

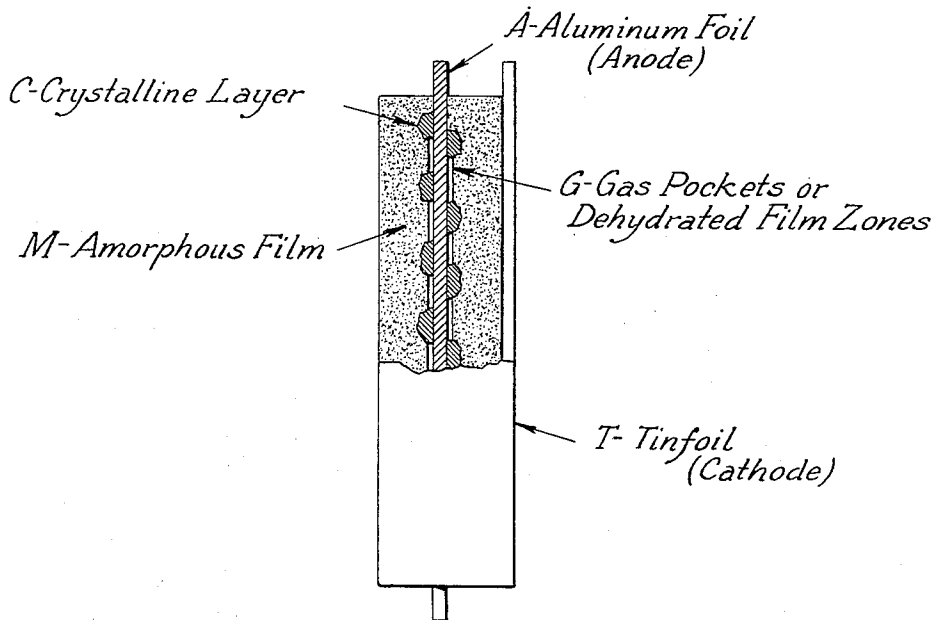
March 22, 1932.

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1,850,298

ELECTRIC CONDENSER AND PROCESS OF MAKING SAME

Filed July 20, 1927



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ELECTRIC CONDENSER AND PROCESS OF MAKING SAME

Application filed July 20, 1927. Serial No. 207,322.

This invention relates to condensers mainly for use in electric circuits carrying pulsating currents, and is particularly designed to produce such a condenser of high capacity per unit of plate area and consequently per unit of volume of space occupied by a multi-plate structure, so that it can be used in the apparatus for eliminating the "A batteries" in radio receiving sets without necessitating too large a container for such apparatus.

To accomplish this it is necessary to use sheets or strips or films of conducting material of the minimum thickness separated by the thinnest possible sheets or layers of a most efficient dielectric. According to the preferred form of the present invention these results are secured by forming a condenser out of a thin sheet of aluminum foil on the surface of which a thin dielectric coating of a non-conducting crystalline aluminum compound has been formed by electrolytic action, covering that coating with a film of amorphous material which is a good conductor, when moist, and preferably superposing a thin sheet of metal foil on said film. The aluminum foil then forms the anode connection for the circuit in which the condenser is to be used, and the other metal foil serves as a connector from the other terminal of the circuit to the moist amorphous film which forms the cathode, the crystalline layer on the aluminum contributing to the formation of a dielectric between the two conducting bodies above described and serving as a mechanical binder holding the two together.

While other bases than aluminum such as magnesium or beryllium could be used for such a built-up structure, and conducting films of various compositions could be used, I have so far secured the best results from the materials and treatment I will now describe. It is important, however, that the conducting film shall be amorphous in character, whatever its composition.

I prepare an electrolytic bath by adding commercial ammonium carbonate to a saturated solution of monobasic ammonium phosphate until the resulting evolution of carbon dioxide ceases, and then add powdered borax (the bath being maintained at a temperature

of from 65 to 90 degrees centigrade) until a saturated solution is obtained. Any excess of the borax crystallizes out and, after these crystals are removed, the residual bath has a specific gravity of from 1.375 to 1.450. The bath so obtained, though compounded of originally crystalline constituents, appears to be amorphous, and when allowed to dry upon a surface forms a film of amorphous character which is highly hygroscopic, and which, after absorbing moisture, becomes a fairly good conductor of electric current.

In this bath I place a thin sheet or sheets, or a ribbon of aluminum foil, using such foil as the anode, and apply a direct current of about 220 volts. The amperage may be varied within fairly wide limits, the rapidity of the resultant formation of the desired dielectric coating on the aluminum anode varying accordingly. With about 270 square inches of submerged anode surface I employ a current of 30 amperes. This, however, in a constant potential circuit, drops in a few seconds to 15 or 20 amperes and continues to maintain that reduced strength indefinitely.

