

Improvement and analysis of toner based on triboelectric

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Abstract. Toner in the laser printer has played a significant role recently, however, the pollution of toner is not optimistic, toner produces ozone in the process of printing, and because of the characteristics of toner insoluble in water, when it is exposed to air, toner which are small particles will easily to enter the human body and keep in the human kidney, which has a great impact on the health. In the article, the experimental model of quantified triboelectricity is proposed according to the physical principle of toner, which uses mercury as a liquid metal to quantify triboelectricity, aiming to obtain the gain and loss ability of different materials, so as to improve the effect of toner. At the same time, the article includes the concept of charge control agents (CCAs), which is a chemical substance that keeps the charge on the surface of the toner to ensure charged on the toner surface, obtains the basic selection conditions that need to be paid attention to in the selection of CCAs materials, aiming to provide the direction of toner improvement. The article provides the direction and idea of toner improvement by proposing the concept of quantifying triboelectricity and CCAs.

Keywords: Laser Printer, Toner, CCAs, Triboelectric.

1. Introduction

With the development of the technology, the dissemination of knowledge is more extensive, and the demand for paper documents is rising rapidly. Printers have also become an indispensable tool for learning and work in society. Due to the large demand for printers today, the speed and clarity of text and pictures have become the main development direction of today's printers [1]. Compared with other printers, the speed of laser printers is its special advantage, but the pollution of toner is the main disadvantage of laser printers.

The first part of the article is to analyze the internal structure of the laser printer, including low voltage power supply circuit, high voltage power supply circuit and so on, and it will be introduced briefly about the chemical composition of laser printer toner and the physical principle of toner, aims to lead to the analysis of toner, achieve the purpose of the improvement of the toner.

The second part of the article is firstly based on the physical principle, which leads to the quantified of triboelectricity, which is to measure the friction density of the insulator by the liquid mercury and the measured material is respectively connected to the positive and negative electrodes of the power supply. After that will be involved a simple description of the toner identification method of different laser printers, through the comparison of spectrum identification, to obtain the source of toner. It will be easier to choose the material suitable for laser printer by quantifying triboelectricity and the study of toner spectrum is used to identify superior toner, and improve further based on the component from superior toner.

In the third part of the article, CCAs are introduced based on quantified of triboelectricity and toner spectrum to maintain the charge on the toner surface for a long time, in order to ensure that the toner will be not easy to fall off before laser printer move to the next step. The study of toner helps to improve the sharpness of images and text in laser printers, in the while, reduce the harm to human body.

2. Basic components

2.1. The structure of laser printer circuit

The structure of laser printer circuit is mainly composed of control system, low voltage power supply circuit, high voltage power supply circuit, development system and so on. Low-voltage power supply circuit includes voltages, 5V and 24V. For the 220V AC voltage supplied by the power supply is too high, and the motherboard cannot have too high temperature, so the 220V AC voltage will be first through the fuse and arrester, avoid the damage and burning, then go through the filter, rectification, oscillating and voltage regulator to reduce the voltage and finally receive 5V and 24V DC working voltage [2]. Relevant processes are shown in figure 1 below.

