4-1967

A Study of the Conductivity of Several Conductive Polymers

Howard W. Renner
Western Michigan University

A STUDY OF THE CONDUCTIVITY OF SEVERAL CONDUCTIVE POLYMERS

by

Howard W. Renner

A thesis submitted to the
Faculty of the Department of Paper Technology
of the
Degree of Bachelor of Science

Western Michigan University
Kalamazoo, Michigan

April, 1967

TABLE OF CONTENTS

ABSTRACT: The purpose of this thesis is to compare the conductivities of several solutions now in use in producing electroconductive paper. The testing procedure involved the use of a Kiethly 610 B electrometer with two aluminum discs for conductance through the sheet and two brass strips for conductance across the sheet. Attempts were made to improve the conductance of the solution by the addition of surface agents in the belief that this would lead to better dispersion and thus to better film continuity. No effective method was found to improve the conductivity of a solution of given concentration. Increasing the concentration from 10% to 30% however did give substantial improvements in conductivity.

HISTORICAL BACKGROUND: The copying processes for office use began to make their appearance in the early 1950's. The early processes were generally photographic in nature, relying on a positive and a negative paper. Later processes were developed and named "dry" processes because there was no need to use chemical solutions in the copying machine. Included in the dry processes are Thermofax, Xerography, and Electrofax.

The Electrofax process involves the use of a ZnO coating on one side of the sheet. This coating is charged with static electricity and exposed to the original by use of a lens system. When dark areas occur on the original, e.g. type or letters, no light will strike the charged sheet. Areas of the sheet that are exposed to light will dissipate their charge while unexposed areas will retain their charge. These charged areas will attract the toner particles which are fused or dried and the copy is completed.

The removal of the charge from the light exposed areas is a fundamental step of the process. The mechanism involved is the light releasing the charge from the ZnO particles that it strikes and the charge being removed by traveling through the resin layer which serves as a binder for the ZnO. The composition of this resin layer plays a very important role in the quality and speed of the copying process.

Most (1) has pointed out that a resin binder used with CdS or ZnO should not react chemically with it and also the resin should properly wet and disperse the oxide particles. He notes that too much work put into the system to wet the particles will result in loss of photoconductive properties of the ZnO. Also, sometimes a mixture of resins will work much better than a single resin. Useful resins include polystyrenes, silicons, acrylic and methocrylic esters, chlorinated rubber, vinyl polymers and copolymers, cellulose esters and ethers and alkyds. Resins with strong polar groups, e.g. carboxyl, chloride, etc. are preferred.

Levene (2) states that five desirable characteristics of electrophotographic paper are: 1. Better electrofax sensitivity 2. Whiter sheet 3. Smoothness and wrinkle resistance improvements 4. Immunity to humidity effects 5. Consistent performance. These five areas are necessary for the paper to match the future speed of the electrophotographic processes.

Some work has been done in the area of humidity effects by Fird and Vaurio (3). They reached the conclusion that humidity effects are dependent on the type of binder used with the ZnO. The best type of binder of those which they tested was a vinyl benzene quaternary ammonium polymer compound. It exhibited the best conductivity with the least change due to humidity. KCl was tested but showed poor results below 60% R.H.

Carbon or metallic particles introduced during or as a subsequent coating were effective in reducing the resistance of the sheet, even at low humidity. Also suggested was trying to improve the conductivity by the addition of a more hygroscopic material than cellulose in the paper. But at high humidities, these showed a tendency to soften the sheet so much as to make it unusable.

Hayek (4) has pointed out that antistatics are used in the textile industry and may be usable on paper. He claims that the action of an antistatic agent is the same as that of a conductive agent. They both probably work on the same principle of adsorption of water by the antistatic agent on the surface of the fiber. This is born out by the dependence of the effectiveness of antistatic agents on R.H.

The work of my thesis will be in the area of the resin binder. It will concentrate on the addition of both surface agents and conductive agents in an effort to accomplish two objectives. First to increase the conductance of the resin layer and second to keep variation in conductance due to humidity effects as minimal as possible.

EXPERIMENTAL DESIGN: The paper stock used as a coating base was cut into 8 inch by 10 inch grain long sheets. All coatings were applied to the felt side.

The coatings were measured in graduates and the necessary dilutions and additions carefully measured out. Any bubbles formed from entrapped air while mixing were allowed to rise out. Mixing was accomplished by inverting the graduate five or six times.

A small amount, about 10 ml., of the coating mixture was poured on the top of the sheet and a draw down was made using either a number 3 or a number 11 rod.

The samples were conditioned by allowing them to stand overnight in a constant temperature and humidity room. The condition here provided for 50% relative humidity.

These samples were then tested for the amount of resistance offered to electric current both through the sheet and across the sheet. The resistance through the sheet was measured using two aluminum discs each 4.90 square inches in area. A five kilogram mass was used to provide for constant force on the discs. The measurements were taken with a Kiethly 610 B electrometer.

