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Abstract

In recent years electro-osmosis drying devices applied to walls in both modern and historic masonry has become one of the leading innovative techniques to prevent damages caused by capillary rising water in building materials. Since the scientific community is raising many doubts on these techniques we aim to propose a fast, simple, non-invasive and economic method to evaluate the dehumidification process in porous building materials. In this paper we suggest a procedure to monitor water content inside laboratory specimens of such building material (e.g. brick, mortar and plaster) and verify any kind of possible effect of electro-osmosis on water diffusion, above all drying kinetic. A promising method is based on the quantitative determination of surface water content through near infrared absorption. We exploited an optical reflectance measurement realized through an Avalanche Photo Diode (APD) that we personally designed. We studied the correlation of material reflectance in a narrow absorption band of liquid pure water in the near infrared portion of the spectrum (940- 980nm), and the gravimetric water content through linear regression models from fully-saturated to completely dry conditions. Water content and drying behaviour during and after electroosmotic fields were monitored techniques such as gravimetric method IRT and optical reflectance. This allowed us to visualize the surface water content gradient of different building materials and to compare the results of our technique to the outcome of the older and established ones. We suggest a procedure to monitor water dynamic inside laboratory specimens of such building material and verify any kind of possible effect of electro-osmosis on water diffusion

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Corresponding Author	nicola ludwig
Corresponding Author's Institution	state university of milano
Order of Authors	jacopo melada, Marco Gargano, Ivan Veronese, nicola ludwig
Suggested reviewers	Alwx de Fernandes, Antonio Sansonetti, Mario Milazzo, elisabetta rosina, Ermano Grinzato

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Does electro-osmosis work in moisture damage prevention? Applicability of infrared based methods to verify water distribution under electric field.

J. Melada, M. Gargano, I. Veronese, N. Ludwig
Department of Physics Aldo Pontremoli. State University of Milano – Italy

Abstract
In recent years electro-osmosis drying devices applied to walls in both modern and historic masonry has become one of the leading innovative techniques to prevent damages caused by capillary rising water in building materials. Since the scientific community is raising many doubts on these techniques we aim to propose a fast, simple, non-invasive and economic method to evaluate the dehumidification process in porous building materials. In this paper we suggest a procedure to monitor water content inside laboratory specimens of such building material (e.g. brick, mortar and plaster) and verify any kind of possible effect of electro-osmosis on water diffusion, above all drying kinetic. A promising method is based on the quantitative determination of surface water content through near infrared absorption. We exploited an optical reflectance measurement realized through an Avalanche Photo Diode (APD) that we personally designed. We studied the correlation of material reflectance in a narrow absorption band of liquid pure water in the near infrared portion of the spectrum (940- 980nm), and the gravimetric water content through linear regression models from fully-saturated to completely dry conditions. Water content and drying behaviour during and after electroosmotic fields were monitored techniques such as gravimetric method IRT and optical reflectance. This allowed us to visualize the surface water content gradient of different building materials and to compare the results of our technique to the outcome of the older and established ones. We suggest a procedure to monitor water dynamic inside laboratory specimens of such building material and verify any kind of possible effect of electro-osmosis on water diffusion

1 Introduction

Many degradation phenomena affecting buildings materials like freeze-thaw cycles (Ruedrich et al., 2011) 2011), mechanical behaviour weakness (Foraboschi et al., 2014) salt decay processes (Steiger, 2005; Benavente et al., 2007), biodeterioration (Warscheid et al., 2000) and health problems (Bornehag, 2004) are driven by the presence of water inside them. Moisture can be conveyed inside a building material by many different processes such as vapour condensation, direct exposure to meteorological events, capillary rise, accidental leakage of conductors and operating humidity. Rising damp is one of the main causes of wetness in buildings, both outdoor and indoor, and a widespread problem affecting modern and historical construction. It is related to the capillary suction exerted by porous materials on the groundwater and surface water that slowly penetrates inside a wall. Capillary suction of groundwater and rainfall percolation is much more efficient than condensation in causing dampness (Camuffo, 2014). Its dynamics depends primary by the thickness of the wall, the sorptivity of the materials and the evaporation potential of the immediate microenvironment (Hall et. Al, 2007). The absorption and transport of water inside a porous medium is a complex mechanism which involves multiple phases and various driving processes (Guimarães et al., 2018). Although many studies are carried out, the reliable procedure for rising damp removal is still a problem especially since it is hindered by the scarce knowledge of the mechanisms involved. Among the multitude of dehumidification and reconditioning methods, the electro-osmotic treatments effectiveness is controversial (Panasyuk et al, 1967; Bertolini et al., 2009). Electro-osmosis is successfully applied in the consolidation of soils for many years (Bjerrum et al., 1967; Mitchell et al., 2005; Wu, 2017) and also in other field of study (Li et al, 2013). Despites its application on the dehumidification of buildings is quite widespread and documented many doubts arises in the scientific community, for example (Pavlendova et al., 2015;). In a recent study Franzoni pointed out one of the core problems in the study of dehumidification processes against rising damp: an accurate and quantitative evaluation of water presence in the materials; hence the effectiveness of the treatment (Franzoni, 2014). One parameter suited to identify the amount of free water inside a porous material is the water content (w_c). It is defined as the ratio between the mass of water inside a material (m_w) and the mass of the dry sample (m_d) and is expressed as percentage:

$$w_c = \frac{m_w}{m_d} 100 \quad (1)$$

Measuring the water content and water content distribution of building materials in the easiest, cheapest and least-invasive way possible is indeed a fundamental key of the process and still an open challenge (Agliata, 2018). Many existing non-invasive methods are influenced by uncontrollable factors such as non-homogeneous density, porosity, chemical reactions, surface treatments and weathering, salts presence, mould and insect damage; above all in historical buildings (Camuffo, 2012). The most accurate methodology is oven-dry gravimetry which is an absolute, precise and repeatable measure but it is invasive and destructive and this is a great problem in culturally valuable constructions. We aim to study the effectiveness of electro-osmosis treatments monitoring the drying behaviour of different laboratory samples. This is achieved by means of infrared thermography, gravimetry and an innovative optical reflectance technique. Those methodology allow us to identify possible moisture diffusion's variation in presence and absence of a direct current applied on the different samples.

