

## THE ELECTROSTATIC BEHAVIOUR OF MATERIALS USED IN RESTORATION-CONSERVATION PROCESS

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The paper deals with the electrostatic charging characteristics of materials used in the restoration-conservation of cultural heritage. An apparatus for the direct measurement of electrostatic charging potential was built. The charging was done by triboelectric and/or Corona effect. The remanence of the charging potential was estimated by measuring the half-time. The undertaken study allows a selection of conservation materials according to cultural heritage preservation requirements.

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### 1. Introduction

The superficial resistivity  $\rho_s$ , used in thin films characterization, is defined as the resistance per surface unit ( $\Omega/\square$ ). The superficial resistivity is related to material resistivity  $\rho$  and the thickness  $w$  of the thin film under consideration [1,2].

The materials having a superficial resistivity  $\rho_s$  bigger than  $10^{16} \Omega/\square$  become strongly charged, at an electric potential of the order of some kV. The materials with a superficial resistance less than  $10^{12} \Omega/\square$  become less charged, while those having a  $\rho_s$  less than  $10^3 \Omega/\square$  are not charged at all. Generally, the materials having a superficial resistivity less than  $10^{12} \Omega/\square$  are considered as antistatic materials.

In practice, the measurement of electrostatic charging value is done by both direct and indirect methods measuring the superficial or volume resistance. The indirect methods have the disadvantage that the resistivity cannot be determined under the same conditions as those of material utilization, the measured value depending on many factors, such as: electrode nature, composition, the firmness of the sample-electrode connection, the voltage applied between the electrodes, the measuring time, etc. For this reason the indirect methods give results differing by one or two orders of magnitude from the real ones. The direct methods permit the determination of electrostatic charging voltage by measuring the charge density, the electrostatic potential, the charging-discharging rate. The direct methods also give the opportunity to study the dependence of electrostatic behaviour on the sign of accumulated electrical charge.

### 2. Dust and its effects on cultural heritage

We aimed to study the impact of electrostatic charging in the preservation activities, because this phenomenon occurs in exhibition as well as in storage rooms, as a consequence of using insulator materials (synthetic curtains, plush, moquette, plexiglass, varnished wood) on the one hand, and by specific activities associated with friction (cleaning of objects and showcases, furniture polishing, visitor's circulation in the exhibition, maintenance means), on the other hand.

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The negative effects of electrostatic charging on the preservation of cultural heritage are well known. Thus, the dust particles from air are strongly attracted by electrostatically charged materials, changing the aspect of objects and altering their conservation condition.

The term “dust” includes a mixture of substances, most of them inorganic, but also some organic compounds, which are deposited on the surfaces of museum objects.

In this context, a parameter was accepted – the air quality index, which means the accumulation of small airborne particles within 24 h.  $40 \mu\text{g}/\text{m}^2$  represents the limit over which the effect is considered harmful for sensitive objects. The particles sized under  $25 \mu$  are the most dangerous for the conservation of cultural heritage, as they penetrate easily through the ventilation system [1].

The size analysis of urban dust particles indicated that more than 50% of them have sizes between  $0\text{-}4\mu\text{m}$ , and the mean dust content of an industrial city is: total carbon – 26.5%, ash – 54%,  $\text{SiO}_2$  - 25.6%,  $\text{CaO}$  – 6.2%,  $\text{MgO}$  – 1.7%, coal black – 0.6% [2]. Among these components, the silicates and silica –  $\text{SiO}_2$ , amorphous or crystalline, coming from the erosion of building materials (cement, mortar), insulating materials (glass fibres) or from soil, are especially harmful, because of their high hardness (between 5 and 7 on Mohs scale) being able to scratch such materials as iron, aluminium, soft steel or even marble.

Another important component, the carbonaceous fly-ash emitted into the atmosphere by heavy fuel oil combustion, is particularly reactive, adsorbing the atmospheric  $\text{SO}_2$  and generating sulphuric acid at high humidity.

Another damaging factor for the cultural heritage conservation is the biological component of the dust, consisting especially in fungal spores. This is one of the most frequent causes of microbiological deterioration for the objects made of organic materials, if the microclimatic conditions are favorable to fungi growth and reproduction. Also, the free radicals originating in industrial activity and exhaust gases ( $\text{SO}_2$ ,  $\text{NO}_x$ ,  $\text{O}^3$ ) can be linked, by electric interactions, on electrostatically charged materials, forming acid solutions at high humidity, with devastating effects on the health of cultural heritage objects.

