BODY IMAGE FORMATION HYPOTHESES BASED ON CORONA DISCHARGE: DISCUSSION

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SUMMARY

A paper entitled "Body Image Formation Hypotheses Based on Corona Discharge" was presented at the Dallas Conference on the TS (Turin Shroud) in 2005 by G. Fanti, F. Lattarulo and O. Scheuermann. It contains hypotheses, experimental results and comments; however, some questions which came up during the discussions at the SSG (Shroud Science Group) level, led the author to write the present paper.

After a presentation of the main points regarding CD (Corona Discharge), and the definition of the hypotheses regarding the assumed model, some new evidence is presented and discussed here, such as the exsiccation of limited parts of linen fibers. The paper then explains different points raised by the SSG, such as the radiation direction, the 3-D effects of radiation and its mathematical representation, the image resolution, the double draping configurations of the TS, and the color on the linen fibers.

The experimental results obtained to support the hypothesized mechanism show no appreciable chemical-physical differences from the image features of the TS. These results confirm that the proposed CD mechanism could have been involve d in the TS body image formation.

1. INTRODUCTION

The Turin Shroud (TS) is a 4.4 m long and 1.1 m wide linen sheet that wrapped the corpse of a scourged, thorn-crowned man who was stabbed in the side with a lance and crucified (Jumper 1984, Adler 1996). There are also many marks caused by blood, fire, water and folding impressed on the sheet that partially cancel the double body image (front and back) indelibly

impressed. The wounds are what interest forensic pathologists most because they would be difficult to produce.

The body image is extremely superficial, but in some areas of the frontal image, such as those of the face and perhaps the hands, it is superficial on both sides (Fanti 2004). This means that, considering the thickness of the fabric where the image of the face is, there is a very superficial image on the top and one on the bottom, but nothing in the middle; the top and bottom images correspond in both shape and position. CD (Corona Discharge) images have this characteristic.

The TS is believed by many to be the burial cloth Jesus Christ was enveloped in when placed in a tomb in Palestine about 2000 years ago. It is the most important relic of Christianity and has generated more controversy than any other relic.

Scientific interest in the TS started in 1898 when S. Pia, who photographed it, noticed that the negative image on the TS looked like a photographic positive. In 1931, G. Enrie photographed the TS at high resolution using an orthochromatic plate. In this photograph, the TS body image looks like a photographic negative and its luminance levels can be related to the 3D image of a human body. The bloodstains are of human blood, transposed to the linen fabric by fibrinolysis (Adler 1996).

A scientific analysis of the TS in 1978 by the STURP (Shroud of TUrin Research Project) (Jackson 1984, Jumper et al. 1984, Adler 1996) found no explanations for the body image on the TS. One explanation states that the image formed as if it were caused by exposure to a short-lived but intense source of energy coming from the body enveloped in the TS itself.

Many hypotheses and experimental tests have been carried out on linen fabrics to explain the formation of the body image, but for the moment no exhaustive solution has been found. The hypothesis of a source of radiation from inside the enveloped body has a large consensus even if some points must be still be demonstrated. Although good experimental results have been obtained on the basis of other hypotheses, all these proposals are unable to describe all of the characteristics of the body image listed (Fanti et al. 2005).

The characteristic of corona or electric imaging was first noted by Allan Mills (1981) and by Alan Adler in 1982 (A. Whanger, 2008). In 1983, O. Scheuermann proposed a possible body image formation mechanism based on CD and obtained some interesting experimental results, but his studies were interrupted for many years because of the 1988 radiocarbon results. A. Whanger (1998, 2002, 2008) also found evidence of images on the TS formed with CD in the same years.

In 1984, I. Bensen[1] proposed ball lightening as the source of energy for the body image formation. In 1985, R. Morgan reported a hypothesis of image formation by means of CD made

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[1] *From A. Whanger (2008), Igor Bensen, quite independently, "speculated that the Shroud image was produced by corona discharge." He contacted A. & M. Whanger in 1984, who shared some of Scheuermann's research work with him." He found that thermally 50 watt-seconds produced a very clear image on linen, while 100 watt-seconds burned through the linen, and 25 watt-seconds produced only a barely visible image. He then used 50 watt-seconds in a corona discharge (his transformer was 20,000 volts), and varied the time at 1/5, 1/10, and 1/20 of a second. The image on linen could be readily seen in all, but was distinctly clearer in the 1/10 second exposure. He also made some observations using a plasma ball. Using his limited data, and incorporating estimations of the area of the Shroud body images and the probable distances of the Shroud from the body, he speculated on the conditions that might produce the Shroud images. ... He estimated that the electrical energy required would be about 11,000 kilowatts, and the electro-potential at least one hundred million volts, and possibly up to two hundred million volts. This being in the range of lightning bolts, he further speculated that ball lightening could be a possible source of such energy."*

To explain at the same time the cause of the presence of images of many objects on the TS, discovered by him (1998), A. Whanger continued in reference to I. Bensen: "He stated that in such high energy fields, one would get secondary corona discharge off all the objects in that field!" Therefore objects like plants, flowers and others, posed near the TS Man could have generated images by means of secondary CD acting on them.

by G. Coote who proposed the piezoelectric effect of quartziferous rock subjected to an earthquake as the source of an electrostatic field. In 1986, J.B. Judica Cordiglia obtained some images on linen samples using an electric technique. In 1997, E. Lindner proposed an electron source as the cause of the body image formation. In 1998, F. Lattarulo theoretically proposed a hypothesis of image formation based on CD generated by an outer source and in 2000, G. De Liso obtained some images on linen cloths during earthquakes, but these works were not broadly considered. In 2005, O. Scheuermann improved his studies with F. Lattarulo and the author showing that electron CD radiation is a very good candidate to explain the TS body image formation.

In this paper, following a presentation of the hypothesis of the TS body image formation, some results of images obtained with CD experiments (described by G. Fanti et al. 2005) are briefly presented and compared with the TS image characteristics. The paper ends with a discussion of some of the aspects of the images experimentally obtained with CD in light of some questions coming from the SSG (ShroudScience Group) after the publication of the CD paper in 2005.

2. CORONA DISCHARGE

A Corona Discharge (CD) is an electrical discharge (Chen J., 2002) brought on by the ionization of a fluid surrounding a conductor which occurs when the potential gradient exceeds a threshold in situations where sparking is not favored. In a CD, a current develops between two high-voltage electrodes in a dielectric fluid, usually air, by ionizing the fluid so as to generate a plasma (which is the fourth state of matter beyond solid, liquid and gas) around one electrode. This leads to the collection of electrons and ions made by stripping the electrons from atoms and electronic emission from the negatively polarized electrode. The ions generated are used as the charge carriers to the other electrode. CD usually involves two asymmetric electrodes, one highly curved (emitter, injector or active conductor) and one of low curvature (collector).