1.1 Electro-osmosis principles

Active electro-osmotic dehumidification systems are based on the electrokinetic effects caused by the application of a direct current in a saturated porous system and the resulting water migration processes inside pores and capillaries. The electro-osmotic flow is explained by the formation of an electrical double-layer at the interface of the solid's pore system and the water solution (electrolyte) as explained by Helmholtz, Gouy-Chapman, Stern and Grahame theories (Bagotsky, 2005; Brown et al., 2012). The electrical double-layer is due to the spontaneous charging of a solid surface interacting with an electrolytic solution. The solid surface influences all charged and polar species in solution. Ions with a charge opposite to that of the solid system (counter-ions) are attracted by the solid surface and their concentration would be grater in proximity of the liquid-solid interface. Ions with the same surface charge (co-ions) arranges consequently far from the solid surface until a steady state condition is reached. In masonries affected by rising damp a spontaneous electrical potential (streaming potential) is generated (Franzoni et al., 2014). Ordinarily internal surface of pores and capillaries of building materials is negative charged (Mundula et al., 1997). To obtain the dehumidification of a building's component through active electro-osmosis the insertion of electrodes drilled into the wall and placed in the ground is needed to obtain an electric potential difference between the two sides. Usually inside the wall is installed the anode (positive pole) and in the ground the cathode (negative pole). Under the application of an external electric field the ions accumulated in the electrical double-layer tend to restore the electro-neutrality of the system, moving towards the negative electrode among the nearby ions (Di Fraia et al., 2017). The resulting transport of water is related to the intensity of the voltage gradient, to the properties of porous material (i.e. geometry of the pores and capillaries, solid's chemical composition) and to the chemical composition of the water solution itself (Bertolini et al., 2009). Scientific community is doubtful about the reliable effectiveness of those methods since the clear role of the electro-osmosis in the dehumidification process of real buildings is controversial and not well documented (Franzoni, 2014).

2 Materials and methods

2.1 Trial 1

First step was the comparison between two tiles (T1 and T2: 15.4 x 7.2 x 0.7 cm) and two cement-lime plasters sample (P1: 23.3 x 3.0 x 1.1 cm and P2: 19.5 x 3.3 x 1.9 cm). They were saturated with deionized water and then vertical observed: two of them in electrical field and the other two far enough between insulating media (cardboard and PVC). Measurement of w_c, reflectance and infrared thermography were done followed the drying process inside the climatic room for 53 hours. The experiment was conducted inside a climatic room to ensure constant environmental condition both because unsaturated (moisture transport driven by capillarity and evaporation potential) and electro-osmotic flow are influenced by environmental condition and fluid viscosity (Sanchez et al., 2012).

2.2 Gravimetry

Gravimetric water content was measured by means of a Kern EW 1500-2M balance with an accuracy of 0.01 g according to the standard UNI NORMAL 40/93. Water content (w_c) and relative water content ($w_{c,rel}$) were calculated as follows:

$$w_c = \frac{m_m - m_d}{m_d} 100 \quad (2)$$

$$w_c = \frac{m_m - m_d}{m_d} 100 \quad (3)$$

M_m is the mass of the sample weighted at different moisture content, m_d ($w_{c,rel}$ =0%) is the dry mass and $m_{w,sat}$ ($w_{c,rel}$ =100%) is the saturated mass.

2.3 Infrared Termography

Infrared thermography (IRT) is a well-established technique which is used for years to qualitatively map the moisture accumulated on and within building structures (Ludwig et al., 2004, Kylili et al., 2014; Barreira et al., 2016; Ludwig et al., 2017). This approach combines a non-contact, non-destructive testing technique with excellent resolution over a wide range of temperatures due to the optical nature of IRT. This tool is extremely useful due to the wealth of information given by the thermographic image, which delineates the spatial distribution of wet areas. In fact, the temperature of damp areas may be lower than that of dryer areas due to surface evaporation, or the temperature may be higher due to the higher thermal inertia of water compared to the dry building materials. For this reason, qualitative tests are sometimes unreliable, and reliability is particularly important in the field of cultural heritage preservation because the assessment of moisture is crucial. In addition, IRT investigates only the amount of water within a thin surface layer that includes the plaster, and the technique can be used to rapidly survey large surfaces, allowing repeated measurements through time to monitor, for example, the phenomenon of water rising from the ground due to the capillary movement of porous materials. A similar approach is near infrared imaging, which uses a bandwidth of 1000 nm to 2500 nm to detect water due to its very strong absorption band at approximately 1940 nm and less intense at 970 nm, 1140 nm and 1450 nm. It is interesting to measure evaporative flux to evaluate the effects of moisture on degradation phenomena occurring in building structures (Grinzato et al., 2011). This approach doesn't measure directly the water content but could give an estimation of the evaporative flux which depends also on materials properties, first porosity and pore structure, and environmental conditions. Another important advantage in the optical reflectance approach is the possibility to perform a high spatial resolution measure on a large area.

