# 1 INTRODUCTION

## 1.1 Motivation

Adhesion of particles on surfaces is a subject of particular interest in process engineering because of its importance in a wide range of industrial fields. One interesting application is the electrophotographic process, also called xerography, which was invented by Carlson and Kornei in 1938 [1]. Since the first commercially available electrophotographic equipment in 1950 this technique has been widely applied because of the high printing quality and low page costs. Nowadays typical commercial high-speed printers use paper speed of up to $1.5 m/s$, corresponding to 600 A4 pages per minute at a print resolution of 600 dots per inch (dpi) [2]. However, a complete transfer of the toner particles to the paper is not yet possible. A fraction of the particles remains sticking on the photo conductor (PC) surface and has to be mechanically cleaned afterwards. General information on the electrophotographic process can be found in reviews of Goel [1], Schein [3], and Williams [4]. These works show that further improvement of this process requires understanding of the fundamental physical mechanisms of adhesion.

In this work the adhesion behavior between toner particles as well as model particles and substrates is investigated by various experimental techniques at boundary conditions relevant to the electrophotographic process, in order to understand the physics behind the adhesion phenomena. The measurements are compared with model calculations. Furthermore, it is shown that the adhesion force can be tailored by systematical modifications of the particle and the substrate surfaces.

## 1.2 Adhesion force in the electrophotographic process

Prints resulting from the electrophotographic process consist of micron-sized toner particles. Toner particles are charged triboelectrically: They are mixed with carrier particles (ferrite particle with a polymer coating) and intensively agitated. In this process the toner particles tend to become negatively charged. The toner-carrier mixture builds a thick layer on the magnet roller (MR) (Figure 1-1). When this layer contacts the jumper roller (JR), part of the toner particles is transferred onto the JR, so that the JR is covered with several monolayers of toner particles. The carrier particles cannot be transferred because of the strong magnetic force between the particles and the MR.

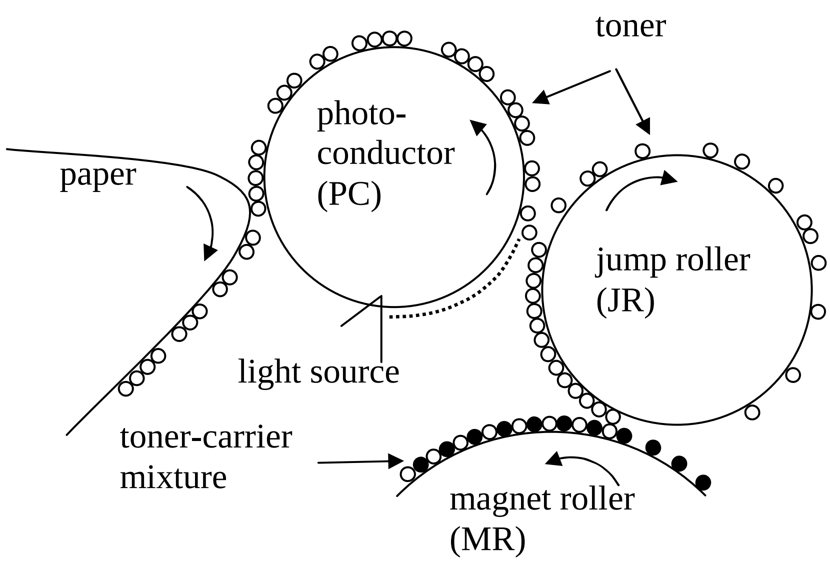


Figure 1-1 Schematic diagram of the electrophotographic process [2].

In the meanwhile, a charge pattern is produced on the photoconductor (PC) surface. The PC surface consists of a light sensitive material. The specific resistance of this material reduces from approximately $10^{14}\,\Omega cm$ to $10^{7}\,\Omega cm$ when the surface is moved from the darkness to the light. The charge pattern is created in two steps: In the darkness the surface becomes homogeneously charged by means of a corona. As for the toner particles, the charge is also negative. Then the locations that will form the toner image are illuminated with a tightly focused light beam emitted from the print head. The local resistance reduces so that the surface charges flow off, while the positions, which are not illuminated, remain charged.

When the toner particles on the JR approach the PC surface, the particles can be removed from the JR by the electric field force of a transfer corona and jump to the PC surface. The particles adhere on discharged locations of the PC surface. The particles are not able to adhere on the positions which are not illuminated because of the strong repulsive force between the particle charge and the surface charge on the PC. As a consequence the toner image is created on the PC. This process is called the jump process. The toner particles are finally transferred from the PC to the paper in the electric field of a second transfer corona. In the transfer processes the electric field force has to override the adhesion force. Unfortunately, this is not always the case. For example, the transfer from the PC to paper usually has an efficiency of approximately $90\%$, the rest of the toner has to be removed mechanically from the PC and disposed. This results in dissatisfying printing quality and in additional costs for waste management. This process is described in detail by Schein [3].

In order to improve this process it is necessary to understand the physical background of the process. The transfer of toner particles in the electrophotographic process can be reduced to the fundamental phenomenon: The electric field force of the transfer corona outbalances the adhesion force between the particles and the substrates. The most important adhesion forces in this process are the van der Waals force, the electrostatic forces and in some case also the meniscus force [1, 5, 6]. However, these forces and their dependences on various parameters are still insufficiently understood. It is a major concern of this work to tailor the toner-substrate adhesion basing on a better understanding of the nature of the forces.

## 1.3 Structure of the thesis

In this study the essential forces determining the electrophotographic process are investigated systematically. The thesis is organized as followed:

Chapter 2 provides a brief overview of the most important adhesion forces in the electrophotographic process. Various models of the van der Waals force, the electrostatic force and the meniscus force are introduced.

In Chapter 3 a new model for the van der Waals force is derived by combining the Hamaker summation method with the Hertz model or FEM simulation for the prediction of particle deformation. The influence of the applied normal force, the material property as well as the roughness can be included into this model.

Chapter 4 describes particles and substrates with various material properties and roughness observed in this study. The methods applied to characterize the adhesion partners and to measure the adhesion force are introduced in this chapter as well.

The characterization of the particles and substrates is described in Chapter 5. The bulk and surface properties of the probes are investigated with various techniques to give a holistic view of the investigated materials.

The adhesion forces measured with various methods are presented in Chapter 6 along with model calculations. It is discussed in detail, how the adhesion force can be influenced by means of varying the properties of the adhesion partners and the measuring conditions. The comparison of the measuring results of various methods at different conditions shows the complexity of adhesion phenomena.

The results are summarized in Chapter 7, followed by an outlook concerning needs for the future research work.