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Field induced radial crack patterns in drying laponite gel

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Abstract

We present a study of crack patterns in a layer of laponite gel allowed to dry in a static electric field. Crack patterns in natural and synthetic clays have been studied extensively with interesting results. Since clay platelets have a surface charge in aqueous solution, it is natural to expect the cracking patterns to be affected by an electric field. This is the first report of such an observation in a radial electric field. The nano-sized disc-like laponite particles carry a quadrupole moment due to their charge distribution. The interaction of the quadrupole moment with the field gradient in a non-uniform field of radial symmetry is probably responsible for the characteristic pattern observed. The cracks start radially from the positive electrode. The same geometry with no field does not produce the characteristic pattern, neither does a uniform field with rectangular geometry.

Keywords: Crack pattern; Laponite; Gel

Desiccation cracks in clay materials make an interesting study which may be of practical importance [1–4]. Clay particles are flat and plate-like usually of micron size with a surface charge [5], so they are likely to be influenced by an external electric field. It is more convenient in laboratory experiments to study clean chemistry customized synthetic clays like laponite RD. We let films of laponite gel dry in a static electric field, the pattern of desiccation cracks formed is found to be strongly affected by the geometry and the direction of the electric field gradient. A radial electric field with cylindrical symmetry produces a radial pattern of cracks, distinctly different from a drying gel in the same geometrical set-up but with no field. A uniform electric field in rectangular geometry is also found to have no effect. Moreover, reversing the direction of the field reverses the pattern, the cracks always starting from the positive terminal. It is possible to interpret the origin of the pattern from the known charge distribution on the laponite platelets [6].

The experimental procedure is as follows: 2.5 gm laponite RD (Rockwood Additives) is mixed with 50 ml. distilled water. The mixture is stirred for 15 min in a magnetic stirrer and deposited in circular petri dishes of 12 cm diameter and allowed to dry. The thick suspension just before formation of the gel is mildly alkaline with a pH of 9.5. Two electrodes constructed from aluminium foil are fitted to the petri dishes. One is in the form of a thin rod placed at the centre of the dish and the counter-electrode consists of an aluminium strip placed at the edge of the petri-dish in the form of a short cylinder. A static field is applied from a constant

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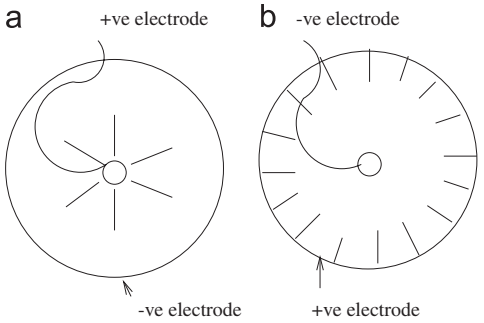

Fig. 1. A schematic diagram showing the crack development for two experimental set-ups, (a) with the centre electrode positive and (b) with the central electrode negative.

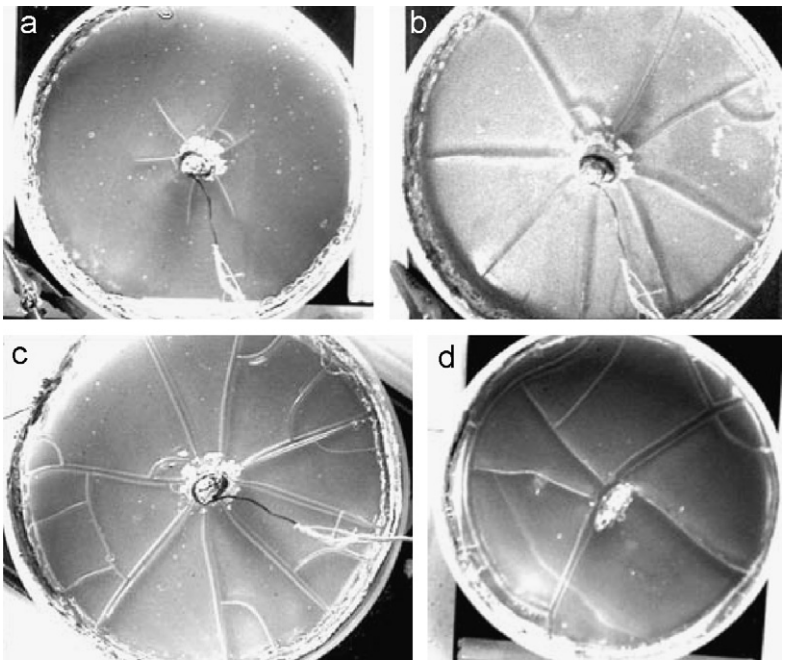

Fig. 2. (a–c) Three successive crack patterns developed for a field of 200 v with the centre terminal positive, photographed, respectively, 24, 48 and 72 h, after deposition (d) shows a crack pattern in a similar set-up, but with no electric field.

voltage power supply, between the two electrodes. For comparison we dry a set of samples in an identical arrangement but without the applied voltage.

A schematic picture Fig. 1 shows the geometry of the set-up. We find that radial crack patterns start developing earlier in the samples with applied field, than in the sample without field. With the positive terminal in the centre, the cracks appear at the central electrode and move out radially in a very straight and symmetric array.

The pattern has been photographed at intervals of 24 h. Three successive stages of the pattern are shown in the series of photographs Fig. 2a–c. Fig. 2(d) shows a crack pattern where no field is applied. In Fig. 2a–c the cracks start exactly from the central electrode and spread radially.

Some cross-radial cracks appear later on. In the samples without field, the pattern is a network of cracks forming rectangular peds as normally observed [3]. Here the gel adheres to the central electrode and the cracks never meet it, unlike the case with the static field. If the central electrode is attached to the negative terminal of the power supply, the cracks appear at the outer boundary of the petri-dish and radiate inwards. However, the pattern is less regular in this case, and disordered cracks start forming earlier. The static field has been varied