2.4 Optical reflectance

Non-invasive sensor aimed to the detection of water content and/or surface wetness are not a new problem, nor a resolved issue, in conservation studies (Camuffo, 2012; Camuffo, 2017; Hola, 2017). The feasibility of using an optical measure to assess surface water content is plausible since water selectively absorbs electromagnetic radiation in different ranges of the electromagnetic light spectrum depending on its state (De Ninno et al., 2014) and temperature (Praprotnik et al., 2004). The presence of moisture greatly influences spectral reflectance in the infrared region, especially in the major water absorption bands (Tian et al., 2015). The absorption bands of the liquid water derive from the different components of water in function to the hydrogen bond's strength of water molecules which are coordinated within each other in a structure that is neither rigid nor constant over time (Kitadai et al. 2014). We select water absorption bands in the near infrared region (800 nm - 2500 nm) imputed to intra-molecular vibrational transitions. Liquid water in the near infrared shows 5 predominant absorption bands at 760 nm, 970 nm, 1190 nm, 1450 nm, 1940 nm (Curcio et al., 1951). Some other works dealings with the detection of water using near infrared absorption characteristics are focused on the 1450 nm, 1940 and 3000 nm absorption bands (Milliken et al., 2005; Tian et al., 2015; Magrini et al, 2017). The band selected for the development of this study is the one at 970 nm, attributed to a combination of symmetrical and asymmetric stretching of the molecules (Iakovenko et al. 2002). Indeed, one of the main advantages working in this region of the spectrum is that a Si solid state detector can be used which is cheaper than the detectors needed for longer wavelength. This methodology

would directly identify, in a non-invasive way, the moist areas independently from the surface temperature. The development of an infrared remote sensing technique could be useful in the diagnosis and monitoring of water diffusion in cultural heritage materials because most of the degradation processes affects the surface of these materials. Another important advantage is the possibility to perform a high spatial resolution survey on a large area as in IRT. Liquid water concentration in the outer open pores of materials under investigation has been measured with the help of a non-invasive reflectance measurement device. It is based on a multi-pixel photon counting (MPPC) module by Hamamatsu Photonics K.K., model C11208, built with a matrix (1 mm x 1 mm) of Si Avalanche Photo Diodes (APD) operating in Geiger mode. The APD was equipped with a Y-shape coaxial optical fiber in which the light was conveyed from the light source to the samples in the external bundle and the resulting signal were collected by the internal one. Light, at the entrance of the detector, was filtered by a band-pass filter with a centre peak wavelength at 970 nm (Thorlabs GmbH) and FWHM of 10 nm to measure reflectance only in the water characteristic absorption band at 970 nm. For the calculation of the reflectance a 20% standard (spectralon, labsphere) was used as a reference and subsequently normalized to 100%. An incandescent bulb HL-2000-FHSA was used as light source. Environmental conditions inside the climatic chamber were monitored using a temperature (t) and relative humidity (RH) data logger (EasyLog EL-USB-2). Reflectance was calculated as follows:

$$R\% = \frac{C_m - C_d}{C_w - C_d} 100 \quad (4)$$

C_m are the photons counted by the detector at different moisture content, C_d are the dark counts and C_w the counts on the grey reflectance reference.

2.5 Trial 2

We arranged a second laboratory test on different type of commercially available plasters, bricks and mortars. Slabs of two bricks (LT1 and LT2), two lime putty mortars (MA1 and MA2), two cement-lime mortars (MC1 and MC2) and two plasters with powdered bricks “cocciopesto” (CP1 and CP2) were used. The samples properties were reported in Table 1. Samples were oven dried for one night at 102±2 °C to obtain the dry weights (m_d). Then they were vertically placed, as in the previous experiment inside a climatic room at 25 °C and 40% relative humidity. Samples saturations by capillary rising was monitored by IRT. The saturation occurs with a water solution 0.5 M of NaCl. After one night of imbibition the samples were took out from the water solution and weighted. Samples LT1, MA1, MC1 and CP1 were placed on an aluminium plate with a copper filament on top, both connected with a direct current (DC) generator. The aluminium plate was connected with the negative pole and the copper wire to the positive ones with an applied potential difference of 30 V/m. Meanwhile samples LT2, MA2, MC2 and CP2 were placed in the same environmental condition on an PVC plate far enough not to be affected by the electric field. Drying behaviour was observed by means of IRT, optical reflectance and gravimetry measures for 6 days on the top and on the bottom of the samples.

sample	volume (cm^3)	dry density (g/cm^3)	saturated density (g/cm^3)	w_c at saturation (%)
LT1	344.8	1.66	1.90	14.39
LT2	311.9	1.75	2.01	14.41
MA1	414.8	1.41	1.66	17.88
MA2	485.1	1.41	1.65	16.55
MC1	400.5	1.60	1.99	24.57
MC2	385.0	1.62	2.01	24.64
CP1	351.1	1.62	1.93	19.13
CP2	396.6	1.44	1.73	20.20

Table 1. Samples used in trial 2 and trial 3

We personally designed and 3-D printed a fiber-holder in black polylactide (PLA). This has three holes for the accommodation of the optical fibers at -45°, 0°, 45° with respect to the normal. The base has 6 cm diameter hole which is in contact with the sample and forms a cylindrical black box which allow us to perform all the

measurements without saturate and damage the high sensitive photodetector. The light spot area on the sample is about 7 cm^2. The same incandescent bulb light source of the previous trial was used. It was brought to the sample with an optical fiber having an angle of 45° with respect to the normal. A 0° fibre optics conveyed the reflected light to the detector through the 970 nm bandpass filter. For the computation of the reflectance a white reflectance standard (99% spectralon, labsphere) was used. Reflectance measures were performed on the top and on the bottom of the slabs to detect moisture diffusions inhomogeneities.

