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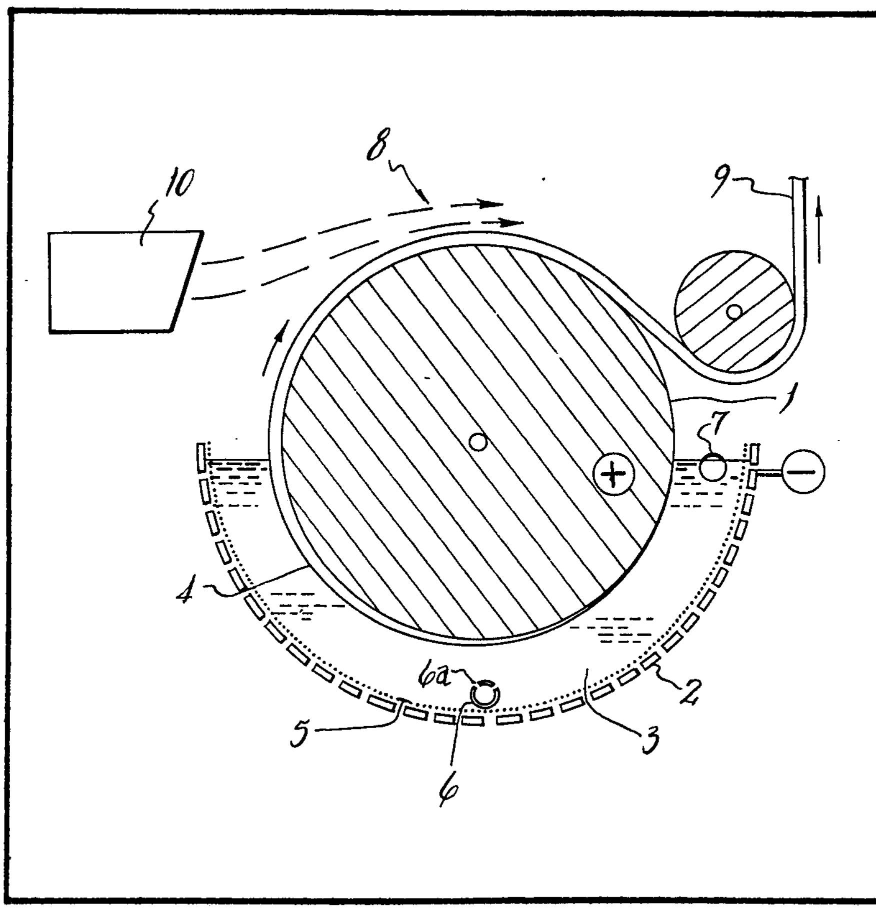
(71) Applicant
T & N Materials Research Limited,
(United Kingdom),
20 St. Mary's Parsonage,
Manchester,
M3 2NL
(72) Inventors
Michael Alan Willis,
Alan William Atkinson
(74) Agent and/or address for service
D. D. E. Newman, R. F. Hadfield, J. A. Crux,
20 St. Mary's Parsonage,
Manchester,
M3 2NL

(54) **Making flexible sheet material**

(57) In a method of making flexible sheet material which incorporates fine plate-like particles of an expanded layer silicate such as exfoliated vermiculite, an aqueous suspension 3 of the silicate particles is submitted to electrophoresis to deposit said particles on a rotary cylindrical anode 1 which is partly immersed in the suspension, and the electrophoretic deposit leaving the suspension as the anode rotates is first dried in contact with the anode by a stream 8 of unreactive gas at elevated temperature and the deposit is then stripped from the anode.