An example of CD can be found in a plasma ball, or “Incandescent Electric Light” as called by its inventor Nikola Tesla in 1894 (Fig. 1). A plasma ball is usually a clear glass sphere filled with a mixture of various gases at low pressure, and driven by a high frequency alternating current at high voltage (approx. 35 kHz, 2–5 kV), generated by a high voltage transformer. A smaller sphere in its center serves as an electrode. Plasma filaments extend from the inner electrode to the outer glass insulator, giving the appearance of constant multiple beams of colored light. A pink area around the inner sphere where CD is formed is visible. The ions generated in the gas are used as charge carriers to the other electrode. An atom is ionized if it is subject to a strong electric field; it generates a positive ion and an electron.

CD may be positive (if the emitter is positive) or negative, but the relative physics are different as a result of the difference in mass between electrons and positively charged ions. A neutral atom in a fluid, which is a region subject to a strong electric field, can be ionized by an exogenous environmental event, resulting from, for example, a photon interaction that generates a positive ion and an electron.

The strong field then separates these charged particles, guides and accelerates them along the field lines. Additional electron and positive-ion pairs are then generated by collision causing a chain-reaction or electron avalanche. An ion species generated in this series of avalanches is attracted to the less curved electrode, completing the circuit, and maintaining the current flow. During CD, blue/white glowing can often be seen because most of the emissions are in the UV (Ultra Violet) range. A negative CD happens in a non-uniform corona and generally has less energy than a positive CD, but the electron density is greater.

It must be observed that CD is a partial discharge (for example the pink around the inner sphere in Figure 1) and differs from a total discharge, which is also sometimes visible in the plasma ball as a blue/white bolt of lightning.

CD has applications, for example, in photocopying or ozone and NOx manufacturing. It is generally avoided in electric power transmission, where it is sometimes referred to as Partial Discharge.

Placing a conductive object near, or in contact with the glass alters the high-frequency electric field, causing a single beam to migrate from the inner ball to the point of proximity or of contact. An electric current is produced within any conductive object near the sphere as the glass does not block the electromagnetic field, but only the current, generated by the electric current flowing through the plasma. The glass acts as a dielectric in a capacitor formed between the ionized gas and the conductive object (see Figure 2).

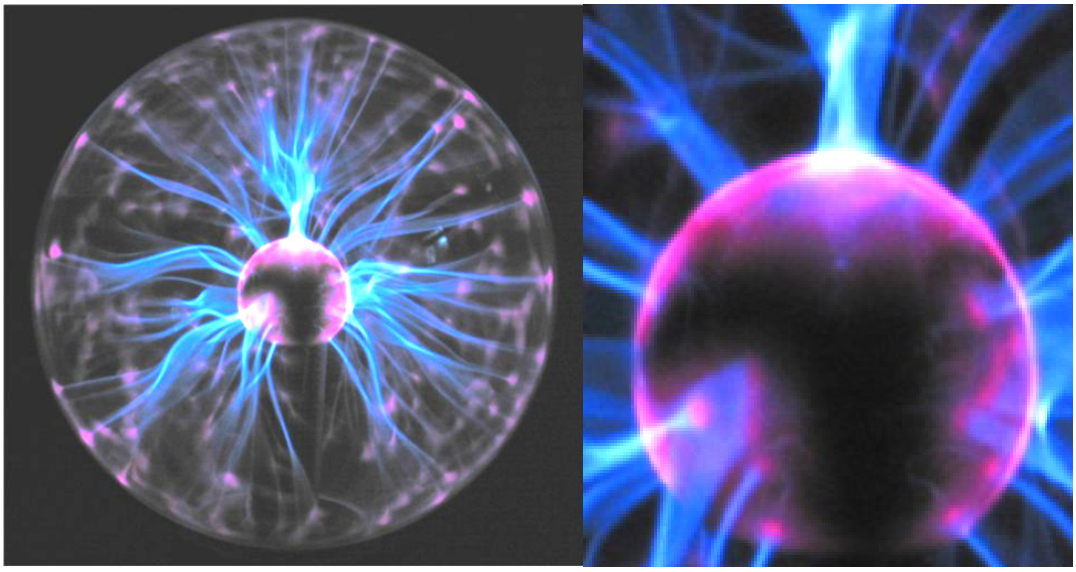

Figure 1. The plasma ball as an example of CD (on the left) and detail of its inner sphere (on the right) partially covered by pink CD .

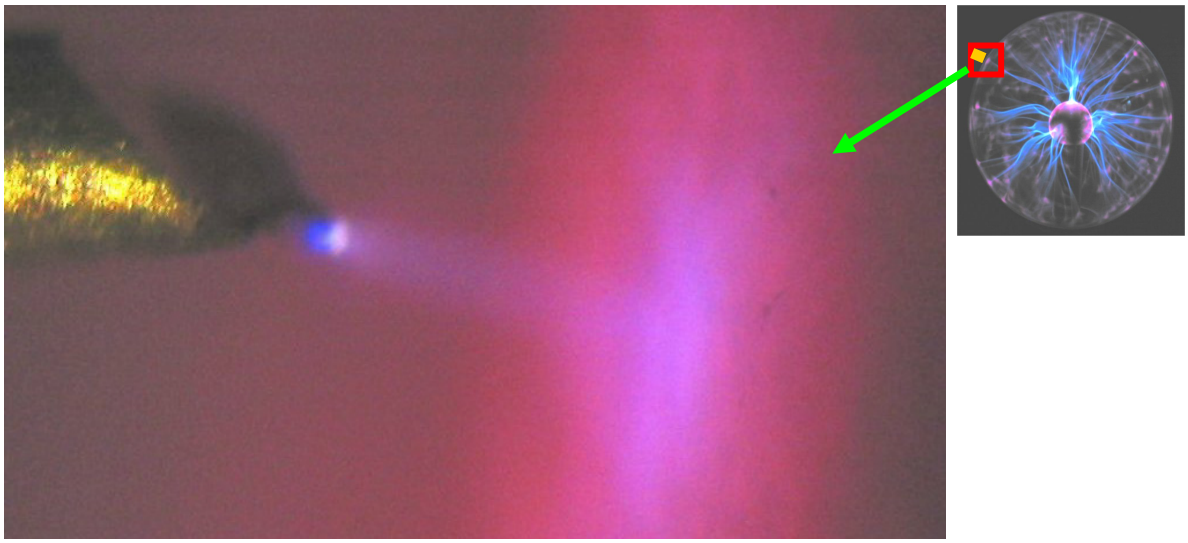

Figure 2. CD in air at a conductive point in proximity to a plasma. The point of a needle (on the left) is put in the proximity of a plasma ball as is shown in the photo on the right. The glow due to CD is also evident in the air around the tip of the needle.

