The Secondary and the Tertiary Figures produced on Photographic Plates by Electric Discharges

By

Usaburo Yoshida and Shinsuke Tanaka

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When one of the electrodes of an influence machine is placed on the sensitive film of a photographic plate and the other is connected to the metal plate under the photographic plate, and when a momentaneous brush discharge is made to occur on the photographic plate, a beautiful discharge figure will be impressed on the plate after developement. In the arrangement shown in Fig. 1, let P_1 P_2 be two photographic plates piled up by their glass sides, E be one of the electrode and M a smooth metallic plate separated from the sensitive film of the photographic plate P_2 by a small and thin insulating material whose thickness does not exceed ca. 0.5 mm. When by means of an influence machine a moderately high potential difference was applied momentaneously between the electrodes E and M, impressions of the brush discharges would be obtained on the photographic plate P_1 and P_2. Mikola[1] called the figure on the upper plate P_1 "the primary figure," and that on the lower plate P_2 "the secondary figure." Some examples of such figures are represented in Fig. 8 and Fig. 9. The figure b in Fig. 8 is the secondary figure corresponding to the primary negative

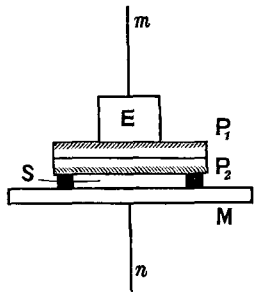


Fig. 1.

[1] Mikola, Phys. Z.S., **18**, 158, (1917).

brush a in Fig. 8. The secondary figure corresponding to the primary negative one consists of two parts: concentric rings which are at right angles to the branches of the primary negative brush, and the short branches which radiated outward from these rings. As these branches in the secondary figure are of the same nature as those in the positive brush discharge on a photographic plate, we may call it "the secondary positive figure" as Mikola[1] and Pedersen.[2] The secondary figure corresponding to the positive primary figure a in Fig. 9 is reproduced in b of the same figure. This secondary figure consists of a system of diffuse lines which are nearly at right angles to the branches of the corresponding primary positive figure. These diffuse lines in the secondary figure become more separated from each other with a thicker air space between the photographic plate P_2 and the metallic plate M. It was observed by the writers that these diffuse lines in the secondary figure, on some of the photographs taken with a sufficiently thick air space, had fine structures characteristic to the regular primary negative figure. Judging from this, the secondary figure corresponding to a primary positive one seems to be of a negative nature, and it may be called "the secondary negative figure" as Mikola and Pedersen.

If the arrangement is like that shown in Fig. 2, the primary figure will be impressed on the upper surface of the plate P_1, the secondary on the lower surface of the middle plate P_2 and the other "the tertiary figure" will be impressed on the upper surface of the plate P_3. When the electrode E on the photographic plates is positive, the primary figure is a positive one; the secondary and the tertiary are respectively a negative and a positive nature, and they are similar respectively to the negative and the positive secondary figures in the case of two photographic plates before mentioned. On the contrary, when the electrode E is made negative all of these three figures become to be of the opposite natures respectively. With four photographic plates P_1 P_2 P_3 P_4 and with two air spaces s_1 s_2 as shown in Fig. 3, four discharge figures may be obtained separately on each

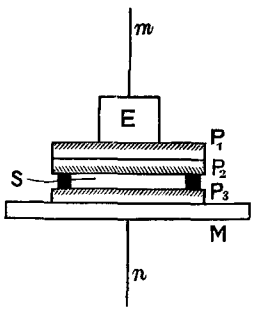


Fig. 2.

[1] Mikola, loc. cit.

[2] Pedersen, K. Danske Vidensk. Selskab, I, No. 11, 1, (1919).

plate. The figures on any two successive plates in this case are of the opposite natures as in the former cases. The figure impressed on the lower surface of the fourth plate P_4 being similar to that appeared on the lower surface of the second plate P_2, every one of these figures are respectively similar to the corresponding figures obtained in the cases of two and three photographic plates.

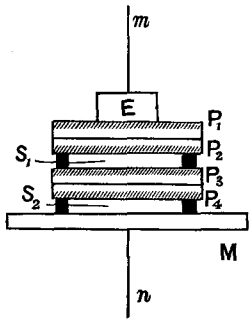


Fig. 3.