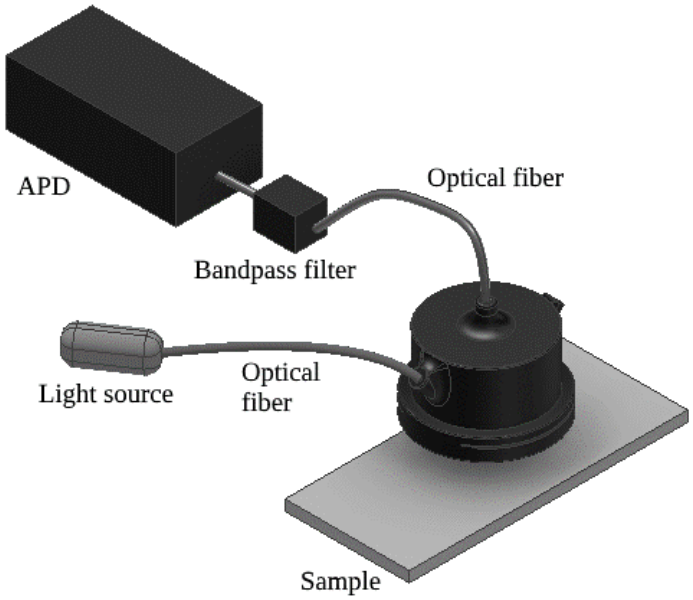


Figure 1.. Schematic representation of the optical measures setup. The 3D-printed fiber holder allow us to easily perform spatial measurements on the sample area.

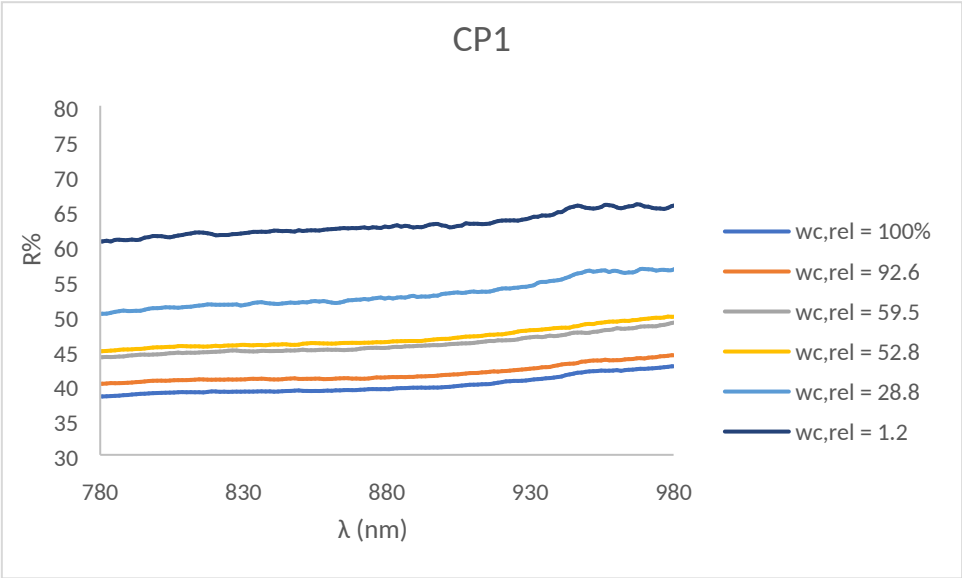


Figure 2. NIR reflectance spectra of sample CP1 in trial 2 obtained using Prime X cooled Spectrometer. The effect of moisture content on reflectance the whole spectrum more than the value in specific band at 970 nm. But the change in reflectance due to water content has shown to be dependent on the kind of material.

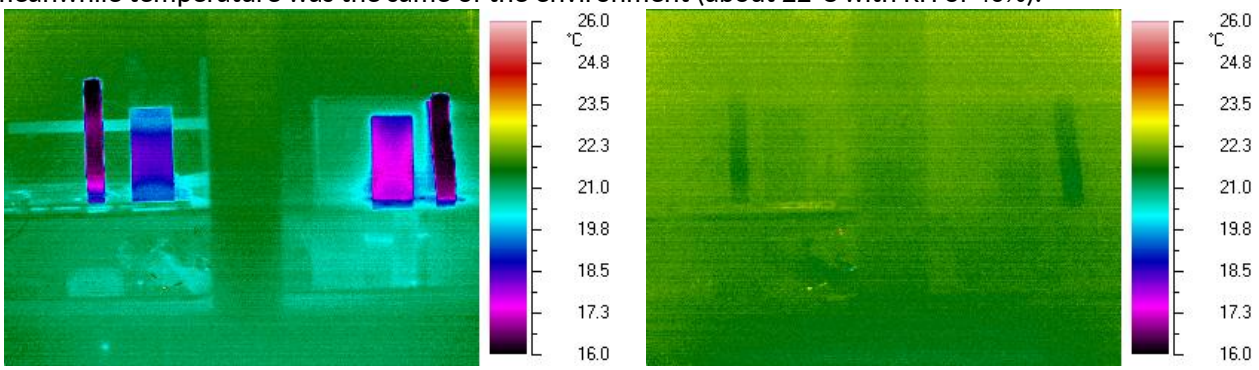
Calculated reflectance values by means of APD were compared with reflectance measured with the same scheme with a commercial spectrometer: a Prime X Spectrometer of the B&WT TEK Inc. This instrument has Si TE-cooled core which spectral range is 200-1000 nm with 0.88 nm resolution. Figure 2 reports an example

of the spectra obtained by means of Prime X spectrometer. The effect of moisture content on reflectance affects the NIR spectrum more than the single value in band at 970 nm. Otherwise this change in reflectance due to water content depends on the kind of material so simple reflectance measurement cannot be correctly used as water content index (Tian et al., 2015). Being the difference between the optical reflectance measured with APD and Spectrometer negligible we will report only the data acquired with the APD.