The paper presents a method and an especially conceived apparatus for a direct measurement of electrostatic charging characteristics of materials used in restoration-conservation of cultural heritage, with the aim of selecting them according to the conservation demands.

### 3. Apparatus for electrocharging potential measurements

The conception of the apparatus permits the the electrostatic charging of materials under similar conditions to the customary utilization ones. It was also intended to perform absolute, nondestructive and reproducible measurements, and to study the materials behaviour under extreme conditions.

The apparatus makes possible the direct measurement of materials electrostatic charging, using two complementary methods for charging: the triboelectric and Corona effect.

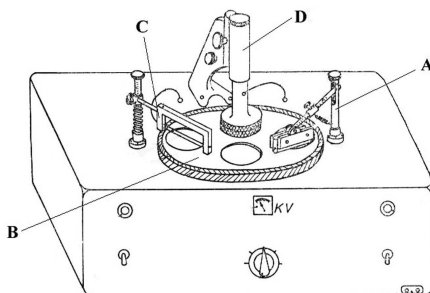


Fig. 1

The first method of charging permits the determination of charging potential under customary utilisation conditions of materials, while the second one offers the possibility to measure the maximum charging potential, to choose the charge sign and to study rough materials. The electrostatic charging by triboelectric effect is fulfilled by means of a device A (Fig. 1), on which the friction material is attached. This device allows the friction force adjustment and ensures the stability of force value during the measurements.

The electrostatic charging by Corona effect is achieved by means of a monofilar corotron C, located over the sample, connected at d.c. voltage supply, variable between 0 and 10kV, with changeable polarity, thus allowing the sample to get charged with positive or negative charges. The corotron is made up of a cantal wire, with  $\phi=0,1$  mm, fastened on an adjustable holder, which permits the wire positioning at a convenient distance from the sample, in the range of 6-15mm.

The sample electrostatic charging potential is determined by a capacitance tester D, placed over the sample, at a distance which can be varied within micrometric range. The tester D is brought over the sample at a distance adjustable within 0,5-2 mm. The tester-sample distance is measured by a micrometer coupled with the tester. The signal collected by the tester is amplified and displayed by an electronic voltmeter connected to a xy recorder.

The difficulty of measuring a d.c. potential on sample surface was overcome by choosing a special shape for the sample - a disk with four symmetrically arranged radial circular holes, fastened to a metallic support, rotating with the speed of 2000 turns/min. The capacitive tester "reads" the potential of charged areas and "0" for circular holes, alternatingly. Therefore, the d.c. charging potential of the sample is converted into an alternating signal, easy to amplify and to process.

In order to carry out a comparative study concerning the electrostatic charging potential of some conservation materials we had in view to keep constant the following working parameters: corotron voltage, corotron - sample, distance, friction force, tester - sample distance. These parameters can be modified if their influence over the charging potential is under study. All the materials were preconditioned at 35% RH and 20 °C and the measurements were carried out under the same conditions. The half-time of the maximum value of electrostatic charging potential was also determined in order to estimate its time behaviour. It must be underlined that the essential characteristic of materials under study is not only the maximum value of electrostatic charging, but also its half-time, defining the electrostatic remanence of materials.

The study was done on some materials and substances frequently used in the restoration-conservation area, for storage, exhibition or transport, labeled from 1 to 16 in Table 1. We have determined the maximum value of the electrostatic charging and the half-time of the charging potential, using the Corona effect as well as friction, for some of the samples.

..as well as the influence of coatings or impregnation on electrostatic charging, using conservation substances labeled from 11 to 16 in Table 1. Besides, the effect of an antistatic substance - petroleum distillate PRONTO (10) - on highly insulating materials was studied.

Table 1. Types of materials.

No.	Materials and substances	No.	Materials and substances
1	Glass	9	Wood
2	Plexiglas (meta-metacrilat de methyl )	10	Antistatic substance PRONTO
3	Polyester	11	Polyethylenglycol
4	Polyethylene	12	Paraloid B 72
5	Leather	13	CERPI wax
6	Wool	14	Nitrovarnish
7	Cotton	15	Schellack
8	Multi-ply paperboard	16	Micro-crystalline wax

#### 4. Electrocharging potential measurements

The electrostatic charging was measured for all the materials labeled from 1 to 9 in Table 1 as well as the influence of coatings or impregnation on electrostatic charging, using conservation

substances labeled from 11 to 16 in Table 1. Besides, the effect of an antistatic substance – petroleum distillate PRONTO (10) - on highly insulating materials was studied. The maximum values of electrostatic charging potential and the half-time of the materials under study are given in Table 2.