As regard to the secondary figure produced on the photographic plate P_2 in the arrangement shown in Fig. 1, explanations of its formation were given by Pedersen[1] and Toepler.[2] They considered that this secondary figures was the impression of the brush discharge in the thin air space between the photographic plate P_2 and the metal plate M beneath it. Actually the writers were able to detect that a weak glow appeared in this air space at the instant of the electric discharge; and the consideration given by Pedersen and Toepler seems to be a reasonable one. If we consider the primary cause of the formation of the secondary figure in the above manner, the fact that the nature of the branches of this figure on the photographic plate P_2 is of the same polarity as the metallic plate below it seems to be understood immediately.

It was already stated that the secondary figure both positive and negative consisted of a system of diffuse lines which were nearly at right angles to the branches of the corresponding primary figure. As regard to the explanation of this nature of the secondary figure, the writers' opinion is essentially the same as that given by Pedersen[3] and is described below.

In the sketch shown in Fig. 4, let E be the cathode, M the anode, P_1 P_2 two photographic plates and s be the air space between the anode M and the photographic plate P_2 as in the case of Fig. 1. When a sufficiently high potential difference is applied between E and M, brush discharges will take place on the upper side of the photographic plate P_1 and in the air space s. In the brush thus formed on the upper side of the plate P_1 a great number of negative ions will be

1 Pedersen, loc. cit.

2 Toepler, Phys. Z.S., **22**, 78, (1921).

3 Pedersen, loc. cit.

generated as conveniently indicated by the shaded part a_0 a_4 in the figure; and consequently by electric induction positive charges will be accumulated in the anode M as shown by the shaded part c_0 c_4. The vertical component of the intensity of the electric field in the air space s beneath the cathode will become very strong in this case, and the brush discharges will now occur across the air space s in this region. The irregular blackening of the photographic plate in the part of the secondary figure just beneath the electrode E may be due to these brush discharges. The free positive charge thus accumulated on the lower surfacc of the photographic plate P_2 by these brush discharges are conveniently shown by the shaded part b_0 b_1 in the figure. The shaded parts b_2 b_3 b_4 on the same photographic plate P_2 represent the distribution of the free charges on the diffuse lines in the secondary figure which are nearly perpendicular to the branches of the primary figure on the plate P_1. If the distribution of the electric charges at a certain stage of the formation of brush discharges be such as that shown in Fig. 4, then the vertical component of the electric field in the air space s will be weaker at the portion just in front of the place denoted by b_4 than at the place more remote such as represented by b_5. In this state of affair, when the range of the primary figure on P_1 is a little increased than a_4, the brush discharges across the air space s will occur at the place such as denoted by b_5, but not at the portion just in front of the place denoted by b_4. This state is present in all stages in the developement of the primary and the secondary figures. The fact that the secondary figure consists of a system of diffuse lines which are nearly perpendicular to the branches of the corresponding primary figure seems to be explanable in the above way. The distance between the two successive diffuse lines in the secondary figure increases with the thickness of the air space s and with the total thickness of the photographic plates P_1 P_2. This seems to be due to the fact that the variation of the vertical compo-

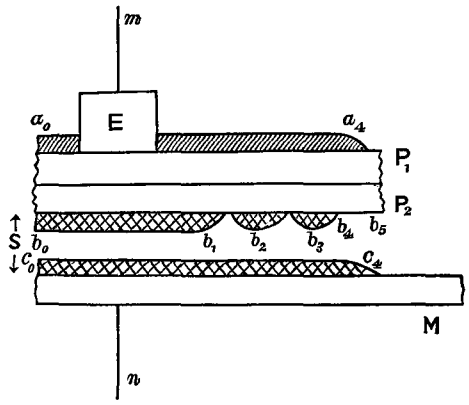


Fig. 4.

nent of the electric field in the neighbourhood of b_4 along the lower surface of P_2 become smaller as the thickness of the air space s and the total thickness of the photographic plate P_1 P_2 are increased. The next brush discharges across the air space s will now occur no more at the place denoted by b_5, but at the place more remote from b_4.

The electric charge accumulated on the lower surface of the photographic plate P_2 is due to the brush discharge across the air space s; and it is positive when the electrode M is anode. The horizontal component of the intensity of the electric field along the lower surface of the photographic plate P_2 will be very strong at the portion just in front of the place denoted by b_5; and consequently the positive brush will shoot out of b_4 and grow toward b_5 along the surface of the photographic plate P_2. The brush discharge across the air space s at b_5 will, if occur, be previous to the arrival of the terminals of the positive brushes above stated to b_5; and these latter positive brushes will be prevented from arriving at the place denoted by b_5 on account of the accumulation of positive ions on b_5 by the former brush discharge. This seems to be the reason that all brushes in the secondary positive figure, which are generated from a diffuse line perpendicular to the branches of the corresponding primary negative figure, do not reach the next diffuse paralled line in the same secondary figure. For the explanation of the secondary negative figure we are only to reverse the signs of all the charges.