3 Results

3.1 Trial 1

The first experimental trial on two tiles and two plasters (Figure 3) shows the thermographic condition, R% and w_c at saturation and dry condition. In this trial the climatic chamber was used to mitigate RH variation meanwhile temperature was the same of the environment (about 22°C with RH of 40%).



a) Time = 60 minutes b) Time = 2880 minutes

Figure 3. Thermography of a cement plaster stick and a tile with and without static electric field respectively on left and right in a) in saturated condition after 1 hour of 40% RH and 22°C. In this condition thy appear under thermographic inspection totally dry after 48 hours b).

In plasters sample the increase of the calculated reflectance during drying is evident (Table 2). This is not so evident in the tiles, probably because the commercial tiles were too smooth, the water content was negligible or the fiber configuration was not the correct one for this type of material. At t = 1 hour the evaporative cooling of both materials surface is also evident and it is more pronounced in samples without the applied electric field.

	P1 top	P1 bottom	P2 top	P2 bottom	T1 top	T1 bottom	T2 top	T2 bottom
Dry	53.71	52.98	53.71	51.82	42.12	41.13	40.48	46.59
Saturated	34.38	38.16	30.26	37.88	38.03	37.72	38.31	36.08

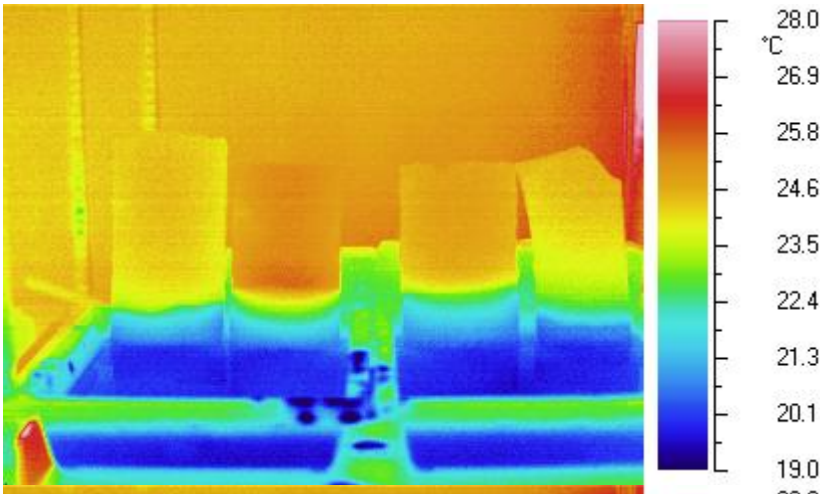
Table 2. Optical reflectance (R%) values of the plasters and tiles samples both in saturated and dry condition. Saturated samples are darker than dry ones.

From the first trial it is possible to single out some effect of electro-osmosis notably on the tile in the left sides of a) image. After the complete study shown below this effect was supposed due to the thinness of the tile and to the big heat capacity of the metal arm under it. This example would underline the extreme sensibility of the thermographic method in detect even very little thermal effects that can be confused with electro-osmotic one.

3.2 Trial 2

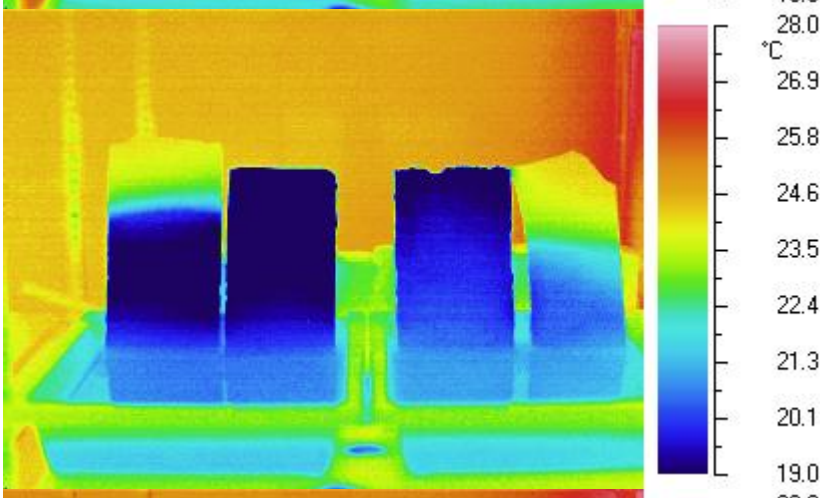
After the first trial the experimental procedure was implemented with a 3-d printed specifically designed fibre-holder which keeps a constant angle of 45° between incident and reflected light. This let us avoid specular reflectance contribution. That's because at high moisture content the reflected radiation is spatially heterogeneous and presents a maximum value due to specular contribution whereas at lower moisture content this effect is negligible (Monnard et al., 2016). The samples used in this second trial are described in Table 1. Saturation by capillary absorption took 24 hours and was controlled by infrared thermography. It can be seen in figure 4.

a)



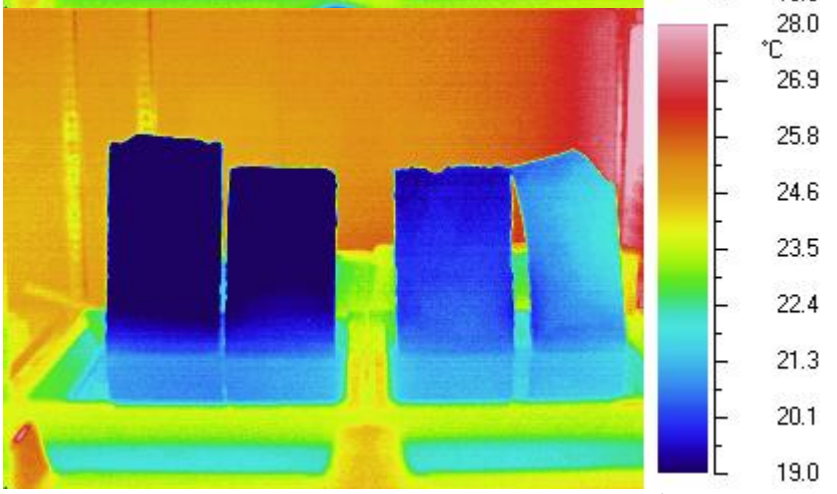
Time =15 minutes

b)