As a result of this electrolytic action, the metallic aluminum at the surfaces of the anode sheets is transformed into an apparently crystalline aluminum compound, at first giving the appearance of a light opaline color, but darkening as it grows thicker, finally reverting to a light grayish color as the process goes on and the surface layer of modified aluminum further thickens. The crystals of the layer of the crystalline aluminum compound have considerable dielectric strength and efficiency of themselves, and when they are dry and the interstices between them are not filled with some material which is a good conductor, this crystalline layer forms an effective dielectric coating, and this condition can be preserved under action of a current when in use, in the manner hereinafter explained. With the current density in the bath above mentioned I obtain a layer of this character of the necessary thickness for ordinary purposes in about five minutes. The thickness of the coating necessary to be produced, of course, depends on the voltage which the condenser is designed to withstand

in use. Of course the electrical resistance of the non-conducting layer so formed increases with its thickness and this can be gauged empirically by observing the changing colors of the surface. The fact that current continues to flow through the electrolytic couple after this layer is formed on the anode in the bath shows that it is not a good dielectric when wet. The reason for this probably is that the liquid bath solution penetrates to the aluminum plate or sheet through the interstices between the crystals forming the coating, and such solution is, of course, a good conductor. Doubtless the same result, of producing conductivity, which I have found can be obtained by plating the crystalline surface with silver, is similarly due to the electrolytically deposited silver penetrating the interstices between crystals and so forming contact with the aluminum plate or foil which supports the otherwise dielectric crystalline coating.

I next remove the aluminum foil from the bath and allow the adhering film of the bath solution to dry thereon, and the sheets or ribbons of foil thus prepared may then be stored for use later. When ready to use this dry foil for making condensers, I first expose it to an atmosphere of about 50% humidity for about 20 minutes, which causes the exterior of the film coating to become tacky, and I then apply thin tin foil, or other metal foil, to one side of the coated aluminum foil and roll or press it into close contact therewith.

If the treated aluminum foil is to be used immediately after removal from the electrolytic bath, the drying of the adhering film may be checked at the proper point, leaving the surface still tacky and the tin foil applied immediately without any such humidifying step as above described.

Complete units of this construction in sheet form may be stacked and pressed together to produce a condenser of a desired capacity, or a composite ribbon so formed may be coiled upon itself, the anode of the condenser circuit being connected to all the aluminum base sheets or convolutions, and the cathode to all the tin foil sheets or convolutions.

I believe that the efficient operation of my invention is due to the fact that the dielectric properties of the aluminum compound formed on the surface of the aluminum foil are supplemented by the perfect dielectric properties of a film of gas formed on the aluminum surface when current is supplied to the condenser in use, and that this gas formation then holds back the residual moisture in the coating film of the original bath solution, and so heightens the dielectric property of the layer of crystalline aluminum compound on the surface of the foil. When the current is shut off probably this gas is absorbed by the outer film of bath solution, and also any excess of gas generated in use is similarly ab-

sorbed. Anyhow, no gas is liberated during the operation of the condenser, even under heavy loads. Doubtless the outer tin foil further seals the gas containing zone of amorphous material. The coating of half-dried film of the amorphous bath solution also retains its original moisture indefinitely because it is sealed between two sheets of metal foil, tin on one side and aluminum on the other. This moisture makes the adherent film of bath solution, or that portion of it which remains moist while in use, a fair conductor. This is proven by the fact that the condenser will operate even if the tin foil sheets cover but a small portion of the surface of the aluminum elements. The resistance of the condenser is slightly increased when the area of the tin foil is thus reduced, but not nearly as much as the reduction in tin foil areas should theoretically increase it. From this I conclude that the moist film of bath solution is a fairly good conductor, though not as good as the tin foil the film really forming the effective cathode.

The product of the above described process is a condenser of great efficiency and capacity per unit of cubic space occupied. The aluminum foil is made as thin as possible while ensuring enough body after the electrolytic action to prevent its being nearly all turned into the crystalline dielectric compound by the electrolytic treatment. If this step (the original treatment of the aluminum foil in the electrolytic bath) is carried too far, the crystals so formed will penetrate the remaining aluminum foil when the tin foil is pressed on it because the remaining aluminum sheet has become too thin to physically resist the puncturing action of the adjacent crystals then pressed against it. The tin foil is made as thin as possible consistent with having it hold together in handling. The conducting coating film under the tin foil has a hardly appreciable thickness, and the layer of crystalline aluminum compound on the aluminum foil is but little thicker. Consequently, a dozen units of this character stacked and pressed together form a package of only about an eighth of an inch in thickness, but such a package will withstand a heavy current indefinitely, and without heating or gassing. It is important that the crystallization step in my process should result in the production of small crystals, as large or coarse grained crystalline masses are not so efficient, and also the larger crystals are liable to puncture the base foil when the condenser is subjected to external pressure.