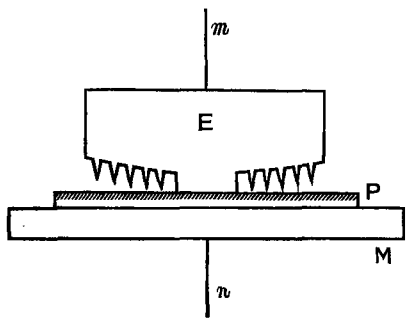


Fig. 5.

The main features of the secondary figures may be imitated by using the arrangement shown in the sketch in Fig. 5. Here M is a plate electrode, P a photographic plate and E is the other electrode placed on the film side of the photographic plate P. The electrode E has many circular and concentric sharp edges on its lower surface. These circular edges are so made that the small distance between the photographic plate P and any one of these edges increases regularly by a small amount as we recede from the center of the electrode. The brush discharges take place in this case between these circular edges and the photographic plate and also from the central part

of the electrode E along the film side of the photographic plate. The photographs obtained under such a condition are represented in Fig. 10. The figure a in Fig. 10 is the photograph obtained when the electrode E is anode, and the figure b is that obtained when E is cathode. These figures are very similar to the secondary positive and negative figures respectively in their main features.

It is already stated that, when the three photographic plates as shown in Fig. 2 are employed, the natures of the figures on these successive photographic plates are of the opposite polarity alternately. Thus, for example, when the primary figure is positive the secondary is negative and the tertiary figure is positive. The primary cause of the formation of the secondary and the tertiary figures in this case will be the brush discharge across the air space s in Fig. 2; and the positive and the negative ions generated by this brush discharge will be attracted towards the photographic plates P_2 P_3. The ions thus accumulated on the lower surface of P_2 will be negative, and those accumulated on the upper surface of P_3 will be positive. Consequently the figure on the upper surface of P_3 will be positive, and that impressed on the lower surface of P_2 will be negative contrary to the primary positive figure impressed on the upper surface of the plate P_1. For the explanation of the secondary positive and the tertiary negative figures we are only to reverse the signs of the charges.

It is also stated before that, the same phenomenon as described above has happened in the case of the four photographic plates arranged as shown in Fig. 3. A quite similar explanation as that given for the case of three photographic plates seems to be true also in this case.

The nature of the tertiary and the quartan figure is essentially the same as that of the secondary one; and it seems to be explained similarly as in the case of the secondary figure obtained in the arrangement shown in Fig. 1.

In the case of the secondary positive figure obtained under the condition represented by Fig. 1, the direction of the growth of the short positive brushes which originated from the diffuse lines perpendicular to the branches of the corresponding primary negative figure are toward outside as was stated before. But this is not always the case when some insulating material such as glass plate or paraffin paper &c. are introduced between the photographic plate P_2 and the metal plate electrode M as shown in Fig. 6. In this figure, E is one

of the electrodes, P_2 the photographic plate whose thickness was about 1 m.m. in the present case, and P_3 is the insulating material; between P_2 and P_3 there is an air space s whose thickness was 0.12 mm. in the present case. Under such experimental conditions, the direction of the growth of the short positive brushes in the secondary positive figure impressed on the lower surface of the photographic plate P_2 is different according to the thickness of the insulating plate P_3. When the thickness of this insulating plate is about 0.1 mm. the direction of the growth of these short positive brushes is toward outside; but when it is about 1 mm. these positive brushes grow in the opposite direction. This nature of the positive brushes in the secondary figure is represented by Fig. 11. In the case of the figure a in Fig. 11 the thickness of the insulating plate P was 0.1 mm., and the direction of the short positive brushes is toward outside. The thickness of the insulating plate in the case of the figure b in Fig. 11 was 0.75 mm., and the direction of the growth of the short positive brushes is reversed in this case. With a proper intermediate thickness of the plate P_3, the writers were able to observe that any such positive brush did not appear in the secondary positive figure as shown in Fig. 12, the thickness of the insulating plate P_3 being 0.25 mm. in this case.

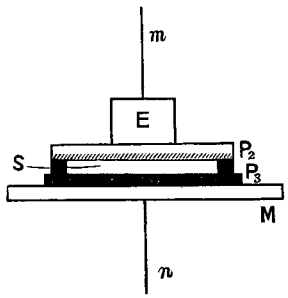


Fig. 6.