Time =240 minutes

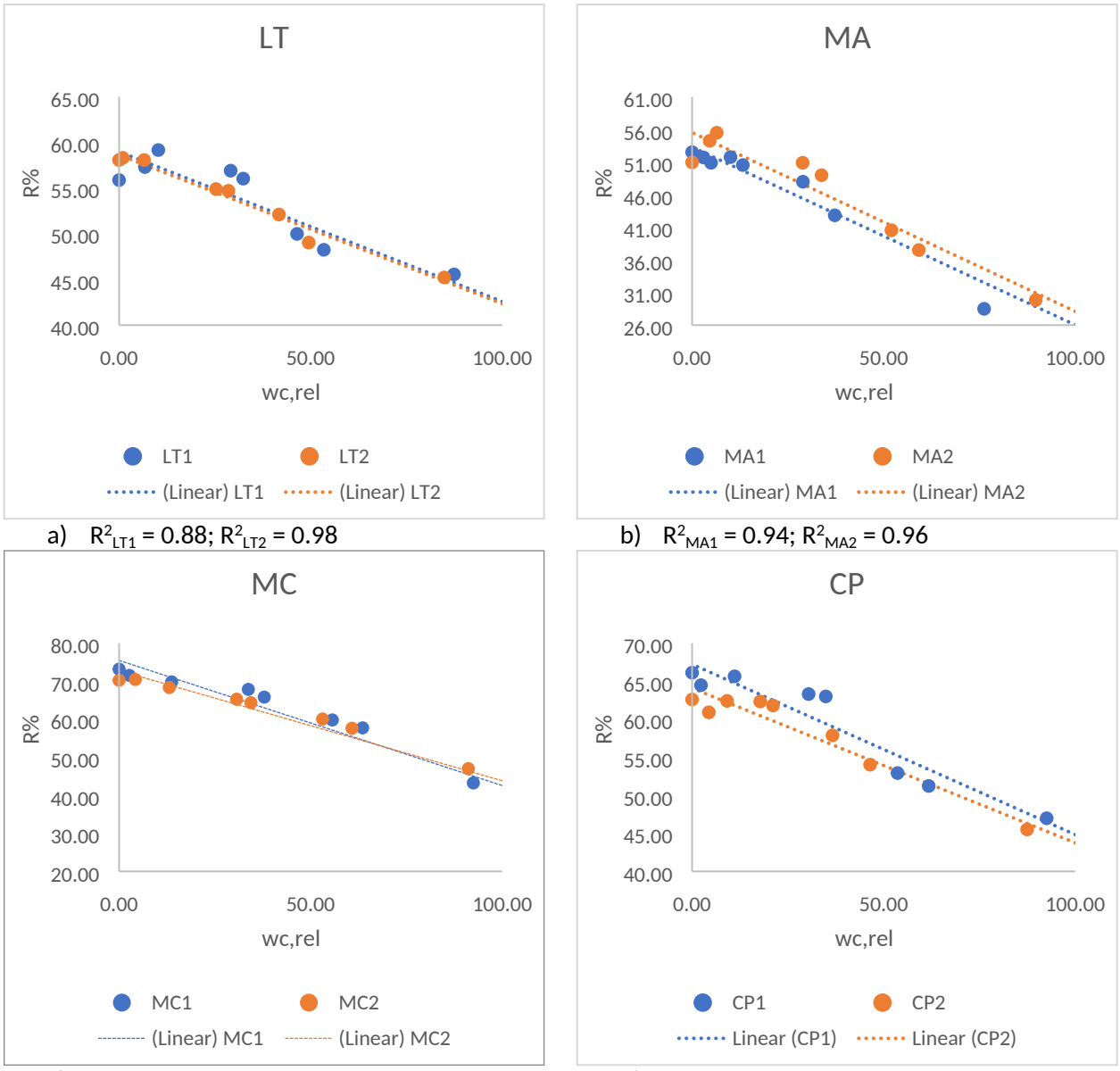
c)



Time =1080 minutes

Figure 4. Capillary saturation of four samples controlled by infrared thermography. a) beginning of the saturation process. b) condition after 4 hours, different materials shown different adsorption behaviour. c) end of the imbibition step, the samples are all saturated.

During this trial the climatic room was regulated to maintain 40% RH and a constant temperature of 25°C. Samples were weighted twice a day and at the same time R% was measured on the top and on the bottom for each sample; thermal images were taken every 15 minutes from saturation to equilibrium condition with the environment of laboratory. Calculated $w_{c,rel}$ and R% are plotted for each type of material. The mean percental error between each material's top and bottom is lower than 3% so the mean R% values of each samples was used.



a) $R^2_{LT1} = 0.88$; $R^2_{LT2} = 0.98$

b) $R^2_{MA1} = 0.94$; $R^2_{MA2} = 0.96$

c) $R^2_{MC1} = 0.94$; $R^2_{MC2} = 0.95$

d) $R^2_{CP1} = 0.96$; $R^2_{CP2} = 0.93$

Figure 5. Correlation between reflectance @970 nm and relative water content for the different samples. Due to the uniformity of the measured reflected light between top and bottom for each sample the mean values were reported to have a simpler reading outcome.

