

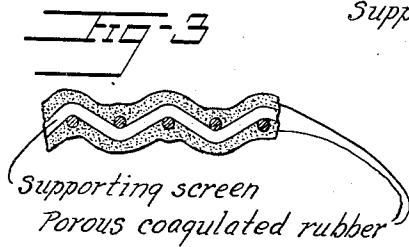
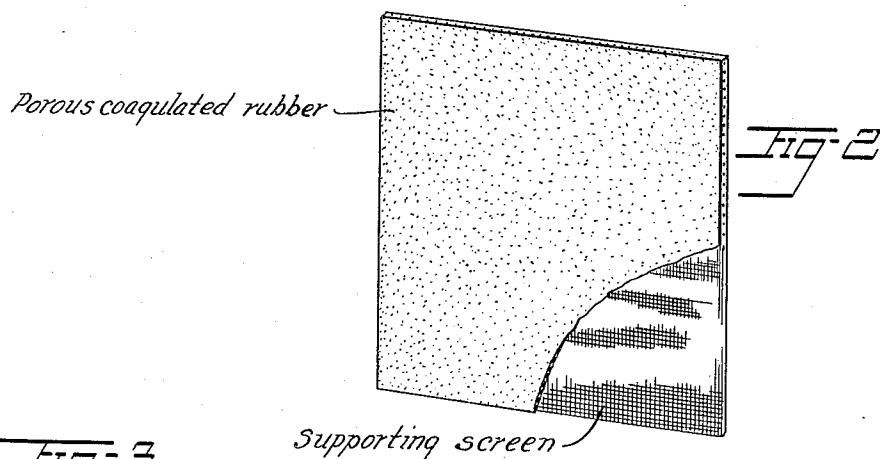
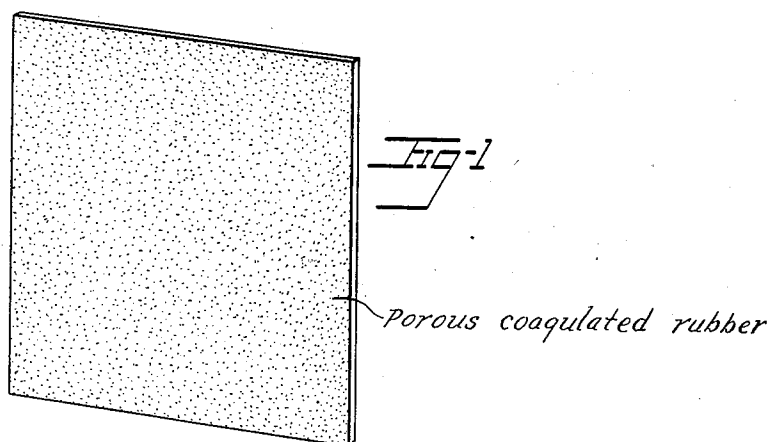
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PERMEABLE DIAPHRAGM

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PERMEABLE DIAPHRAGM

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This invention relates to the arts of electroplating and electrodeposition and has as its object to provide an improved porous diaphragm permeable to the electric current, and particularly a diaphragm having an unusually high capacity for electro-endosmosis.

Permeable diaphragms are employed in many electrolytic processes for the purpose of separating the different fluids employed. For example, they may be employed in the cells used for the electrolytic decomposition of water into oxygen and hydrogen, in order to prevent the readmixture of these two gases. They are also frequently employed in galvanic cells to separate the different solutions which are placed in contact with the anode and cathode. Of particular importance, however, are the diaphragms which are frequently employed in the cells used for the electrophoretic deposition of suspended particles from aqueous dispersions.

In the production of coatings by electrophoresis it is of the utmost importance that no gas bubbles be formed or entrapped within the deposited coating to render it porous. Gas evolution at the anode—upon which such deposits are ordinarily formed—is readily prevented by employing an anode of a metal such as zinc or cadmium which readily goes into solution under the influence of the current. Elimination of the gas at the cathode, however, is more difficult and is ordinarily effected by interposing a permeable diaphragm between the cathode and the dispersion, the current passing readily through the diaphragm, but the gas bubbles remaining within the cathode space and escaping from the surface of the liquid contained therein.