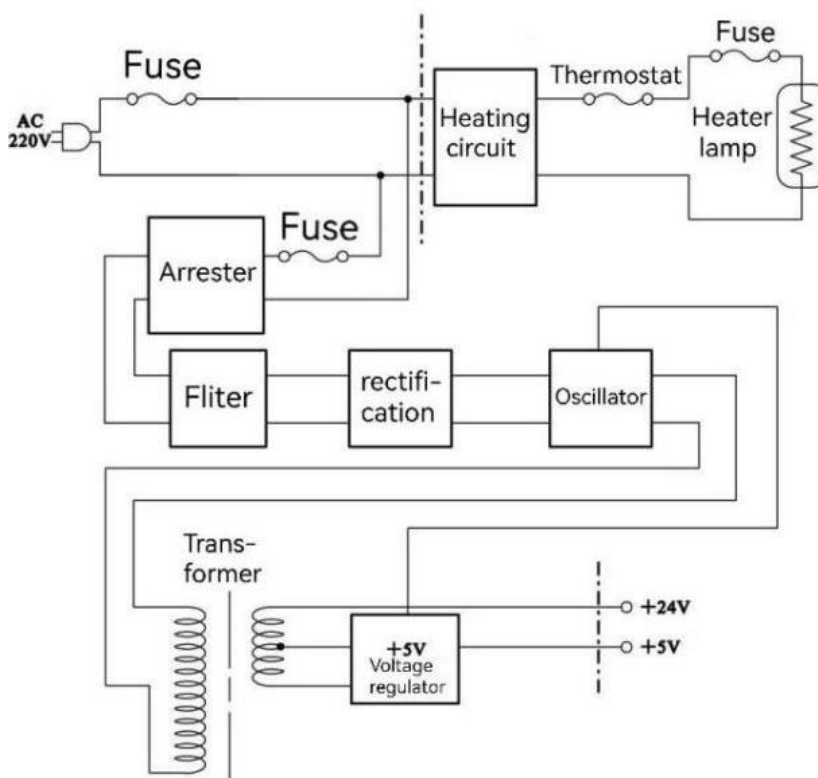


Figure 1. LENOVO Low-Voltage power supply circuit of the LJ2050N-type laser printer [2]

Within the control system, it is mainly divided into several modules, including random access memory (RAM), data control module, and engine control module [2]. RAM, namely a data memory, is an internal memory that exchanges data directly with the central processing unit (CPU) [3]. The data control module, including a control panel, performs scanning and connects to the external computer equipment. Engine control module for sensing the paper and controlling the motor for the purpose of controlling paper feeding.

The high voltage power supply circuit mainly powers the imaging system, such as laser unit, fixing part, developing component, etc., for these modules require higher temperature or higher voltage. The high voltage power supply circuit converts the 24V voltage generated by the low voltage power supply circuit to the high voltage to supply the normal operation of this part of the system [2]. Relevant processes are shown in figure 2 below.

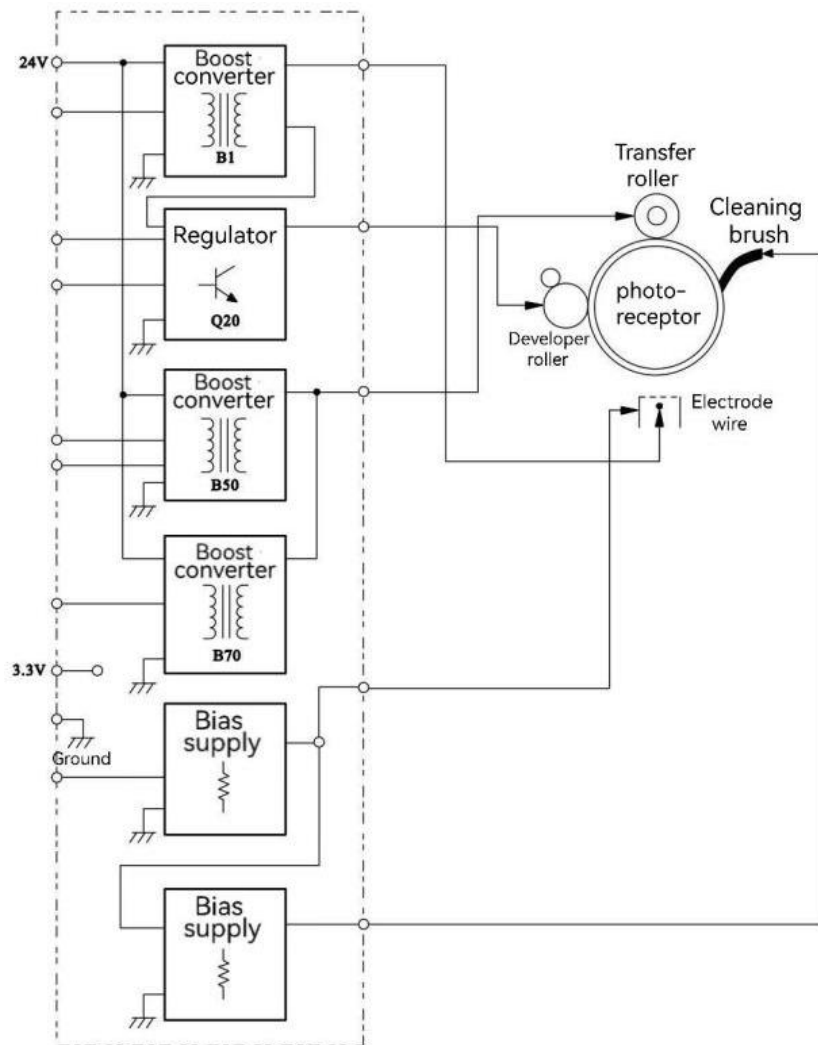


Figure 2. LENOVO High-Voltage power supply circuit of the LJ2050N-type laser printer [2]

Laser printers have two signal interfaces, one is USB interface, the other is IEEE1284 signal interface. When the computer connects to the laser printer to transmit digital signals to the laser printer through these two ports, the internal USB driver will transmit the signals and instructions to the CPU circuit, allowing the CPU to convey instructions, and at the same time, transmit the working state signal to the computer to observe whether the printing goes smoothly with the computer [2]. Relevant processes are shown in figure 3 below.