Figure 3. Hand image glow on a linen cloth: the hand touches a cloth put on a plasma ball.

If a hand touches a linen cloth that is in contact with the plasma ball (see Figure 3), the same effect is evident and the hand image glows on the cloth. As will be shown in this paper, this effect can be compared in some ways with the TS body image formation.

In light of the discussion about the TS body image formation, it must be observed that CD also forms:

- UV luminescence;
- heating;
- ozone (O_3) and other reactive substances as nitric acid (NHO_3);
- acoustic effect;
- electromagnetic interference.

Heating (from about 50 °C to 150 °C) and UV luminescence are probably the two most important effects for the body image formation because they could be responsible for the polysaccharides dehydrating of the linen cloth. Although electrons are the medium that triggers the process, it is the UV light and heating that produce the image: they react with the linen fibers, and break their C=C chemical compounds. This is what can almost be interpreted from experimental tests done using a plasma ball.

Ozone and other very reactive substances such as nitric acid must also be considered in the CD process; however according to the author, they do not seem to be the direct cause of image formation. Experimental results obtained from long-time expositions to the CD produced by a plasma ball show that the reactive gases promote the ablation that cancels every possible image trace. Other researchers, like F. Lattarulo (2008), think, instead, that the reactive gases play an important role in the image formation. The actual contribution of these reactive gases should be more thoroughly studied in the near future.

The acoustic effect and electromagnetic interference are obviously not relevant to the image formation.

3. HYPOTHESES

Before discussing the body image formation based on CD, it is necessary to point out some hypotheses relative to the ambient conditions in which the body image formed. First of all, it must be explained how the TS was placed around the human body.

In agreement with Figure 4, the human body, characterized by a high cadaveric stiffness, was enveloped in the TS and put horizontally over the tomb stone. There were plants around the corpse that prevented body-sheet contact in correspondence to the sides of the body.

An alternative hypothesis was discussed by Fanti et al., in Dallas (2005), that postulates that the Man was tightly wrapped in the TS by means of bandages. However, if the body was tightly wrapped, we would also see bloodstains in the lateral parts of the body (for example the legs), but these are not really visible on the TS. Therefore, this hypothesis is not considered here and the TS Man is assumed to be enveloped as shown in Figure 4.

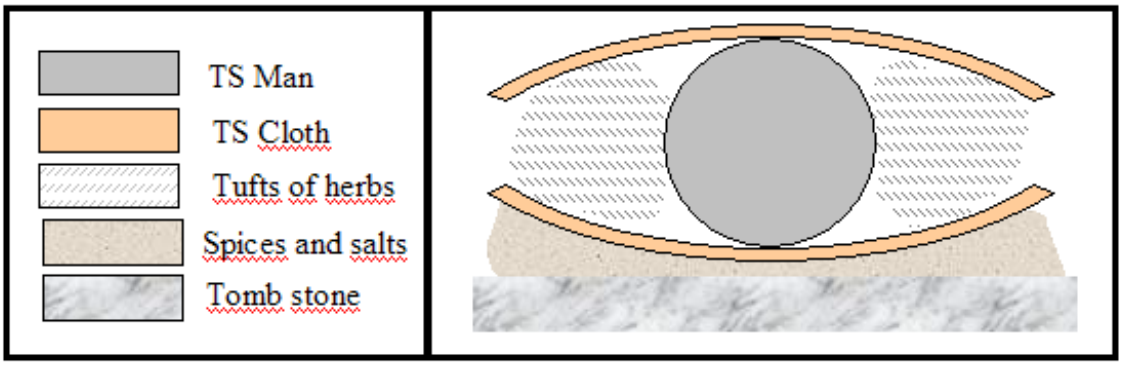

Figure 4. Hypothesized configuration of the how the TS body was enveloped in the TS.

The Man in the tomb was the source of an intense electric field, in other words the corpse radiated electrons, but the possible cause of this emission is beyond the scope of the present paper[2]; therefore, electrons coming from the human body were attracted to the surrounding ambient as it is represented in Figure 5. The body enveloped in the TS shown in Figure 4 is simplified here, but the radial electrical field lines generated by the energized body and the corresponding positive and negative electrical charges present in the tomb are indicated.

There are also other hypotheses. One is that the generated electric field caused avalanche re-starts and streamers in the air around the TS human body to form CD. The TS was inside the glow-CD layer, i.e. the length of the emitted streamers was greater than the body-cloth distance. Another is that the glow-CD layer was interrupted by the presence of the TS and it re-started on the outer surface of the TS. The outer streamers were energetically less severe so that the

[2] *Some facts are considered and discussed in this paper trying only to find a scientific explanation to what can be detected; an energy capable of causing all the effects detected in the TS body image is here hypothesized, discussed and supported with experimental results. The eventual hypothesis of a particular event, perhaps related to a very rare natural phenomenon such as a ball lightening, or perhaps connected to a supernatural energy (such as a corpse dematerialization, that let the electrons free, in connection with the Resurrection - phenomenon that cannot be discussed on a scientific level because it is not reproducible) is out of scope of the present discussion. In fact some works that make reference to a supernatural event like dematerialization are classified as non-scientific. This step-by-step procedure, that for the moment only hypothesizes a possible energy responsible of the image formation, without detecting the phenomenon that caused it, seems to be necessary when scientific analysis is not able to completely explain and reproduce what is tested on the TS image.*

intensity of the image impressed on the outer surface of the linen was reduced. This could also explain why the superficiality of the TS body image is double in some image areas where there was a more intense electric field (G. Fanti and R. Maggiolo 2004).