Reflectance decreases while increasing water content in every type of the observed materials. The determination of water content based on a single-band reflectance values implies that for each type of material a dry reference reflectance sample is available and representative. This could be a problem in spatially heterogeneous materials. Due to the interesting results obtained the measurement system could be improved in many terms, one example is the incorporation of multiple bands which generally makes regression models more robust against covariates since absolute measurement values can be set in relation to each other (Haubrock et al, 2010). For our aims the feasibility of using the absolute reflectance at 970 nm for the rapid, simple and economic monitoring of the moisture content variation over time should be more accurately investigated but those results are promising.

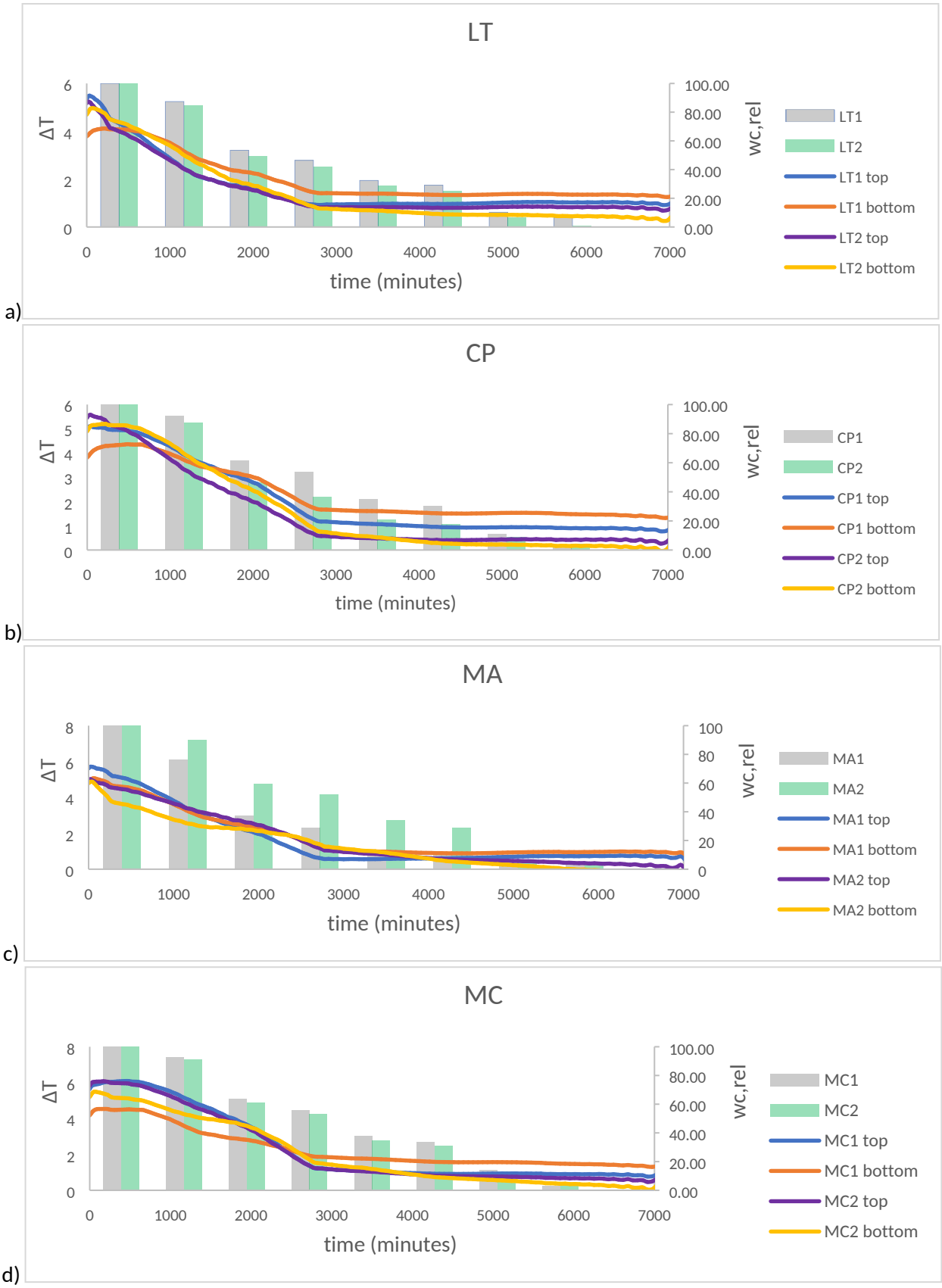


Figure 6. Evaporative cooling of specimens (lines) and water content (bars) plotted against time of drying. On the left (grey bars) with electrical field and on the right (green bars) without; a) LT1 and LT2; b) CP1 and CP2; c) MA1 and MA2; d) MC1 and MC2.