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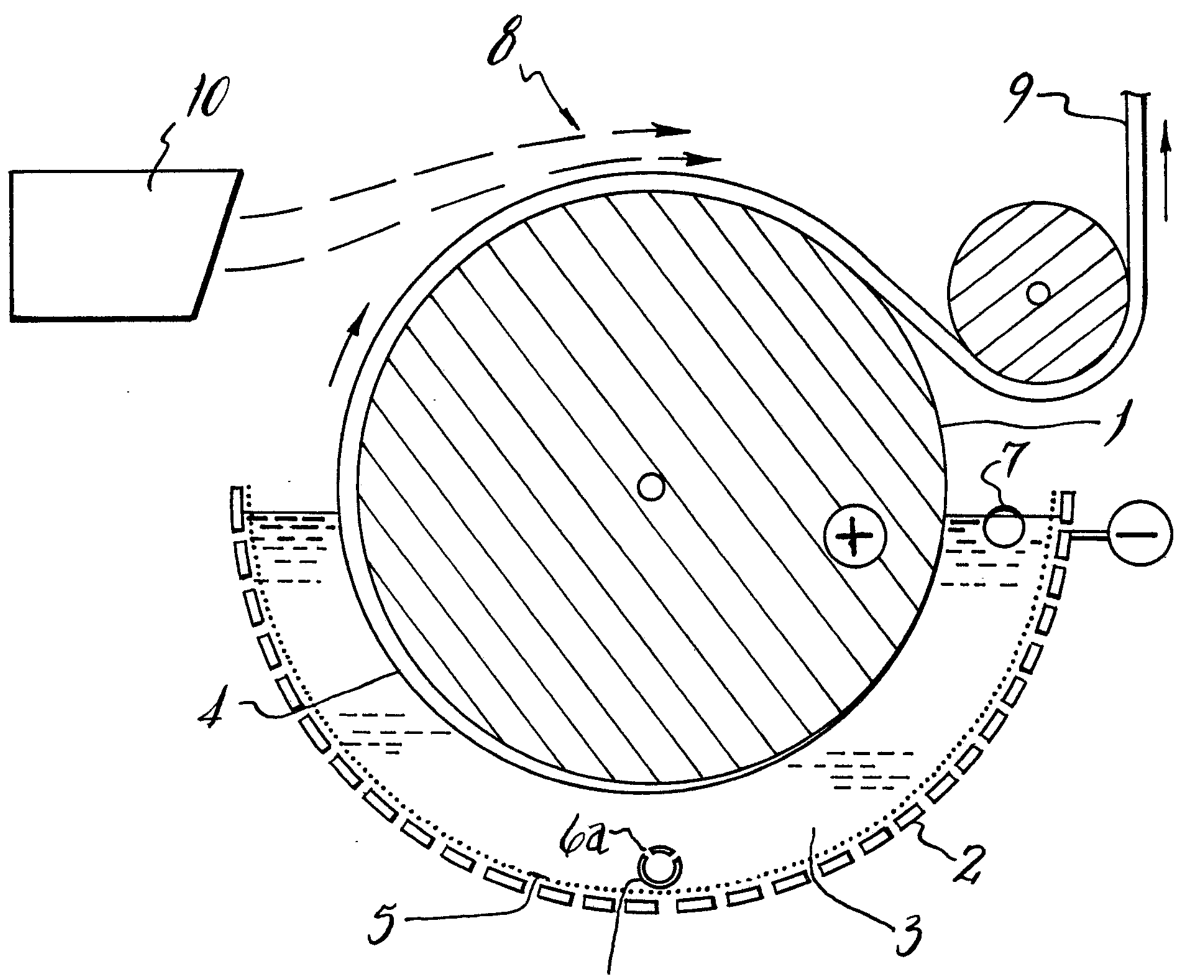
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SPECIFICATION
Method of making flexible sheet material

This invention relates to a method of making flexible sheet material, more particularly flexible sheet material having a content of exfoliated vermiculite or similar expanded layer silicate such as expanded hydrobiotite.

It is disclosed in British Patent Specification 1 593 383 that flexible sheet material composed substantially wholly of lamellae (fine plate-like particles) of exfoliated vermiculite adhering together by mutually attractive forces can be made by evaporating certain aqueous suspensions of exfoliated vermiculite while they are in contact with a shaped surface, or alternatively by removing water from the suspensions by absorption into an absorbent part of a shaped surface. Electrophoretic methods of deposition of the lamellae from the suspension are referred to as being advantageously used when rapid removal of water is required. After the bulk of the water has been removed by such methods, the vermiculite layer may be stripped from the surface against which it is shaped, or alternatively left in place as a noncombustible coating on the surface.