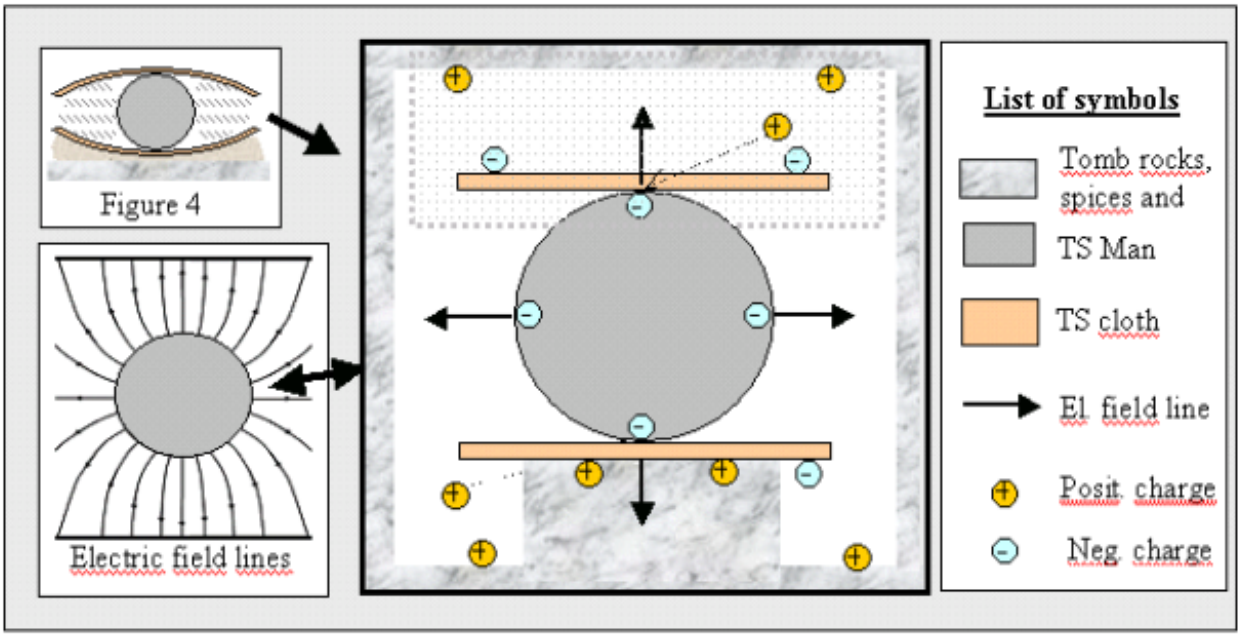

Figure 5. Simplified scheme of the body enveloping shown in Figure 4 with an indication of electric charges and corresponding electric field generated (on the bottom left). The dotted box on the upper half of the scheme corresponds to the representation of Figure A1.

3.1 Mathematical model

As presented in part by the author in SSG message #12705, the following mathematical model can be adopted with the hypotheses explained above.

The electrical behavior of the upper half dotted box of the scheme in Figure 5 can be modeled as that of a capacitor that is a passive electrical component consisting of two conductive electrodes (the human body wetted with fluids and the stone), separated by dielectrics (the TS and the air). They prevent a charge from moving directly between the plates that can store energy.

The process of storing energy, called charging, involves electric charges of equal magnitude, but opposite polarity, building up on each plate. A charge may, however, move from one plate to the other through an external circuit, but when any external connection is removed, the charge on the plates persists. The separated charges attract each other, and an electric field is present between the plates. The reference capacitor consists of two wide, flat, square parallel plates separated by a thin dielectric layer. Assuming that the plates size *l*, with area *(l x l=) A*, is much greater than their distance *d*, the instantaneous electric field between the plates *E(t),* if the instantaneous charge on a plate $-Q(t)$ is spread evenly is:

$$E(t) = -Q(t) / \varepsilon A \qquad (1)$$

where ε is the permittivity of the dielectric. The voltage V(t) between the plates is equal to the integral along the *x* position between the plates:

$$V(t) = -\int E(t)dx = Q(t)d / \varepsilon A \qquad (2)$$

The measure of the stored charge on each plate is the capacitance C (measured in farad) that is typical of the system under examination:

$$C = Q / V \qquad (3)$$

Therefore, the stored charge in the capacitor is:

$$Q = C\,V \qquad (4)$$

If we combine Eq. (2) with Eq. (4), the capacitance is inversely proportional to the plates' distance:

$$C = \varepsilon A / d \qquad (5)$$

If the distance is not constant in the condenser, the capacitance, and consequently the stored charge (if the voltage is constant), decreases as the distance increases.

The charge separation persists in the two plates and energy is stored in the electric field, until the charge is allowed to return to its equilibrium position, releasing the energy via CD. Electric energy is necessary, and then work $W(t)$ is done to move a charge between the plates in the capacitor. It may be evaluated in the following way. The electric power P is:

$$P(t) = dW / dt = V(t)\ \ I(t) \qquad (6)$$

where I is the current intensity:

$$I(t) = C\,dV / d\,t \qquad (7)$$

From Eq. *(6)* and Eq. *(7)* we obtain:

$$dW = C\,V(t)\,dV \qquad (8)$$

and then:

$$W(t) = C\int V(t)dV\ = (C/2)\ V(t)^2\ \ = C\,V^2 / 2\ =\ Q\,V\ /\ 2 \qquad (9)$$

An electric power increase related to CD causes a glow-CD layer increase, that must be of the order of 10 cm to be able to reproduce the TS body image; this fact leads to necessity to have very high voltages. The electric power increase also causes an increase of image intensity.

The imaging mechanism in the CD hypothesis is related to the charge stored and then to the number of electrons acting on the TS fibers. As the stored charge is in some way proportional to the luminance levels of the TS image, the so called 3-D effect of the body image is strictly connected to the distance of the two capacitors' surfaces: human skin and the TS fabric.

4. EXPERIMENTAL RESULTS

As reported in a recent paper (G. Fanti et al. 2005), many experiments have been performed with CD to obtain images very similar to that of the TS. Some experimental results are briefly reported below. A commercial plasma ball was used to generate images of objects on a linen cloth placed on the glass surface (see Figure 6).

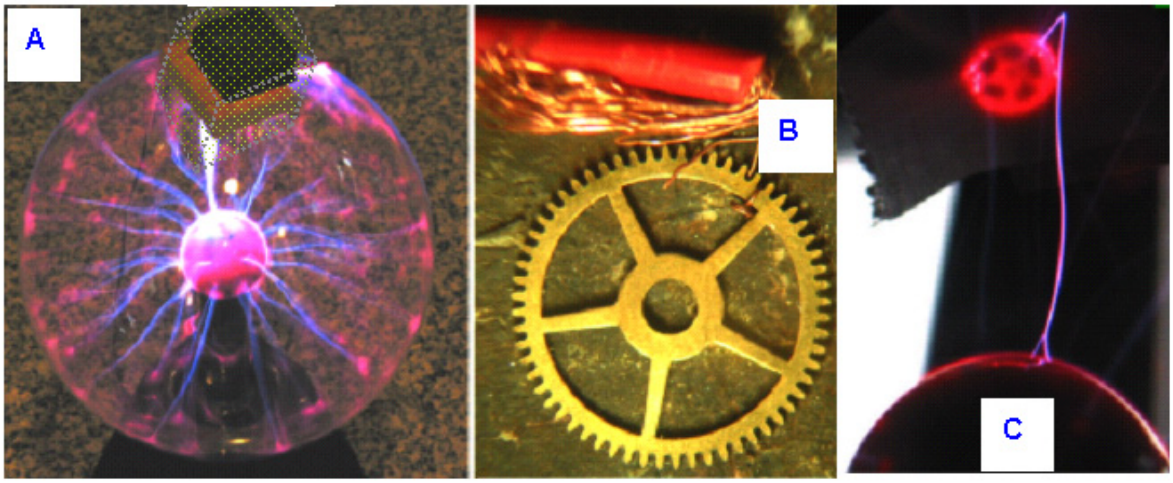

Figure 6. System set-up used to obtain TS-like images on linen sheets. A) Plasma ball; The dotted box on the upper half of the scheme corresponds to the representation in Figure A1 of Appendix. B) Bronze watch wheel. C) Bolts of lightening and CD in the air outside of the sphere between the cloth and wheel.