In the first place, it was evident that the natural materials get electrostatically charged less than the synthetic ones, fact known from practice. Due to their higher superficial and bulk resistivity, the synthetic materials also exhibit superior remanence of electrostatic charging (1-2 order of magnitude) in comparison with the natural materials.

The charging by friction gave rise to a considerable scattering of results, that is why Table 2 gives the mean values. Besides, a dependence of charging potential value and the charge sign on the friction material was noticed. Charging by triboelectric effect is limited to materials with a flat, smooth surface, having a minimal mechanical resistance.

Observing the values in Table 2 it can be noticed that good insulators as glass (Fig. 2) or synthetic materials like polyethylene, polyester (Fig. 3), plexiglass, show high electrostatic charging values. The halftime is one order of magnitude longer than that of natural fibre sample surpassing 500 sec. for polyethylene. In the case of plexiglass, the remanence could not be measured, the half-time being particularly long (some hours).

As for the natural fibre samples, a higher electrostatic potential was recorded for cotton plush (245 V) and multi-ply paperboard (240 V), which can be due to the discontinuous characteristic structure, leading to an increase of specific resistance.

The wool tissue shows a high charging potential (350 V), but a half-time (5.5 s) close to the one of all natural fibre materials (2.5 s – leather, 5.8 s – cotton, 0.5 s – wood, 4.5 s - paperboard).

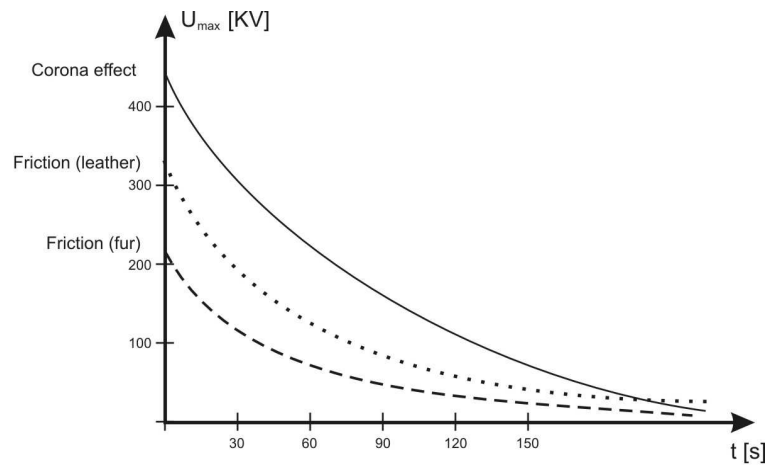


Fig. 2. The electrostatic charging for glass.

Table 2. Charging voltage and half-time.

No.	Material	Charging method		Half-time $t_{1/2}$ (seconds)	
		Corona effect (charge sign)	Friction (Material)		
		Charging voltage ( $U_{max}$ )	Charging voltage ( $U_{max}$ )		
1.	Glass	+	430	30	
			Leather	323	60
			Cotton	195	12
		Fur	20	42	
	Glass + antistatic spray	+	40	6	
2.	Plexiglas (meta-metacrilat de metil)	+	46	UD	
	Plexiglas + antistatic spray	+	27	30%	

3.	Polyester (PES)	+	14		10%
	PES water-repellent	+	25		50%
4.	Expanded polyethylene	+	48		>500
5.	Leather	+	17	21	2.5
	PEG impregnated leather	Do not get charged			
	Leather + Paraloid B72	+	8		3
	Leather + CERPI wax	+	6		3.5
	Synthetic leather	+	18	25	2
6.	Wool	+	35		5.5
7.	Cotton plush	+	27		3.5
	Unsize cotton	+	19		5.8
	Cotton [101 g/m <sup>2</sup> ]	+	18		2
	Sized cotton	+	11		1
8.	Multi-ply paperboard	+	24		4.5
	Paperboard + Paraloid B72	+	23		30
9.	Unvarnished wood	+	18		0.5
	Wood+ nitrovarnish	+	42		3
	Wood+ nitrovarnish + antistatic spray	+	32		1.5
	Wood + schellack	+	27		2
	Wood + schellack + antistatic spray	+	23		1.2
10.	Metal+Paraloid B 72 + micro- crystalline wax	+	30		>200