The electrodeposition of the suspended particles from an aqueous dispersion necessarily entails a considerable and progressive diminution in the concentration of the suspended material, with an accompanying change in the electric properties of the liquid. It is desirable, therefore, to remove the dispersion medium (chiefly water) from the dispersion at the same time that the dispersed particles are removed by electrodeposition and coagulation, and at such a rate that the concentration of the dispersed material remaining in the liquid is maintained substantially unaltered. When a porous diaphragm is disposed adjacent the cathode, the electro-endosmotic flow of the aqueous liquid is normally directed toward the cathode, so that by choosing a diaphragm through which the flow is sufficiently great, the withdrawal of the

dispersion medium through the cathode diaphragm can be caused to correspond in quantity to the deposition of the dispersed substance upon the anode, leaving the dispersion reduced in quantity but unchanged in concentration.

We have discovered that sheets of coagulated, but undried, rubber are particularly useful diaphragms for any of the above purposes. Their permeability to the electric current is high, while the pore size is sufficiently small that suspended particles cannot penetrate them. On the other hand, the pores are of such a uniform size, and the character of the material is such that an unusually high electro-endosmotic flow may be attained.

It is well known that if the current is maintained at a constant value, the volume of liquid transmitted through a single pore or capillary by electro-endosmosis is independent of the diameter and length of the capillaries, therefore, the amount transmitted per unit area of diaphragm if the current over the unit area remains constant is independent of the number or size of the capillaries and depends only on the viscosity of the liquid, on its dielectric constant, and on the potential at the electrical double layer at the interface between the liquid and the wall of the capillary. That is to say that the electro-endosmotic flow through a diaphragm can be modified by changing the characteristics of either the liquid or the material of the diaphragm. Since it is ordinarily undesirable to modify the liquid to any great extent, the characteristics of the diaphragm will ordinarily be modified to meet different conditions, the maximum flow being attained by employing diaphragms made by the coagulation of rubber latex without the addition of foreign substances, and variations therefrom being obtainable by suitable pigmentation or substitution of artificial aqueous dispersions.

Because of the above noted characteristics, the diaphragms employed in the process of this invention may be made from natural or artificial dispersions of rubber or rubber-like substances either with or without the addition of other suspended or dispersed materials, but are preferably made from the substantially unadulterated natural latex of rubber, such as the ammonia-preserved latex of commerce, derived from the *Hevea brasiliensis*. Artificial dispersions of rubber tend to give rise to soft diaphragms of little mechanical strength, which are readily injured when not carefully handled. The addition of considerable proportions of fill-

ers likewise reduces the strength of the diaphragms, and also impairs their electro-endosmotic efficiency. Nevertheless, for some purposes such modifications of the materials from which the diaphragms are made may be very desirable.

The diaphragms are readily prepared by the deposition of the above-mentioned rubber dispersions on forms of the desired size and shape. The deposition is effected by ionic diffusion, either alone or assisted by the electric current. In either case the deposition may take place either on a smooth-surfaced form or on a foraminous supporting web which may be retained within the finished diaphragm.

In the accompanying drawing Fig. 1 represents a plain diaphragm and Fig. 2 a diaphragm reinforced with a wire fabric, which is shown in section in Fig. 3.

The simplest method of producing the deposit is by the immersion in the latex (or equivalent dispersion) of a form impregnated or coated with a substance which gives rise to coagulating ions. The gradual diffusion of the coagulating ions into the latex causes the coagulation of a uniform sheet of rubber on the surface. For example, a porous porcelain mold is impregnated with acetic acid or with calcium chloride solution and immersed in latex until a deposit of about 1/16 inch thickness is formed. About 15 minutes will be required. The deposit is then carefully removed from the mold.

