

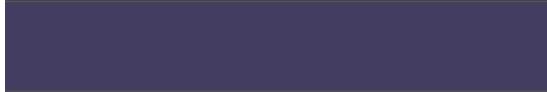


Hongben Zhou (Autor)

Investigation of toner adhesion in the electrophotographic process



Hongben Zhou



**Investigation of toner adhesion in the
electrophotographic process**

**Untersuchung der Tonerhaftung in dem
elektrofotografischen Prozess**

 **Cuvillier Verlag Göttingen**

<https://cuvillier.de/de/shop/publications/1329>

Copyright:

Cuvillier Verlag, Inhaberin Annette Jentzsch-Cuvillier, Nonnenstieg 8, 37075 Göttingen,
Germany

Telefon: +49 (0)551 54724-0, E-Mail: info@cuvillier.de, Website: <https://cuvillier.de>

Contents

1	Introduction.....	1
1.1	Motivation	1
1.2	Adhesion force in the electrophotographic process	1
1.3	Structure of the thesis.....	3
2	Fundamentals of adhesion	5
2.1	Van der Waals forces	5
2.1.1	Van der Waals forces between rigid spherical bodies	6
2.1.2	Van der Waals forces between deformable spherical bodies.....	8
2.1.2.1	Models considering elastic deformation.....	8
2.1.2.2	Models with non-elastic deformation	13
2.1.3	Influence of surface roughness on the van der Waals forces.....	16
2.1.3.1	Van der Waals forces between rigid rough adhesion partners	16
2.1.3.2	Van der Waals forces between deformable rough adhesion partners	19
2.1.4	Influence of the oxide/adsorbate layer on the van der Waals force	19
2.2	Electric forces.....	20
2.2.1	Particle charging processes	20
2.2.1.1	Charging of the toner particle in the developing process	20
2.2.1.2	Charging of the toner particle in the jumping process	21
2.2.2	The electric forces	22
2.2.2.1	General consideration	22
2.2.2.2	The electrostatic force as a function of the contact distance	22
2.2.2.3	The influence of the local charge density and the particle shape	23
2.2.2.4	The influence of the neighboring particles	24
2.3	The meniscus force	24
2.3.1	The dependence of the meniscus force on the contact distance.....	26
2.3.2	The meniscus force between rough adhesion partners	27
2.3.3	The viscous force	28
2.4	Comparison of the adhesion forces	28
3	Modeling of the van der Waals force.....	31
3.1	The analytical approach	31
3.1.1	Comments on the approaches based on energy balances.....	31
3.1.2	Assumptions of the new model	32
3.1.3	The adhesion procedure and the criterion for the separation	32
3.2	The numerical approach.....	35
3.2.1	FEM-simulation of the particle deformation	35
3.2.2	Calculation of the dispersion force	36
3.2.3	Case study 1: elastic and plastic particle with low modulus.....	37

3.2.4	Case study 2: elastic particle with high modulus	41
3.2.5	Case study 3: Adhesion of low modulus particle on rough surfaces	43
4	Materials and measuring methods	49
4.1	Investigated materials.....	49
4.1.1	Toner and model particles.....	49
4.1.2	Organic photo conductor (OPC) and model surfaces	51
4.2	Characterization methods.....	53
4.2.1	Atomic Force Microscopy for the topography measurement	53
4.2.2	Surface Potential (SP) for the surface charge distribution measurement ..	54
4.2.3	q-test for the particle charge distribution measurement.....	55
4.2.4	Characterization of the toner conductivity.....	56
4.2.4.1	The resistance measurement	56
4.2.4.2	The impedance measurement	57
4.2.5	Scanning electron microscopy (SEM)	57
4.2.6	Contact angle measurement	58
4.2.7	Measurement of the mechanical properties	58
4.2.7.1	DMA for the determination of bulk material properties	58
4.2.7.2	Nanoindentation for the determination of microscopic material properties	59
4.3	Methods for adhesion force measurements.....	60
4.3.1	Atomic force microscopy (AFM) measurement.....	60
4.3.1.1	Determination of spring constant of the cantilever	61
4.3.1.2	Probe preparation.....	62
4.3.1.3	Humidity control during the measurement.....	62
4.3.1.4	Force measurement with an AFM	62
4.3.2	Centrifugal detachment	64
4.3.2.1	Probe preparation.....	64
4.3.2.2	Centrifuge measurement with image analysis	64
4.3.3	Electric field detachment.....	65
4.3.4	Comparison of the measuring methods.....	67
5	Characterization of the particles and surfaces	69
5.1	Topography of the investigated surfaces	69
5.2	Charges on toner particles.....	72
5.2.1	Surface potential (SP) measurement	72
5.2.2	q-test measurements	74
5.3	Toner conductivity	76
5.3.1	The resistance measurement	76
5.3.2	The impedance measurement.....	78
5.4	Surface chemistry and contact angle.....	80
5.5	Mechanical property of the materials.....	81
5.5.1	DMA measurements.....	81

5.5.2	Nanoindentation measurements	83
5.5.2.1	Frequency domain measurements	83
5.5.2.2	Time domain measurements	85
6	Adhesion force between particles and substrates	89
6.1	Van der Waals forces between smooth adhesion partners	89
6.1.1	Rigid adhesion partners.....	89
6.1.2	Deformable adhesion partners	90
6.1.2.1	Influence of the contact time	90
6.1.2.2	Influence of the normal force	91
6.2	Van der Waals forces between rough adhesion partners	92
6.2.1	Reduction of the adhesion force due to the surface roughness	92
6.2.2	Distribution of the adhesion force due to the roughness.....	93
6.2.3	Influence of the contact time and history on the adhesion force	95
6.2.4	Influence of the normal force on the adhesion force	97
6.2.5	FEM-simulation of the adhesion force between rough adhesion partners.	99
6.2.6	Adhesion force distribution between a particle and a monolayer of asperities.....	100
6.2.7	AFM-measurements on substrates with well-defined roughness profiles	103
6.2.8	AFM-Measurements with the toner particles.....	105
6.2.9	Centrifugal detachment measurement of toner particles	108
6.2.9.1	Relocation effect in the centrifugal detachment measurement.....	110
6.2.9.2	Influence of the silica coating on the particles	111
6.3	Adhesion force in humid ambience	114
6.3.1	Adhesion force between silica particle and mica surface	114
6.3.2	Adhesion force between polystyrene particle and silicon wafer	117
6.3.3	Adhesion force between rough adhesion partners	119
6.4	Forces on the charged particles	120
6.4.1	AFM-measurement of charged particles.....	120
6.4.2	Centrifugal detachment measurement of charged particles	123
6.4.3	Electric field detachment of toner particles	124
7	Conclusion and Outlook	129
7.1	Conclusion.....	129
7.2	Outlook.....	130
7.3	Suggestions for the electrophotographic process.....	131
8	Nomenclature	133
8.1	Physical constants	133
8.2	Latin symbols	133
8.3	Greek symbols.....	135
8.4	Index.....	136
8.5	Abbreviations	137
9	Literature	139

10	Appendix.....	147
10.1	Main features of Abaqus® 6.4.1	147
10.2	Input file for the FEM-simulation with Abaqus® 6.4-1	147
10.3	Nassi-Shneidermann diagram for the Hamaker Summation	150
10.4	Nassi-Shneidermann diagram for the simulation of roughness effect....	153