The present invention is concerned with making flexible sheet material incorporating fine plate-like particles of an expanded layer silicate, and provides an electrophoretic method which can be operated continuously.

According to the inventoin an aqueous suspension of the silicate particles is submitted to electrophoresis to deposit said particles on a rotary cylindrical anode which is partly immersed in said suspension, and the electrophoretic deposit leaving the suspension as the anode rotates is first dried in contact with the anode by a stream of air or other unreactive gas such as nitrogen at elevated temperature to moisture content below about 50% by weight, and the deposit is then stripped from the anode.

The drying operation strengthens the electrophoretic deposit, enabling it to be detached intact from the rotary anode. A suitable temperature for the drying gas is in the range 50—110°C. Below 50°C drying is slow, and above 110°C there is the danger that the sheet may blister through too rapid evaporation of water from it.

Electrophoresis will usually be carried out at a voltage gradient in the range 0.05—3 volts/mm. A preferred range is 0.25—2.5 volts/mm.

Electrophoresis in aqueous suspensions is often accompanied by electrolysis, and this can give rise to gas bubbles, in particular of oxygen, at the anode. To avoid this, and the possibility of forming a deposit that is flawed owing to the presence of trapped gas, it is desirable to employ an anode whose surface at least is of a metal which supresses oxygen evolution, preferably zinc, copper, aluminium or very pure iron.

During electrophoresis, the cathode is preferably separated from the bulk of the electrophoresis medium by a membrane which is permeable to ions dissolved in the medium (i.e. it allows passage of current-transporting ions) but is impermeable to hydrogen generated at the cathode. This avoids the release of hydrogen gas into the body of the electrophoresis medium, so that the electrophoretic deposit on the anode does not become flawed by occlusion of bubbles of hydrogen.

The expanded layer silicate which is to be present in the electrophoresis medium is preferably an aqueous suspension of silicate which has been exfoliated chemically rather than thermally. Suitable suspensions may be prepared by the methods described in British Patent Specifications 1 016 385, 1 119 305, 1 593 282 and 1 593 383.

The aqueous suspension of expanded layer silicate may contain a dispersed organic polymeric material to bring about formation of an electrophoretic deposit which contains from 5 to 90% by dry weight of said polymeric material. The flexible sheet material thus produced is, by virtue of its water-resistance, cohesiveness and sealing capacity, useful as gasket-facing material, and can be readily secured by conventional adhesives to apertured metal support plates of the type used in gasket manufacture.

Suitable polymeric materials are: natural rubber; acrylonitrile-butadiene copolymers; polyacrylates; acrylonitrile-butadiene-styrene copolymers.

The electrophoresis medium may contain additional ingredients intended to form part of the flexible sheet material, for example: pigments and dyes; and additional water-proofing agents such as glyoxal.

Reinforcing fibres (other than those of asbestos, which for health reasons is not employed) may be co-deposited with the plate-like particles of expanded layer silicate to modify the properties of the flexible sheet material. For example, glass fibre of diameter 12 μm and length in the range 50—150 μm may be incorporated to improve wet strength.

If flexible sheet material of high tear strength is required it can be obtained by electrophoretic deposition onto a rotary anode through the interstices of a net of fabric, for example scrim woven from glass fibres, textile fibres or fibres of organic polymer, the net being fed continuously into the electrophoresis medium around and in contact with the rotary anode. The deposit envelops the fabric net, and the net becomes incorporated in and thus reinforces the sheet which is formed.

The flexible sheet material stripped from the rotary anode will usually be smoother on that side of it which was in contact with the anode. A product with an equally smooth finish on both sides can be obtained by bringing together the less smooth faces of two separate freshly prepared sheets of the material, and passing the assembly between calender rolls under very light pressure, without using adhesive.

Calendering may also be carried out to improve the surface finish of a single sheet; but again, only very light pressure (leading to a reduction in thickness of no more than about 5%) should be employed.