The electrodeposition is effected in the well known manner upon a metallic anode or upon a porous form impregnated with a suitable electrolyte such as alkaline ammonium chloride. The electric current simultaneously causes an electrophoretic migration of the rubber particles toward the anode and a movement of coagulating ions from the anode toward the deposit. As a result the deposit formed is somewhat more firm and compact than that produced by the simple ionic diffusion described above. The concentration, alkalinity, and conductivity of the latex or equivalent dispersion should be so regulated that the deposit formed is smooth, firm, and coherent, without being so dense that it is impermeable. Ammonia-preserved latex which has been aerated until the greater part of the ammonia has been eliminated and the alkalinity reduced to a value corresponding to a pH of 9 to 9.5 is quite suitable. The current density at the anode may conveniently be from 0.05 to 0.2 amperes per square inch, and the deposition may be continued until the deposit has attained the desired thickness.

The deposited diaphragm is preferably washed thoroughly to eliminate coagulating substances from its pores, and is impregnated with a neutral or slightly alkaline electrolyte. Since coagulated rubber shrinks upon drying, the walls of the pores fusing together upon the elimination of the water contained therein, and the whole structure becoming permanently impermeable, it is necessary to maintain the diaphragms continuously moist until they are used. Preferably they are preserved by immersion in a slightly alkaline solution containing a preservative such as phenol which prevents the decomposition or putrefaction of the sugars or proteins naturally present in rubber.

The freshly coagulated deposits are quite flexible and extensible, hence they must ordinarily be supported by some rigid or inextensible means when they are employed as diaphragms. They

may, for example, be confined between perforated sheets of a non-conducting material such as hard rubber or between rubber-insulated woven wire fabric or even between baze metal supports, but are preferably supported internally. For example, a particularly useful diaphragm is produced by depositing rubber upon an open weave textile fabric or a fine mesh woven wire screen until the rubber has completely filled all the openings and the diaphragm has attained a substantially constant thickness.

The rubber diaphragm prepared as described above have pores large enough to permit the flow of the electric current without undue resistance, yet small enough that differences in the liquid level on the two sides of the diaphragm do not cause any appreciable flow. A diaphragm deposited by electrophoresis on a 1/8 inch mesh wire screen, the total thickness of the diaphragm being 9/64 inches, was found to have an electro-endosmotic flow of 1.2 cubic centimeters per ampere-minute when impregnated with a slightly alkaline water solution. This is considerably greater than the flow through porcelain or asbestos diaphragms, which varies from about 0.5 to 1 cubic centimeters per ampere-minute. The electrical resistance, however, is practically the same.

The particular mode of employing the above rubber diaphragms in any electrolytic or electrophoretic cell will be obvious, the rubber diaphragm simply being substituted for that previously employed. The sole precaution necessary is that the diaphragms must be continuously maintained moist, as drying out will impair their usefulness.

It is to be understood that the term "rubber", unless otherwise modified, is employed in the appended claims in a generic sense to include natural or synthetic rubber, reclaimed rubber, gutta-percha and balata, rubber-isomers, and like substances. The term "undried" is used to indicate that the material of the diaphragm has been maintained continuously in a moist condition from the time when the diaphragm was originally formed.

Inasmuch as numerous embodiments of this invention may be made without exceeding the scope thereof, it is not intended to limit this invention to the specific embodiment hereinabove described except as indicated in the appended claims.

We claim:

1. Permeable diaphragms comprising undried unvulcanized coagulated rubber occupying the foramina of a foraminous support.

2. Permeable diaphragms comprising undried unvulcanized coagulated rubber surrounding and supported by a woven wire screen, the mesh of the screen being completely filled with the deposited rubber.

3. Permeable diaphragms comprising undried unvulcanized coagulated substantially pure rubber supported by a foraminous web contained within the deposit.

4. Permeable diaphragms comprising undried unvulcanized electrodeposited rubber occupying the foramina of a foraminous support.

5. Permeable diaphragms comprising undried unvulcanized electrodeposited rubber surrounding and supported by a woven wire screen, the mesh of the screen being completely filled with the deposited rubber.

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