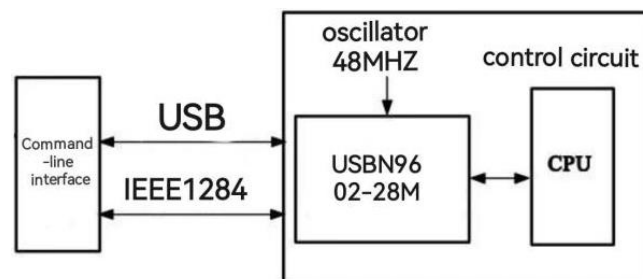


Figure 3. Transmission of the data interface signals [2]

2.2. Toner

The external structure of the laser printer contains several components, such as the photoreceptor, charging roller, toner cartridge, etc. [4], and the laser printer prints texts and images on the paper through the toner inside the toner cartridge. Toner is a powder mixture, mainly consist of granular

plastic, usually not conductive. Because laser printers mainly use static electricity to make the surface of toner bring negative charge, and attach to the photoreceptor, various friction-electric minerals are usually added into the toner. In laser printer, there is no negative charge in the part of the photoreceptor illuminated by the laser. The toner will be temporarily adsorbed in the position of the photosensitive drum through the laser irradiation and then absorbed to the paper through the positively charged developing roller [5]. The particle size and resolution of the toner are closely related. The larger the toner particle is, the lower the resolution of the image is, and the less clear the printed image will be. Scientists have determined from the typical cumulative distribution that the particle diameter of the toner is best maintained at 14-16 microns. In order to ensure the uniform size of the toner does not block, avoiding the situation of low resolution, the toner will add gas phase silicon dioxide, which can increase the flow capacity of the solid in the laser toner cartridge, reduce the emergence of particle agglomeration [6]. The sharpness of the image printed by the laser printer is determined by the toner and the premise that the toner can be successfully printed on the paper is that the friction of the toner in the process of mixing with the current carrier should be large enough so that the toner can be better adsorbed on the surface of the photoreceptor and the surface of the paper. In order to study the properties of the toner and improve the toner, the following will analyze by explaining spectral comparison and quantifying triboelectric.

3. Physic analysis of toner

3.1. Quantify Triboelectric

When toner and carrier stir in the cartridge, the toner needs to get electrons to attach a negative charge on its surface. In order to study which materials and toner mixing would make it easier for toner to gain electrons from carriers, the concept of quantified friction is presented here.

Triboelectricity refers to the friction between two materials, which is closely related to the area of contact and contact pressure. In fact, triboelectricity is just an engineering operation, it actually is generally called contact electrification in physics. Because the pressure between solid materials is difficult to control, it is impossible to accurately know the tribocharge density of the material. Order various materials through the tendency to obtain or lose electrons, which is to measure the triboelectric charge density (TECD). Here, liquid mercury (electronic grade 99.8%) will be used to quantify friction. There are two reasons for choosing mercury here. First, mercury, as a liquid metal, can be well adapted to the solid surface. Second, the surface tension of mercury is large, and the difference in surface morphology does not affect the measurement [7].

The following devices will be used to measure the TECD and the devices is shown in figure 4 below.

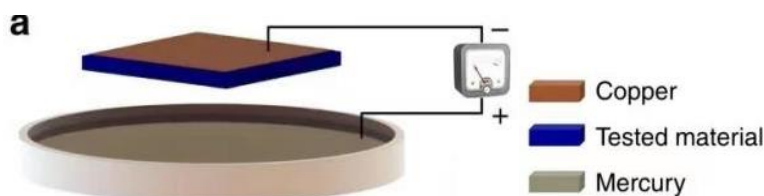


Figure 4. TECD measurement device [7]

The measured object is connected to copper, copper is connected to the negative electrode, liquid metal is connected to the positive electrode. First, in the open-circuit condition, the measured object and the liquid metal contact. The contact causes charge transfer between the materials, leading to the surface of one material lose electrons and one material surface gain electrons. Because the two surfaces overlap, there is no potential difference between the two at this time, and the charge density on the surfaces of the two objects is σ . Now let the distance between the measured object and the liquid metal increase. Because one of the materials are positive and the others negative, the potential difference will occur in the process of moving away. When the separation height reaches a certain

height L , the open circuit voltage reaches the maximum. After obtaining the value of the height L , the material is pushed down again to contact the metal mercury, and the charge with opposite symbols coincides again into a plane [7]. Relevant processes are shown in figure 5 below.