Inasmuch as the reaction between the monobasis ammonium phosphate and the ammonium carbonate produces a dibasic ammonium phosphate it is apparent that such dibasic ammonium phosphate could be used originally to form the bath, if this can be

obtained as a commercial article, and the borax added to this as above described.

The structure of the condenser and the hereinafter explained theory of its operation are illustrated diagrammatically in the accompanying figure of drawing which shows a cross section of a condenser couple.

Referring to the drawing, A is the aluminum foil. C. C. are crystals of the aluminum compound electrolytically deposited thereon. M is the film of amorphous, hygroscopic material adhering thereto as the result of the drying out of the original film of bath solution left on the plate when it was removed from the bath, and G represents a layer of gas at the bottom of the pockets formed between crystals C. C. and separating the moist conducting film M from the aluminum foil A, after the current has been applied to the couple. T is the outer sheet of tin foil.

While it may not be capable of conclusive demonstration, I believe the method of operation of the condenser is substantially as follows:

The crystals C. C. are dielectric in character. To complete the dielectric, however, the interstices between the crystals C. C. must also be empty or be filled with a dielectric material.

When first formed probably minute masses of the moist amorphous coating M extend all the way to the bottom of the interstices between crystals C. C. and touch the aluminum foil, thus completing the circuit, but, when subjected to the action of a current flowing through that circuit, the moisture next to the foil A is dissociated into oxygen and hydrogen, or some other gas is generated at those points by electrical action, and either the gas so generated immediately at the anode physically separates the material M from foil A by its expansive force (as by bending the foil away from the mass M) thus creating a perfect dielectric film of gas between anode plate A and cathode mass M of the condenser, or the gas generated next to foil A forces the moisture there existing further back into the remaining hygroscopic mass M, leaving a thin zone of a dehydrated portion of the material M next to foil A, such dried out zone forming the dielectric. Also, it may be that the electrical dissociation of water in this narrow zone immediately adjacent to foil A, by consuming all the moisture there originally existing, leaves said zone filled with masses of absolutely dehydrated material M, which then constitute the dielectric between the anode foil A, on one side, and the remaining moist, and therefore conductive, portion of the mass M on the other side, which latter forms the cathode of the condenser, in conjunction with tinfoil sheet, T.

Whatever the operation, the result is evidently the formation of a very thin, very effective dielectric, as the condenser develops

great capacity, which can only result from thinness of the dielectric.

So far as at present advised, I believe that the coating M applied to the crystalline surface C must be amorphous in character, because only amorphous masses are highly hygroscopic, and the cathode mass must be hygroscopic in order that it may retain moisture and so become a conductor. Also an amorphous film forms a better seal with tin foil T to prevent escape of the gases and moisture. It may be remarked that the crystalline layer C. C. also serves as an efficient bond for holding cathode mass M on anode foil A, as well as contributing to the creation of the dielectric between them, as above explained.

Also, so far as I have been able to determine, it is important, if not essential, that the bath shall contain an ammonium compound and in proportions sufficient to give it a predominating alkalinity. Phosphoric, boric or other acids will not serve alone in my process. The coating, formed by the film of bath solution partly dried upon the aluminum plate, is also predominatingly alkaline in character, so far as I can determine.

Obviously the electrolytic action of the bath would form the crystalline coating C upon both surfaces of the aluminum foil A, as indicated in the drawing. Such coating on the left hand, or outer surface of the foil A serves as a dielectric between that side of each condenser couple and the tin foil of the next couple to the left, when a series of couples are assembled to form a condenser of commercial character. Also, if the tin foil T of the next couple were omitted partly, the left hand crystalline coating would then cooperate with the amorphous coating of the next couple to form the gaseous portion of such dielectric in the manner above explained.

Having described my invention, I claim:
1. A condenser for use with alternating or pulsating electric currents which comprises, in combination, a thin sheet of a metal capable of forming a fine-grained crystalline non-conducting compound when subjected to electrolytic action, said sheet being coated with a compound of said metal electrolytically formed thereon, an exterior film of an inorganic amorphous material containing moisture and having current conducting properties, and a sheet of metal foil applied to one surface of said coated sheet.

2. The herein described process of forming a base element for use in an electric condenser and for similar purposes which comprises subjecting a sheet of aluminum to electrolytic action in a bath formed by mixing ammonium carbonate with a saturated solution of monobasic ammonium phosphate and adding borax until a saturated solution is produced, said bath forming operation be-

ing carried on at a temperature of from 65 to 90 degrees centigrade.

