics | 59 |
| 5.3 | Experimental results – separation efficiency and specific input of energy | 61 |
| 5.4 | Experimental and simulation results – particle charge..... | 66 |
| 5.5 | Outlook on the application of electronic charging | 70 |
| 6 | High-temperature electrostatic precipitation..... | 73 |
| 6.1 | Design considerations | 73 |
| 6.1.1 | Gas temperature measurements..... | 74 |
| 6.1.2 | Production of a benchmark aerosol..... | 75 |
| 6.1.3 | Aerosol sampling and dilution | 78 |
| 6.2 | Experimental setup and methodology..... | 79 |
| 6.2.1 | Experimental setup | 79 |
| 6.2.2 | Aerosol generator and aerosol characteristics for separation efficiency experiments..... | 84 |
| 6.2.3 | Experimental campaign for CVC measurements | 86 |
| 6.2.4 | Experimental campaign for separation efficiency experiments | 88 |
| 6.3 | Experimental results – Current-voltage characteristics in air and flue gas | 89 |
| 6.3.1 | CVC measurements for the wire electrode E1..... | 90 |
| 6.3.2 | Extraction of the apparent ion mobility from CVC measurements | 95 |
| 6.3.3 | Influence of the electric field on the ion age and its effect on the CVC | 103 |
| 6.3.4 | Sub-onset current analysis..... | 106 |
| 6.3.5 | Estimation of leak currents via the MgO weight | 109 |
| 6.4 | Experimental results – The separation of Fe ₂ O ₃ nanoparticles | 112 |
| 6.4.1 | Separation efficiency and specific input of energy | 112 |
| 6.4.2 | Evaluation of the mobility distributions and the particle charging state | 121 |
| 6.4.3 | Temperature-induced charging effects by thermionic emission..... | 126 |
| 6.4.4 | Estimation of the average particle charge | 129 |
| 7 | Simulation results | 133 |
| 7.1 | 0D modelling approach with radius-averaged values..... | 133 |
| 7.1.1 | Evaluation of the charging kinetics based on the average particle charge | 133 |
| 7.1.2 | Prediction of the separation efficiency curve | 139 |
| 7.2 | 1D modelling approach with charge carrier distribution model..... | 142 |
| 7.2.1 | Adaptation of the attachment coefficient to imitate gas ion dissociation..... | 142 |
| 7.2.2 | Charge carrier distribution without particles in air – Validation of the CCD model | 144 |
| 7.2.3 | Particle charging and precipitation simulated by the 1D HT-ESP model | 150 |

| | | |
|-----------|---|------------|
| 8 | Discussion..... | 162 |
| 8.1 | Comparison of the experimental results to previous HT-ESP research..... | 162 |
| 8.2 | Additional insights gained from the experimental results..... | 164 |
| 8.2.1 | Empirical description of the onset electric field | 164 |
| 8.2.2 | Influence of temperature and ESP geometry on the ion mobility..... | 167 |
| 8.2.3 | Influence of free electrons and residence time on the separation efficiency curve | 169 |
| 9 | Conclusion | 172 |
| 10 | Future perspectives..... | 175 |
| | References | 176 |
| | List of own publications..... | 193 |
| | List of student works | 193 |
| | List of figures..... | 194 |
| | List of tables..... | 200 |
| | Appendix | 201 |
| A.1 | Relevant parameters for the simulation results described in chapter 5.4 | 201 |
| A.2 | Relevant parameters for the simulation results described in chapter 7.1 | 202 |