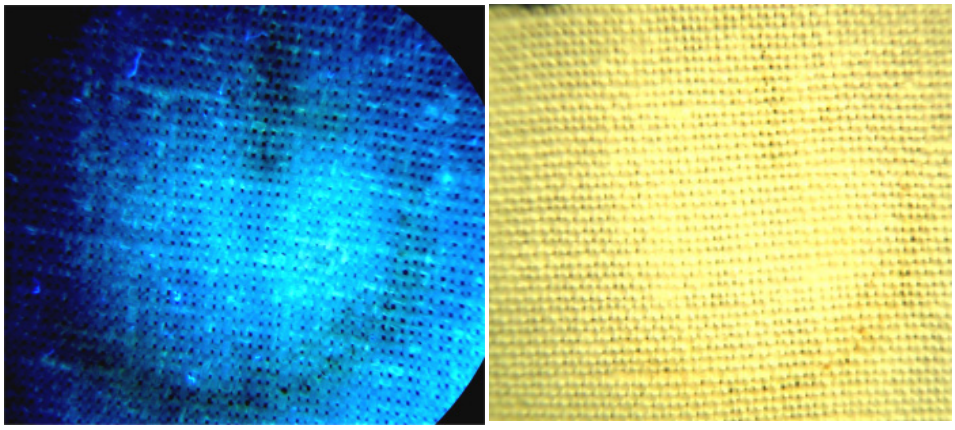

Figure 7. Resulting images on a linen cloth obtained with the system set-up in Figure 6. The image of a watch wheel is clearly visible in UV light on the left; the corresponding image seen in visible light is shown on the right.

After exposition to CD for 300 s, an image on the linen cloth is visible in UV light. After heating this sample with an iron, the wheel image also appears in visible light (see Figure 7).
Just like the TS, the image on the cloth subject to CD is very superficial, but it is also double in some cases. It appears on both the front and back surfaces of the linen cloth but not in the middle (see Figure 8).

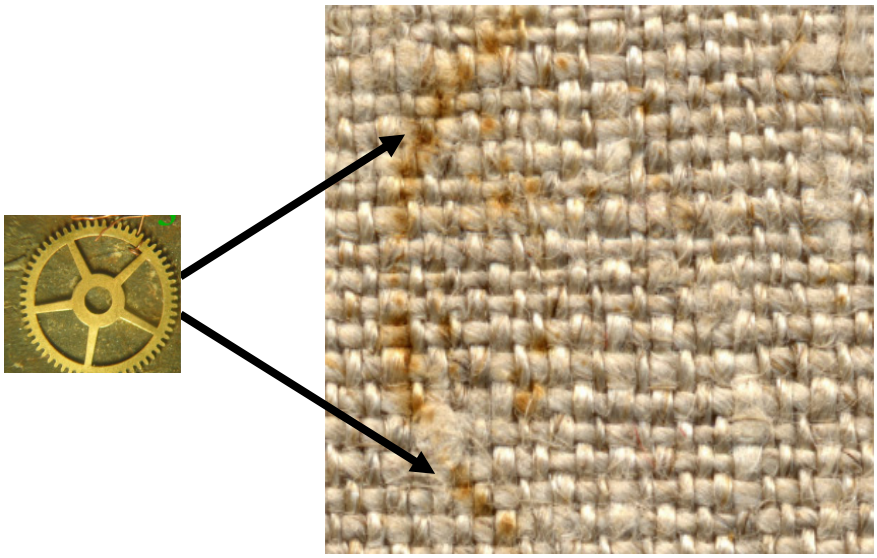

Figure 8. In some cases, when the exposition of the linen cloth to CD causes more evident effects, the resulting image is superficial but double. It appears on both the surfaces and there is no image in the middle.

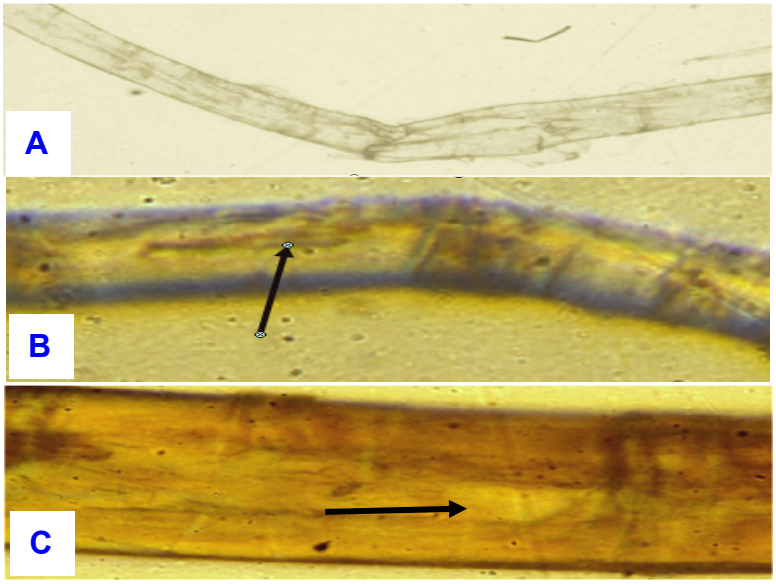

Figure 9. Results of experiments: image fibers obtained with CD. –A) The medullas of the image fibers are not colored. – B) The fiber surface is 'crackled' like that of the TS. – C) All the image fibers are circumferentially colored but after the application of a mechanical stress, sometimes the lack of the external colored layer of the fiber is visible.

The following results were obtained from the microscopic analysis performed on the image fibers produced in these CD experiments, (see Figure 9):

- the image color resides on the 200 nm thick primary wall cell of the TS fibers;
- the medullas of the image fibers are not colored;

- the fiber surface is 'crackled' like those of the TS;
- all the image fibers are circumferentially colored.