3. The herein described process of forming a base element for use in an electric condenser and for similar purposes which comprises subjecting a sheet of aluminum to electrolytic action in a bath formed by mixing ammonium carbonate with a saturated solution of monobasic ammonium phosphate and adding borax and finally allowing a film of the said bath solution to partially dry on said aluminum sheet after its removal from said bath.

4. The herein described process of forming an electric condenser which comprises preparing a base element by immersing aluminum foil as the anode in an electrolytic bath, containing tribasic ammonium phosphate and borax, until a layer of crystalline material is formed upon the surface of said foil and then pressing a second sheet of tin foil against one surface of said base element while the latter is still covered with a moist film of said bath solution.

5. The herein described process of forming an electric condenser which comprises preparing a base element by immersing aluminum foil as the anode in an electrolytic bath, containing an ammonium phosphate and borax, until a layer of crystalline material is formed upon the surface of said foil and then pressing a second sheet of metal foil against one surface of said base element while the latter is still covered with a moist film of said bath solution.

6. As an element upon which coating materials may be deposited and adhere, a base sheet formed of aluminum coated with a layer formed from aluminum, borax and an ammonium compound.

7. As an element in an electric condenser, a base sheet formed of aluminum foil coated with a layer formed from aluminum, borax and an ammonium outer film comprising a mixture of borax and an ammonium compound and water.

8. An electric condenser comprising, in combination, a base element of aluminum foil coated with a crystalline layer formed of an ammonium compound, borax and aluminum, a moist film of amorphous character formed of said ammonium compound and borax, and a sheet of tin foil pressed against one surface of said base element.

9. The herein described process of forming an electric condenser which comprises preparing a base element by immersing aluminum foil as the anode in an electrolytic bath, containing an ammonium phosphate and borax, until a layer of crystalline material is formed upon the surface of said foil and then pressing a second sheet of metal foil against one surface of said base element while the latter is still covered with a moist film of said bath solution, the said bath being

maintained during its formation at a temperature of from 65 to 90 degrees centigrade.

10. The herein described process of forming an electric condenser which comprises preparing a base element by immersing aluminum foil as the anode in an electrolytic bath, containing an ammonium phosphate and borax, until a layer of crystalline material is formed upon the surface of said foil and then pressing a second sheet of metal foil against one surface of said base element while the latter is still covered with a moist film of said bath solution, the said bath being maintained during its formation at a temperature of from 65 to 90 degrees centigrade, and all resulting crystals of borax then forming having been removed from it before electrolytic action is begun.

11. As a step in the above described process the electrolytic treatment of metallic aluminum which comprises immersing it as an anode in an electrolytic bath formed by an aqueous mixture of monobasic ammonium phosphate, ammonium carbonate and borax, and subjecting said anode to a current density of about sixteen amperes per square foot of submerged area.

12. As a step in the above described process the electrolytic treatment of metallic aluminum which comprises immersing it as an anode in an electrolytic bath formed by an aqueous mixture of monobasic ammonium phosphate, ammonium carbonate and borax, and subjecting said bath to a constant potential current of 220 volts and an initial strength of one ampere for every nine square inches of submerged anode surface.

13. A method of forming an electric condenser, which method comprises subjecting a sheet of metal serving as the anode and coated with a crystalline layer on, and into, which has been pressed a mass of hygroscopic material containing moisture and serving as the cathode, to the action of an electric current, whereby there is generated in the interstices of said crystalline layer, and immediately adjacent to the surface of said metallic anode, a thin film of gas which thereupon acts to separate the moist portion of said cathode from said anode surface and thereafter persists, during subsequent action of said current, to contribute toward the creation of a dielectric between said anode and cathode.

14. A method such as is defined in claim 13 in which said gas has been sealed in said interstices by the application, to the outer surface of said cathode mass, of a sheet of material impervious to said gas.

15. A method such as defined in claim 13 in which said cathode mass is amorphous in character, whereby the portion thereof exterior to said crystalline layer contributes a sealing action to confine in situ the gas generated in that portion thereof located in the interstices of said crystalline layer.

16. As an element in an electric condenser a base sheet of aluminum foil coated with a layer comprising a crystalline body formed from aluminum, borax and a dibasic ammonium phosphate, and a superposed film formed of water, borax and said dibasic ammonium phosphate.

17. A bath for electrolytically forming a base element for use in an electric condenser, and for similar purposes, produced by mixing ammonium carbonate, a saturated solution of monobasic ammonium phosphate and borax.

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