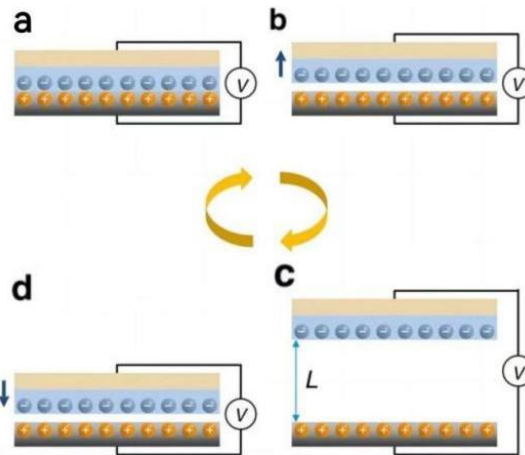


Figure 5. The Theoretical model under open-circuit condition [7]

After connecting the circuit, in a short-circuit condition, the potential difference between the material and liquid metal will drive the electrons to move from one electrode to the other to balance the potential between the two. When the distance between the two objects increases, the measured object attracts the positive charge inside the copper, and because there is a circuit connection between the mercury and the copper, the positive charge on the surface of the mercury will go through the wire into one end of the copper. When the distance between the two reaches L , the charge is almost completely shifted to the copper electrode [7]. Relevant processes are shown in figure 6 below.

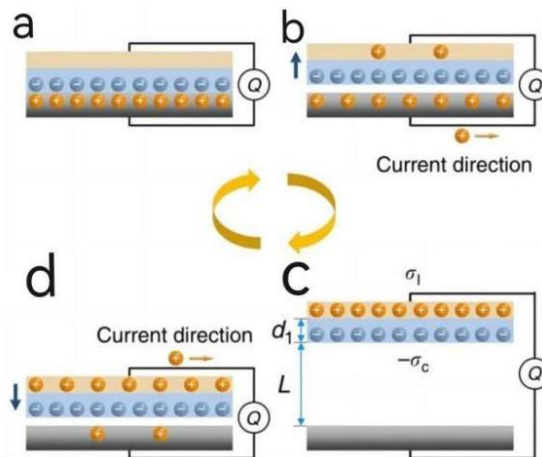


Figure 6. The theoretical model under a short-circuit condition [7]

The TECD is measured by quantifying the total charge transferred between the Cu electrode and the liquid metal.

From Gauss theorem, the electric field strength in the media and gap are approximately given by if the edge effect is ignored:

$$E_1 = \frac{\sigma_I(L,t)}{\epsilon_1} \quad (1)$$

$$E_{air} = \frac{\sigma_I(L,t) - \sigma_c}{\epsilon_0} \quad (2)$$

Where σ_I is defined as the density of induced static charge, L is gap distance, and σ_c is surface charge density.

The voltage between the two electrodes is

$$V = \frac{\sigma_I(L,t)}{\varepsilon_1} d_1 + \frac{\sigma_I(L,t) - \sigma_c}{\varepsilon_0} L \quad (3)$$

where the dielectric permittivity of the material is ε_1 , and its thickness is d_1 .
 Under short-circuit condition, the two electrodes are electrically connected, so $V = 0$, then,

$$\sigma_I(L, t) = \frac{L\sigma_c}{\frac{d_1\varepsilon_0}{\varepsilon_1} + L} \quad (4)$$

As can be seen from the equation, when the denominator of the equation is about equal to L , that is, when the separation distance L is much greater than $\frac{d_1\varepsilon_0}{\varepsilon_1}$, the values of σ_I and σ_c are almost equal. Thus, the measurements of the charge density can be used to represent the TECD of the dielectric surface. In this way, it is possible to quantify the triboelectric [7], thus to obtain the TECD of different materials, and to more precisely order the ability of different materials to get or lose electrons.