5. RESPONSES TO OBJECTIONS

The chemical and physical characteristics of the images obtained on linen cloths after exposition to CD, considered in various tests, correspond to those of the TS reported in a paper (G. Fanti et al., 24 authors, 2005). Nevertheless, some researchers have raised some doubts about the CD hypothesis for the TS body image formation for probably two reasons.
The first reason is that it is frequently not easy for a researcher to admit that his conviction is wrong; if a scientific proof is sure, the researchers has no alternatives, but if the proof is not indubitable, as frequently is in the case of the TS, it is easy that the researcher still remains with his idea. The second one is that CD is an effect that is not very well known and, therefore, it is not very easy to understand in all its details.

The most important comments, most of them coming from the SSG, are discussed here in order to better clarify the mechanism that probably acted on the TS to form the body image, which has not yet been explained by science.

Before listing the principal objections, it is worth clarifying that the CD hypothesis does not contradict J. Jackson's collapse hypothesis (J. Jackson 1990), but that it can improve it from the point of view of soft UV emission. For example, the collapse hypothesis has some difficulty explaining the characteristics of the dorsal image with its 3-D features because that part of the cloth was in contact with the tomb stone. Therefore, every collapse through the hypothetical mechanically transparent body was prevented in correspondence to the dorsal body image.

5.1 Direction of radiation

During the Discussion Section of the 2005 Dallas Int. Conf. on the Turin Shroud, M. Latendresse posed an interesting question: the authors (G. Fanti et al. 2005) state that the radiation effects are almost orthogonal to the skin, but the electric field lines are not.

This is correct and the interpretative model of the effects of radiation must be refined even if the global effect on the resulting image does not change significantly. An initial rough approximation stated that the radiation is orthogonal to the skin, but, in agreement with Figure 10, which represents a scheme of the electric field lines generated by the human body enveloped in the TS, some additional issues must be considered.

-a) If the TS is close to the human body (a few millimeters, such as the case of the images of the face and hands), the radiation can be assumed to be orthogonal because the very short curvilinear electric field lines can be seen as rectilinear.
-b) If the TS is relatively far from the human body (more than 50 cm), the curvilinear lines of the electric field tend to become almost rectilinear and parallel to each other; the electric field lines are not orthogonal to the skin, but this is not the case of the TS which is closer to the human body.
-c) If the TS is in the range between case (a) and (b) (it is known that the maximum body-cloth distance is less than about 10 cm), the effect is more complicated and needs clarification.

In case (c), and in reference to the scheme in Figure 10, we see that when the body-cloth distance is in the range between a few millimeters and 10 cm, the electric field lines are not rectilinear and, if a rough approximation is accepted, they can be assumed to be orthogonal to the emitting surface. When a distance of few millimeters is considered, this hypothesis tends to be more reliable, and this is the case of a large percentage of the TS body image.

If, instead, the TS is almost flat and the body-cloth distance is a few centimeters, as in the case of the TS face, the situation changes. The electric field lines are curvilinear (almost rectilinear in an initial approximation) but they still diverge causing a partial distortion of the reproduced image. On the other hand, as the electric field is less intense in correspondence to the sides of the body, its effect on the image is more negligible and the resulting image appears less distorted, as if it were only reproduced by almost vertical electric field lines.

It is probably for this reason that J. Jackson (1990) assumed that there was a vertical radiation acting on the TS. The image resulting from the model here presented is in agreement with the TS body image features.

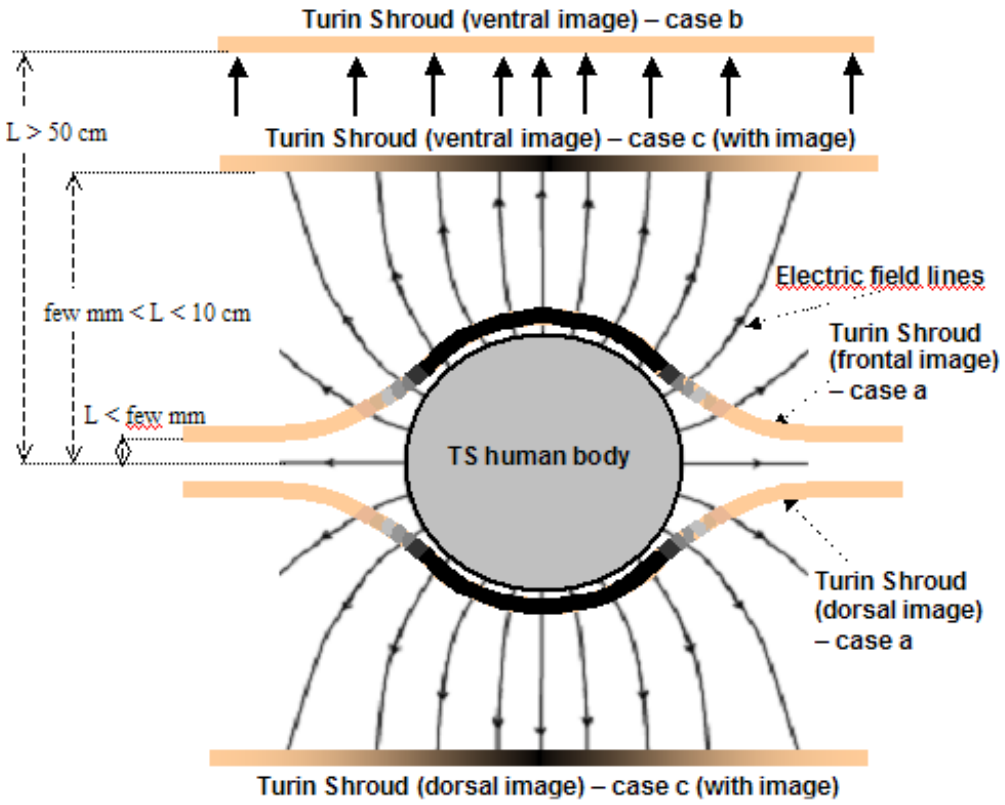

Figure 10. Scheme of a section the TS human body enveloped in the TS and generating an electric field. Three different positions of the TS (case a, b and c) show the corresponding configurations of the electric field lines. If the TS is close to the human body (case a), as it is in a large percentage of the image area, the electric field lines can be assumed to be orthogonal to the skin.

5.2 Radiation is the cause of the TS body image

During the SSG discussions, one scholar manifested his conviction that 'radiations' have nothing to do with the image properties of the TS. A whole paper, or better a book (G. Fanti 2008), would be needed to better explain the reasons why radiation should be assumed to be the cause of the TS body image formation. However, here the scientific fact in favor of radiation are briefly reported.