In Fig. 7, E is the cathode, M the anode, P_2 the photographic plate and P_3 is the insulating plate as in Fig. 6. The shaded parts in this figure represent the distribution of positive and negative electric charges in a certain stage of the developement of the brush discharges along the surface of the insulating plate P_3 and the photographic plate P_2. The negative charges set free in the primary negative brushes on the upper surface of the plate P_2 are represented by the shaded part a_1 a_4; and the positive charges in the anode M are shown

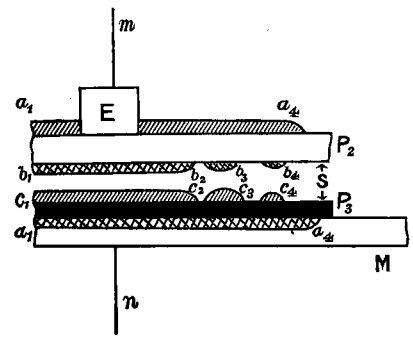
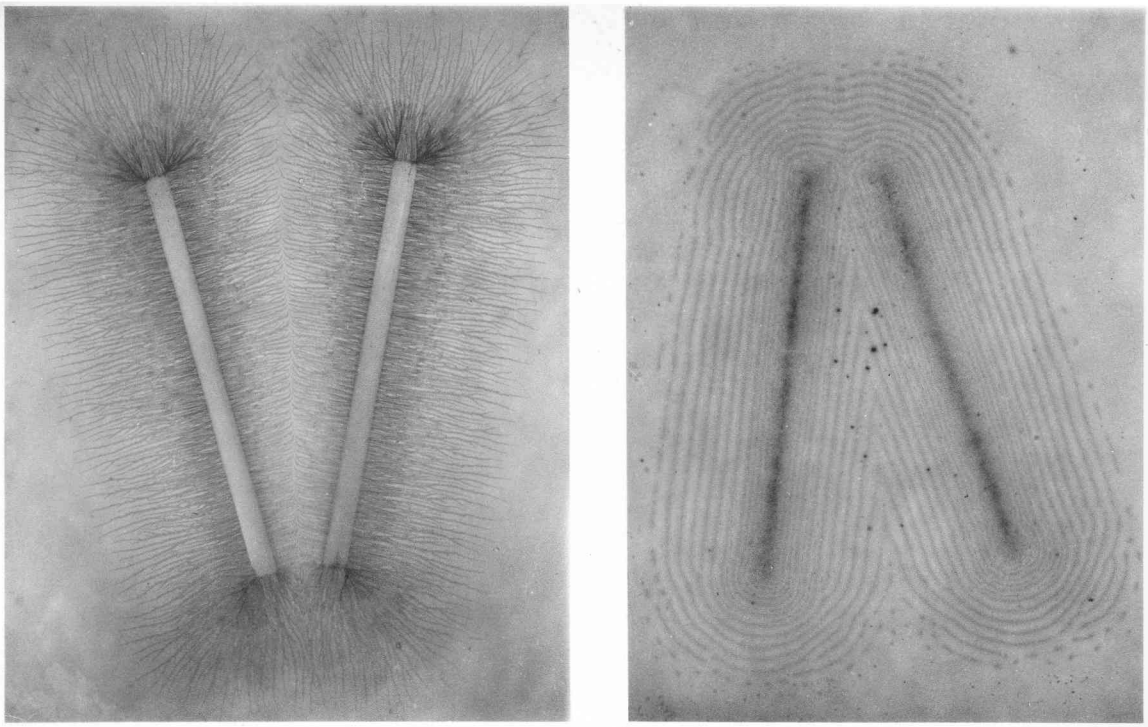


Fig. 7.