Corrugated flexible sheet material can be combined with flat material to form strong, lightweight sheet material resistant to high temperature. The two sheet materials can be bonded by light pressure as just described, at moisture content (in either or both of them) in the region of 20—45% by weight. Alternatively, the sheet materials at a moisture content which is an equilibrium with the atmosphere (i.e. below about 10% by weight) can be stuck together with expanded layer silicate slurry of 1—10% concentration or with other adhesive substance, particularly non-combustible adhesives such as sodium silicate solution.

Flexible sheet material having perforations, or otherwise patterned, can be formed by electrically insulating particulare regions of the rotary anode, as by applying a pattern of polyurethane lacquer spots, before electrodeposition.

The invention is further illustrated by the following Example, and with reference to the accompanying drawing, which is a diagram partly in vertical section showing a form of apparatus by which the invention can be put into practice. The apparatus comprises an electrophoresis cell whose anode 1 is a cylinder which is cast from zinc and has a surface machined and polished to a mirror finish. The cylinder is mounted for horizontal rotation about its longitudinal axis, and has its end faces, and strips 25mm wide at the edges of the cylindrical face, coated with electrically insluating lacquer to prevent electrophoretic deposition on those areas. The cathode 2 of the electrophoresis cell is a perforated tinplate half-cylinder whose cylindrical surface is spaced 15 mm from the anode and whose end walls are lacquered to make them non-conductive. The perforations are 2.5 mm in diameter, with centres 4 mm apart. In contact with the anode and completely covering its cylindrical surface is a membrane 5, which is sufficiently permeable to water and ions dissolved therein to allow passage of electric current, but is impermeable to the hydrogen generated at the cathode during electrophoresis. That hydrogen escapes to the atomosphere through the perforations in the cathode. The membrane is suitably a film if cellulose acetate ('cellophane'), 0.02 mm thick and of mass 32.5 gram/m^2.

A pipe 6 extends axially of the cathode 2 at its lowest part, and has holes 6a spaced regularly along its length for the supply of the aqueous suspension 3 to be subjected to electrophoresis. Each end wall of the cathode has outlets, as at 7, for aqueous suspension depleted in suspended layer silicate. The electrophoretically deposited layer 4 of silicate is dried by a stream of warm air 8 from blower 10, and after detachment from the anode is drawn off (see 9) to be wound on spools. To improve its tear resistance it can be further dried to a moisture content below 10% by weight before winding.

In a typical run a slurry of chemically exfoliated vermiculite (solids content 6.5% by weight: particle size less than 50 μm: prepared according to Example 2 in British Patent Specification 1 593 382) was admitted to the half-cylinder 2. The level of slurry was such that just under half of the anode was immersed in it. At a voltage gradient of 1 volt/mm, with a deposition time of 7 minutes (anode surface speed 0.55 mm/sec), the flexible sheet issuing at 9 had, when further dried in warm air to 5% moisture content, a thickness of 0.25 mm, a mass of 100 grams/m^2 and a tensile strength of 5 MPa.

Claims

1. A method of making flexible sheet material which incorporates fine plate-like particles of an expanded layer silicate, in which an aqueous suspension of the silicate particles is submitted to electrophoresis to deposit said particles on a rotary cylindrical anode which is partily immersed in said suspension, and the electrophoretic deposit leaving the suspension as the anode rotates is first dried in contact with the anode by a stream of air or other unreactive gas at elevated temperature to a moisture content below about 50% by weight, and the deposit is then stripped from the anode.

2. A method according to claim 1, in which the drying gas has a temperature in the range 50—110°C.

3. A method according to claim 1 or 2, in which the anode has a surface of metal which suppresses oxygen evolution.

4. A method according to any one of claims 1 to 3, in which the cathode is separated from the bulk of the electrophoresis medium by a membrane which is permeable to ions but is impermeable to hydrogen generated at the cathode.

5. A method according to any preceding claim, in which the aqueous suspension of expanded layer silicate contains a dispersed organic polymeric material.

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