3.2. Spectral Properties of Toners

There are different laser printers on the market, and different laser printers have different sharpness. By comparing different toner, studying the ingredients of toner in different laser printers, it can be got the ingredient of additives added inside the toner. Most companies design the toner with the ability to identify it for security, so the number can be checked to know which company of the toner came from. By identifying different toner, the manufacturer of the toner is obtained. After obtaining the best toner by printing the clarity contrast, the composition of the toner can be analyzed to obtain the corresponding composition.

Discriminating Power is defined as:

$$\%A = \frac{A_{indi}}{A_{tot}} \times 100 \quad (5)$$

Where A is absorbance, A_{indi} is individual value of absorbance, A_{tot} is total absorbance [8].

4. Chosen of toner

4.1. Study and analyze defects

For the above research, here mainly focus on the laser printer toner materials. In fact, it isn't that the more charge on the toner surface, the better the toner will be. Too much charge may lead to difficulties of removing toner, and too little charge on the toner result to the blur of image and text. Most of the laser printers on the market use polyester fibers. Polyester fiber is a kind of plastic, according to the TECD table, its electronic capacity in the middle, and its electronic capacity also ensures that when the toner contact with carriers, the toner surface will not take too much and too little charges. And the polyester fiber has a low melting point, which is easier to melt on the paper during the process of fixing and developing.

However, after the charge is transferred to the photosensitive drum, the charge on the surface of the toner will gradually begin to disappear, which will easily lead to the toner to fall off, the correct and clear text and images cannot be printed on the paper. To ensure that the charge is maintained on the surface of the photoreceptor, here will be introduced the concept of CCAs. CCAs are used to ensure that the toner particles obtain the correct triboelectric (electrostatic) charge level, which is neither high nor low, and remain toner in the changed condition for a long time [9]. In the selection process of CCAs materials, in addition to selecting the suitable materials through the friction charge density table, it is also necessary to consider that the added chemicals can ensure the product performance, and ensuring that the added chemicals are non-toxic. It is determined that the CCAs

meeting the first two points also needs to have good thermal stability to prevent the chemical from breaking down or synthesizing other substances at high temperature during the subsequent toner melting process. Finally, the chemical should be easy to synthesize. According to the research, only a few dyes are good CCAs. From the many types examined, Certain 2: 1 chromium (III) or cobalt(III) complex azo dyes have been found to be the best negative CCAs [10].

4.2. Development

Although the technology to improve toner has been improved well, toner pollution has always been a problem that scientists have not solved. First of all, because of the resin in the toner inside, resin will produce ozone under the condition of high temperature, and ozone will cause stimulation to the human mucous membrane, causing bad effects [11]. Second, for the toner has small diameter, it is easy to be inhaled by the human body. Because the toner is not soluble in water, the toner will stay in the human body and enter the kidney through the blood circulation, causing adverse effects on the human body. After the study of laser printer, it can be tried to choose other non-plastic insulators, and appropriately reduce the use of CCAs or develop a better charge regulator material which can be dissolved in water, avoid the toner going through the human excretion into the blood circulation.

5. Conclusion

According to the study, it is found that the improvement of toner can solve the problem of laser printer pollution and clarity. Firstly, the study shows that the toner surface has a negative charge after friction. The measured object will be connected to the negative electrode of the power supply, while liquid metal will connect to the positive electrode of the power supply, this method can be used to measure the surface charge density of the object after friction, and to get the gain and loss of the electronic ability of the object. The study of the gain and loss ability of the measured object is conducive to the choice of toner materials, which benefits to solve the adsorption problem of toner. In the article, the identification ability of toner is defined, aims to identify the source of toner, get the composition of superior toner, and further improve the toner. In addition to the analysis of the insulators added in the toner, the CCAs added in the toner is also analyzed, according to the study, it is found that CCAs have the ability to maintain charges on the surface of the toner, and the selection of CCAs is concluded the high temperature resistance, easy synthesis and other requirements.

At present, the pollution problem caused by laser printers is still not solved. As mentioned in the article, the ozone produced by the resin which is one of the compositions of toner and the toner itself have a great impact on the human body. Due to the inability of the toner in water, the human body cannot excrete it out of the body, thus causing the toner to participate in the blood circulation and enter the kidney. In the aspect of laser printer research in the future, new choices can be made on the composition of toner, choose the material which is soluble in water to reduce the harm of toner to human body, in the meanwhile, ensure the performance of the toner.

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