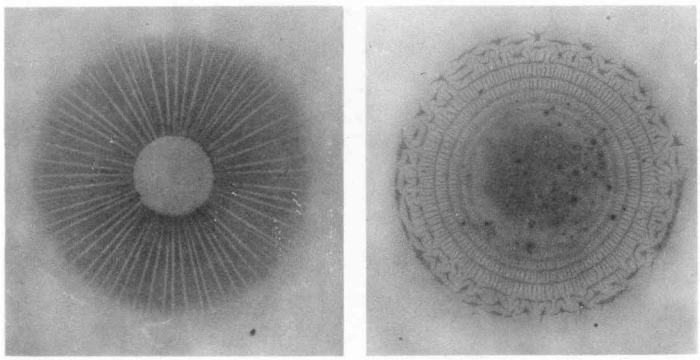
by d_1 d_4. Positive and negative charges accumulated respectively on the lower surface of P_2 and on the upper surface of P_3 are caused by the brush discharges across the air space s between the plates P_2 P_3, and they are roughly represented by the shaded parts b_1 b_2 b_3 b_4 and c_1 c_2 c_3 c_4 as in the case of Fig. 4. The charges in the shaded parts b_1 b_2 b_3 b_4 are evidently positive and those in c_1 c_2 c_3 c_4 are negative. The positive electric charge in the shaded part b_4 will be attracted by the negative charges in a_1 a_4 and in c_1 c_2 c_3 c_4 and will be repelled by the positive charges in d_1 d_4 and b_1 b_2 b_3. The intensity of the repulsive force due to the positive charge in the anode M is different according to the thickness of the insulating plate P_3, and is greater with a thinner plate than with a thicker one. Considering this, it seems very provable that, when the thickness of the insulating plate P_3 is sufficiently large, the horizontal component of the electric field along the lower surface of the photographic plate P_2 at b_4 acts toward inside; and that, on the contrary, it acts toward outside when the plate P is very thin. As we have no exact information as to the distribution of the electric charges in this case, the above consideration is not of course conclusive. But the behavior of the secondary positive figure on the lower surface of the plate P_2 i.e. that the direction of the growth of their short branches is different according to the thickness of the insulating plate P_3 seems very probably to be explained in the above mode.

The arrangement shown in Fig. 2 is essentially the same as that represented in Fig. 6. The only difference is that the two photographic plates are employed in this case instead of one. The part played by the insulating plate in the case of Fig. 6 is now occupied by the photographic plate P_3 whose thickness was about 1 mm. in the present experiment. The secondary positive figure impressed on the lower surface of the photographic plate P_2 consists of a system of diffuse lines perpendicular to the branches of the corresponding primary negative figure on P_1 and short positive brushes originated from these diffuse lines and terminated toward the inside of the figure. As regard to the direction of the growth of these short positive brushes, the same explanation as before seems to hold true also in this case.

In conclusion the writers' hearty thanks are due to Prof. Mizuno for his interest in the research.



a, primary positive. Fig. 9. *b*, secondary negative.



a, primary negative. Fig. 8. *b*, secondary positive.

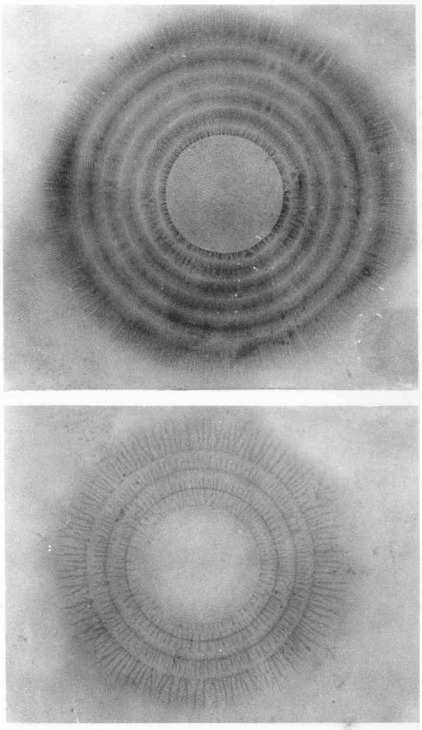
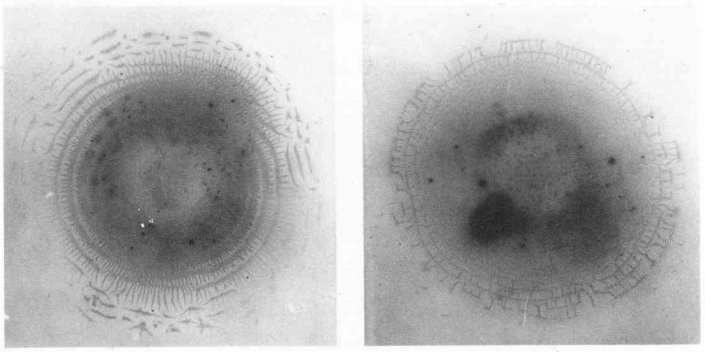


Fig. 10.



a. Fig. 11. *b*.

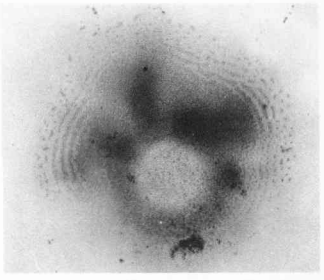


Fig. 12.