- The 3D effect shows that there is a continuous relation between luminance and body-cloth distance, explainable with a source acting at a distance such as energy. The hypothesis that makes reference both to a body-cloth contact effect and to a gas diffusion does not match this continuity.

- The body-cloth contact hypotheses have a hard time explaining why there is also an image in the cloth's areas where contact is very dubious.

- The gas diffusion hypotheses (Fanti 2004) present many obscure points for the explanation of the body image formation, one of which is the low resolution reachable.

- The TS image fibers are separated by non-image fibers. An electric field can explain this with electrons flowing along preferential fibers, but other hypotheses have difficulty explaining this fact.

- The image fibers are continuously colored around their circumference; differently from other hypotheses, electrons traveling along the image fibers explain this fact.

A new preliminary result based on the analysis of some linen fibers (Figure 11) recognized by the author as coming from the TS in correspondence to the human body buttocks (back TS surface that was in contact with the tombstone) can be added to this argument. Some of these fibers have limited segments of about 50 μm, showing signs of apparent localized desiccation or burns (probably caused by a high intensity source of 'radiations'), which can be explained by a source of energy like CD, but not with the effects of the Chambéry fire of 1532.

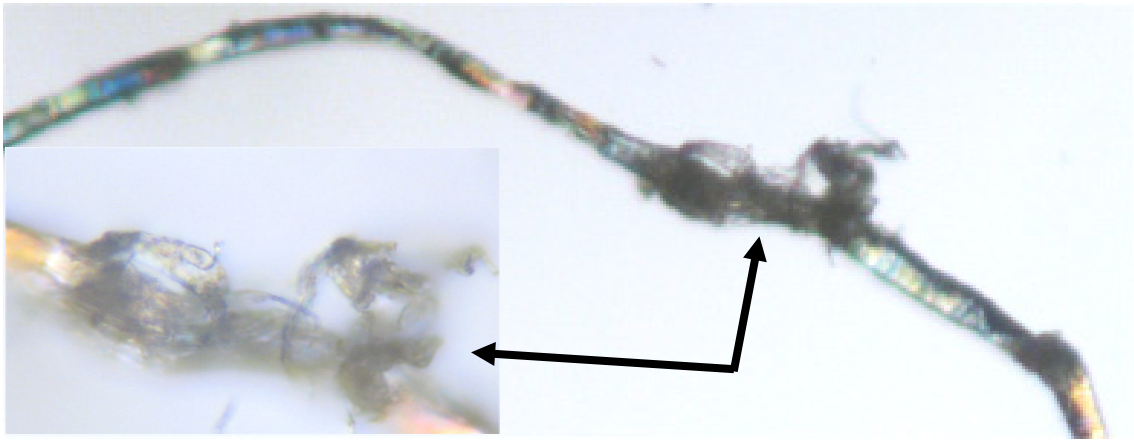

Figure 11. Linen fiber of the TS buttocks area which has a segment of about 50 μm showing signs of apparent localized desiccation.

5.3 Mathematical approximation of the 3-D effect

In Ray Schneider's SSG message #11856 he writes: "*The 3D effect is not particularly close to an inverse square law*".

In the case of TS, the 3-D effect is not as close to an inverse square as some have posited in the past, but, in agreement with some studies (A. Cunico, 1999, and L. Favero, 2001, degree theses), it is better approximated with a negative exponential law as shown in Figure 12. It must be added that the interpolation curve relative to the dorsal body image is quite different from the one of the frontal image and that both of them differ from the curve of the Face image.

This fact is in favor of the hypothesis that there were some asymmetries in the ambient (gravity direction, tombstone and so on), that led to a dorsal image that is not exactly the same as the frontal one. Furthermore, the face image is characterized by a more intense image impressed on the cloth. This fact must be more thoroughly studied in the future, but we can make the hypothesis that the head emitted a greater level of radiation or (as suggested by C. M. Glori) another cloth was put over the head over the TS and this amplified the CD effect in that area.

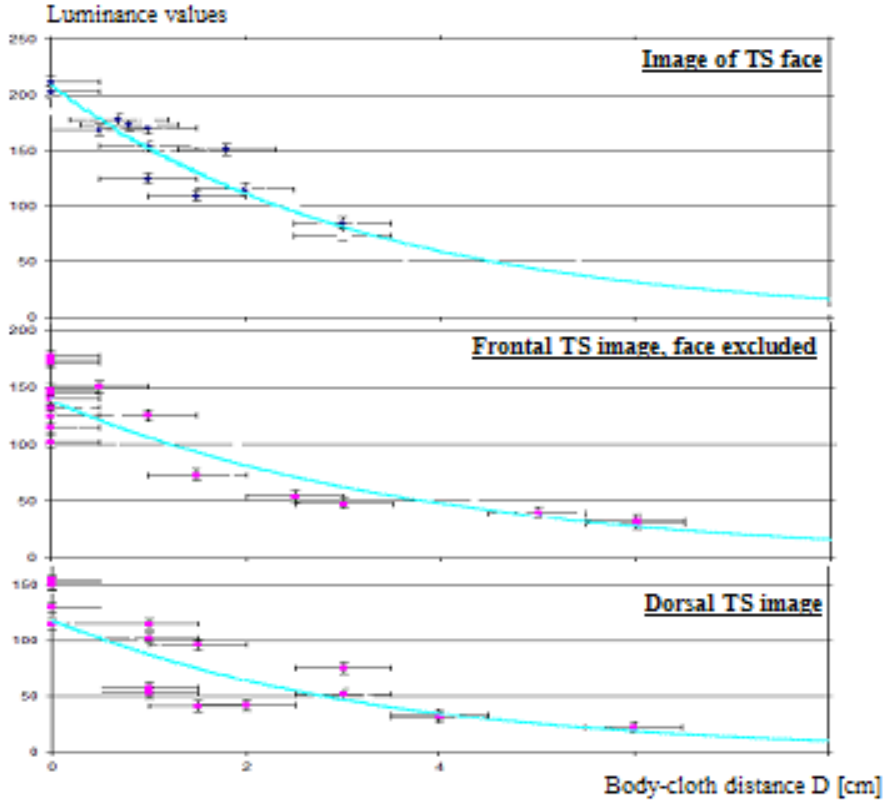

Figure 12. Three different exponential best fittings relative to TS frontal, dorsal and face images (L. Favero 2001)

Three different exponential best fittings relative to the frontal, dorsal and face images (L. Favero 2001, pg.107) can be obtained:

- Frontal image (not including the face): $L = 125\ e^{-0.246\ D}$; correlation = 0.946
- Face image: $L = 215\ e^{-0.311\ D}$; correlation = 0.933
- Dorsal image: $L = 147\ e^{-0.309\ D}$; correlation = 0.979

D being the body-cloth distance evaluated in centimeters and L the luminance in the range 0-255.