UD = undetermined

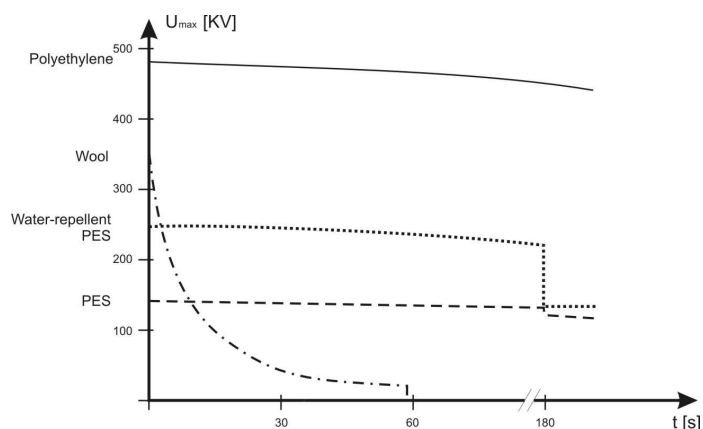


Fig. 3. The electrostatic charging for different materials.

Referring to the consequences of some conservation treatments on electrostatic charging potential, the measurement made evident the antistatic characteristic of PEG, a substance used in restoring archaeological wood and leather. The measurements showed that natural leather impregnated by immersion in PEG was not electrostatically charged.

As to Paraloid B72 protection coverings, it was noticed that this layer applied on natural leather diminishes the charging potential, leaving unaffected the half-time, while applied on paperboard, it does not modify the charging potential and causes an insignificant increase of half-

time. One can conclude that this conservation product does not have a negative consequence regarding the electrostatic charging.

Another product, CERPI wax, a cleaning, softening and hydration agent for leather, leads to a diminution of electrostatic potential, as an effect of hydration, and to a low remanence ( $t_{1/2}=3.5$  sec.), so that it is adequate for restoration – conservation purposes. A water-repellent treatment (based on paraffine and metallic salts) of fabrics causes an important increase of both charging potential (250 V) and remanence ( $t_{1/2}=180$  sec.)

Concerning the conservation substances used on furniture it was revealed that nitrovarnishes produced a greater increase of charging potential than shellack, but the half-time variation is unimportant.

As conservation product for metallic objects, we have studied the microcrystalline wax (Cosmolloid 8OH) covering, over a Paraloid B72 layer used as a protecting mean against UV yellowing. This double layer applied on a metallic disk generated a high charging potential (300 V), with a high remanence ( $t_{1/2}=200$  sec.).

Finally, we tested the antistatic effect of a product – Pronto - (Fig. 4) on electrostatic properties of insulators. From the recorded results, it has been ascertained a decrease of the maximum charging potential and a drastic shortening of the half-time, for highly insulating materials.

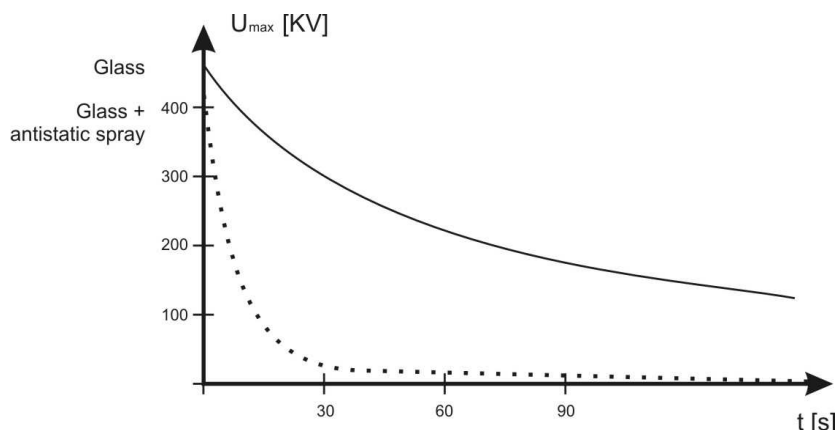


Fig. 4. Electrostatic charging. The effect of antistatic spray.

## 5. Conclusions

The collected data permit a selection of conservation materials according to the preservation requirements for cultural heritage. Thus, such materials as plexiglass, glass, polyethylene, etc., showing a high remanence of electrostatic charging, are not suitable in museums and collections, but only associated with specific antistatic products.

Another remark is that electrostatic charging varies much for materials of the same composition, but different structure – for example, cotton plush and cotton tissue, due to their different superficial resistivity.

As a result of the undertaken study it may be concluded that the method and the especially designed device are effective in establishing the electrostatic properties of a wide variety of materials of different structure and/or composition, various conservation products and protection substances, as well as in ascertaining the effects of antistatic materials on insulators.

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