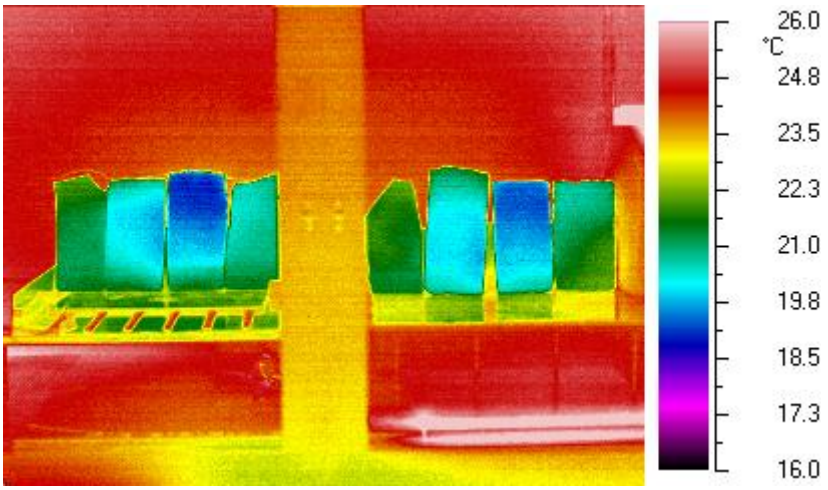
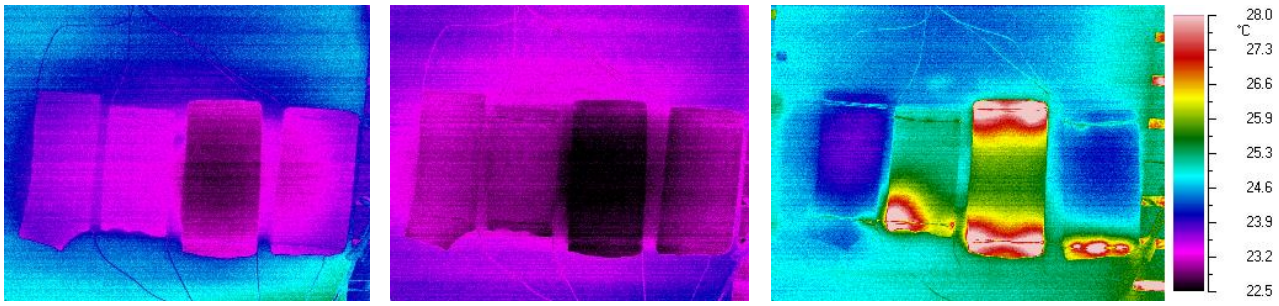


Figure 7. Thermography of the drying samples inside the climatic room. On the left the four samples with the applied voltage of ΔV=30 V/m; on the right the ones without.

The drying behaviour of the samples was characterized by means of IRT and gravimetric method. Thermal gradient ($\Delta T = T_{enviroment} - T_{sample}$) was plotted against time of observation. Drying samples had a temperature lower than the environmental ones of about 5° C due to evaporative cooling. As can be seen in Figure 6 there are no evident difference between samples with the applied voltage neither between top and bottom meaning that the presence of the applied voltage does not affect the drying of the samples. This is justified also by the variation of moisture content during the time of observation (histograms in Figure 6) which is comparable for both the same material samples in the different context. Precisely, samples LT1 and CP1 dried slower than the respective ones without the applied voltage. Meanwhile samples MA1 and MC1 dried faster.



a) ΔV = 0 V/m b) ΔV = 30 V/m c) ΔV = 150 V/m

Figure 8. Thermography of four samples (LT1, MA1, MC1 and CP1) at 25° C and 95% RH at three different applied voltages a) ΔV=0 V/m b) ΔV=30 V/m c) ΔV=150V/m. Some effects of electric field can be observed only with the strongest field. The heating clearly observed in c) are due to joule effect in the conductive solution inside the different materials.

Due to fact we have seen nothing interesting even with a static electric field 10 times stronger than the one usually installed in walls (2,8 V/m) accordingly to Mundula and Tubi (Mundula et al., 1997) we try to apply different voltage to four samples (LT1, MA1, MC1, CP1) saturated with the same solution of the previous trials. The samples were put in the climatic room in horizontal (25° C and 95% RH) for 4 hours for each applied voltage. We want to observe the DC effect on saturated non-evaporating porous samples. Before and after every test each sample was weighted and the gravimetric w_c calculated. For ΔV = 0 V/m and ΔV = 30 V/m no thermal effects are visible by IRT whereas with ΔV = 150 V/m a temperature increase is noticeable near the positive pole (Figure 8). The rising temperature on the chathods is due to the Joule effect in the salts solution inside the samples. Near to this electrode resistence has to be supposed higher than in the other part of the samples due to the different concentration of electrolytes. Indeed the electrochemical desalination of bricks i.e. transport of ions by the application of a direct current is documented (Ottosen et al., 2009). The warmer areas in fig. 8c have different shape and temprerature depending on the charge and amount of iones, we strees in particular that the third sample shows those area both near to positive and negative chatods. We suppose this effect, never observed till now, can be caused by the presence in this cement plaster of both positive and negative iones independent fluxes.

In order to verify any displacement of water inside the samples due to the applied electri field we used thermographic method that has been shown as the most sensible to evaporative flux and connected to water content variation. Therefore, after four hours of applied voltage we suddenly dropped the RH to 30% to observe the evaporation distribution over all the samples surface. In fact if the electro-osmosis worked and induced a moisture shift to one side of the sample we expect to observe a stronger evaporative cooling of the samples on one side accordingly to the electro-osmotic flow directionBut along one hour of measurment no disomhogeneities in evaporation cooling has been observed. This do not demonstrate definitely that an electro-osmotic flow of water do not take place inside the samples but in some ways it underlights the predominance of the capillary driven flow over the electro-osmotic ones even with a high applied voltage.

Conclusions

For the rapid, simple and non-invasive measurement of the water content of a material, a system has been evaluated that exploits the different infrared radiation reflectance at 970 nm, in correspondence of a liquid water absorption band in the NIR. This method, directly related to the liquid water amount, can be easily coupled with the well tested method of passive thermography used for an indirect measurement of water content through evaporative flux measurement. Both methods despite their strong sensitivity of water content and flux evaporation values couldn't be able to single out any water displacement caused by the static electric field. We investigate a large range of applied voltage and finally we can be able to see some effects due to electrical current inside the samples only for very strong field when Joule effect arises and this occurs over the values usually consider for building dehumidification and represent the upper limits of application of this technology. Finally thanks to thermography we observed that electrical fields applied to masonry seem to be affect only ions current inside saturated materials.

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