The across the sheet resistance was measured using two brass strips one inch long and parallel to each other one inch apart. This provided for the measurement of resistance of one square inch of the coated surface. Values were again measured with a Kiethly 610 B.

The samples were then left overnight in a chamber which was 20% relative humidity. The humidity was controlled by a saturated solution of potassium acetate and circulation was provided with a low speed fan.

Measurements of both across and through resistance were taken using the same apparatus.

RESULTS AND CONCLUSIONS: The first agent to be tested was Tamol 850 at both 30% and 10% solids. Also tested was Calgon 261 at 40% and 10% solids. The data is presented in Table I. Several important points can be expressed from the above data. The first of these is the dependence of resistance on humidity. Much less resistance was encountered at 50% than at 20%. This is due to the extra water adsorbed in the sheet at the higher humidity aiding in carrying the current through the paper.

Another observation is in the very large dependence of resistance on the concentration of the conductive agent. For both Calgon 261 and Tamol 850, the resistances were much higher at 10% solids than in the more concentrated form. This is probably due to the dilution of the agent interfering with the conductive mechanism of the agent.

Another effect exhibited is the dependence of the low solids mixture on the draw down rod number. This effect was not observed for the higher solids. This serves as further evidence for the concentration playing an important role as the number 11 rod applies a thicker coating on the sheet than does the number 3 rod, and the resistances were lower for the number 11 rod samples.

There is not enough evidence to say whether or not the resistance had any special correlation to rod number and humidity.

The next step of the procedure was trying to add agents to a 10% solution of Calgon 261. The data collected from these trials is presented in Table II. All samples used in compiling Table II were prepared using a number 11 rod. The most interesting observation to make here is that all of the agents used increased the resistance instead of lowering it. This is further evidence that dilution of the conductive solution only hampers the conductive mechanism of it. Table III shows the resistances obtained from a coating composed of 5% Calgon 261 and 5% Tamol 850. The resistance values are higher than the resistances obtained from mixtures of only Calgon 261 and water or Tamol 850 and water. Again, this is evidence that dilution of the agents only hinders their operation. Also suggested by the data of Table III is that the mechanism of the Calgon and Tamol may be different. This is further born out when it is considered that when the two solutions of 10% each were added together, a pasty precipitate was formed. It is quite surprising that the resultant resistances came out roughly in the same area as other solutions.

From my work, I have concluded several points. First of these is that humidity has an effect on the conductance of the resin layer. Second is the strong dependence of conductance on the concentration and amount of the conductive agent present in the sheet. This is shown by the dependence on rod number and concentration.

TABLE I

Calgon 261	50% R.H. Surface	50% R.H. Through	20% R.H. Surface	20% R.H. Through
40% Solids				
3 rod	.043	5.7	.085	13
11 rod	.042	6.5	.080	7.3
10% Solids				
3 rod	2.9	5.9	4.3	17
11 rod	.85	2.0	1.7	1.3
Tamol 850				
30% Solids				
3 rod	.44	5.6	3.0	21
11 rod	.5	6.8	5.0	28
10% Solids				
3 rod	31.5	7.0	74	6.0
11 rod	15.0	2.8	16	7.3

All values x 10^8 ohms

TABLE II

	50% R.H.		20% R.H.	
	Surface	Through	Surface	Through
Calgon 10%	.85	2.0	1.7	1.3
+ Sodium Glycolate	1.7	.92	4.7	4.4
+ Isopropanol	2.0	3.3	3.5	7.0
+ Plurafac B-26	1.2	2.9	2.5	3.6
+ Plurionic P-123	1.9	1.8	4.6	3.8

All values x 10^8 ohms

TABLE III

	Surface	Through	Surface	Through
Calgon (5%) + Tamol (5%)				
3 rod	95×10^{8}	6.0×10^{8}	35×10^{8}	17×10^{8}
11 rod	10.5×10^{8}	3.8×10^{8}	4.9×10^{8}	6.3×10^{8}
Base Sheet	1.75×10^{11}	4.4×10^{9}	1.2×10^{11}	3.0×10^{9}

LITERATURE CITATIONS:

1. D. S. Most, D. D. Taft, and S. C. Hiedecker; "Some Observations on Resin Functionality and Electrofax Layer Performance," Reproduced Report

2. Martin Levene; "Electrostatic Printing Papers - Features for Performance Effectiveness," TAPPI 46(12):170-5A(1963)

3. Donald P. Fird, Frans V. E. Vaurio; "Electrically Conductive Paper for Non-impact Printing," TAPPI 47(12):163-165A(1964)

4. M. Hayek; "Electrically Conductive and Static-Free Papers," TAPPI 43(2):105-11(1960)