5.4 3-D relationship and resolution

In Ray Schneider's SSG message #11856, he writes: "*The real problem is simultaneously explaining the 3D relationship and the resolution, because they are at odds with each other.* ". The explanation of the 3-D effects on the dorsal image could be a problem in the collapse hypothesis of J. Jackson (1990), but it is not a problem with CD. The relatively high resolution of 4.9±0.5 mm is due to the fact that the electric field lines do not cross each other and the radiation is very directional. Furthermore, it is important to note that higher resolution in the TS body image is found in correspondence to 'almost-contact' areas such as the face and hands. On the contrary, the 3D effect is more evident where the distance of the human body from the TS is greater (few centimeters), see Figure 13.

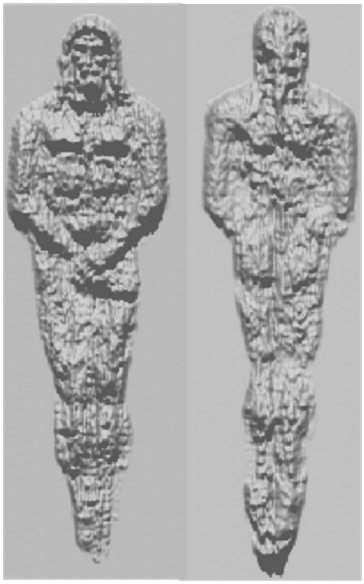

Figure 13. 3-D characteristics of both the frontal and dorsal TS body image.

5.5 Medullas of linen fibers uncolored

In Ray Schneider's SSG message #11970, he writes: "*The problem in capsule form is simply that ... the center of the linen fibers are unaffected by the energy that produced the image. ... I'd be delighted to see evidence that a high-energy process could really do this, ...*"

Figure 8 shows colored linen fibers using CD; the absence of coloration of their inner layer of cellulose (medulla not colored) is quite evident.

The problem could be explaining how an intense radiation source is able to color only a thin layer (about 0.2 micrometers) while leaving the inner cellulosic layer (about 10 micrometers) uncolored. The problem could be further complicated by the fact that the color appears circumferentially uniform.

A simple solution for this problem comes from a paper (G. Fanti et al., 24 authors, 2005) that reports that (A10): "the pyrolysis/ms data showed the presence of polysaccharides of lower stability than cellulose on the surface of linen fibers from the TS". This explains why the radiation source involved the entire volume of the fiber, but only the external layer, called "Primary Cell Wall" (Bos H. L., Donald A. M., 1999), reacted to the radiation by becoming colored.

5.6 Two draping configurations

In Ben Wiech's SSG message #11266, he writes: "*how does your Coronal Discharge hypothesis address the issue of the cloth being in two different positions, a more "draping position" at the time the facial blood was transferred and the flatter position at the time the image went on to the cloth?*"

In agreement with B. Power (2002), a consequence of radiation could be a repositioning of the TS in the tomb. Independently from the energy type, if the involved energy was not negligible, the gas-law ($P\ V = k\ T$) must be considered. The increase in the temperature (T) of the air between the human body and cloth caused by the energy emission would have caused a pressure (P) and volume (V) variation. More specifically, a temperature increase caused by the radiated energy could have caused a pressure increase that would have moved the cloth upwards (Figure 14) then flattening it in correspondence with the face; this could explain why the cloth

was in a more draping position during the bloodstains formations and a more flat position when the body image formed.

In Ben Wiech's SSG message #11498 he writes in reference to J. Jackson's paper (1990): *"While the facial image is well resolved, the ankle region of the frontal image is not..."*

Even if this fact can be explained in other complex ways, the CD effect has no difficulty in explaining it in agreement with B. Power (2002) because the generated pressure could have puffed up the TS[3] in correspondence with the feet, in the hypothesis that some objects were put over the TS in correspondence of the human body sides.

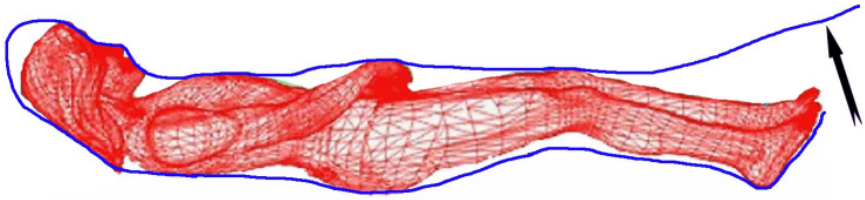

Figure 14. A possible TS configuration during the burst of energy; this fact is confirmed by the almost total absence of a frontal body image in correspondence with the feet[4].

5.7 Lack of fluorescence

One characteristic of the TS body image is the lack of fluorescence in the sense that the background, consisting of linen fabric, fluoresces much more than the body image: this means that the image formation process reduced the background's fluorescence.

The SSG noticed that the modern linen is strongly fluorescent; if the background of the CD test sample fluoresces much more, the non-fluorescence of the CD image is difficult to compare to that of the TS.

Even if a quantitative analysis could be done in the future, it seems sufficient to show here that, like the TS image, the CD images also cause a reduction in fluorescence on the background, as can be seen in Figure 7. It must also be noted that the CD images are easier to detect in UV light than in visible light because the lack of fluorescence is more evident. Furthermore, it is true that modern linen fabrics are very fluorescent, but the fabric used for the experiments, manufactured as the old linens were, show a fluorescence comparable with that of the TS. In conclusion, from a qualitative point of view, just like the TS, the CD image does not fluoresce.

5.8 Bloodstain degradation

Other SSG messages ask why the TS bloodstains are not degraded.

First of all, the question can be inverted: why should a CD radiation degrade the bloodstains? Looking closely at a colored TS fiber, only the primary wall cell, which is about 0.2 micrometers

[3] *In addition, moving away from traditional science for a moment, the following hypothesis can join J. Jackson's collapse hypothesis with the CD one: the TS Man emanated an intense energy that caused a pressure increase. After some fractions of a second, the TS Man dematerialized letting free his atoms and suddenly his electrons generated a CD that caused a 'photo' of his body image on the TS in a moving configuration. The resulting image is not blurred because the acquisition time was less then about 1/10 s, but due to the relative body-cloth distance it is also not well resolved in some portions more distant from the human body.*

[4] *To explain the lack of image in correspondence of the frontal feet image, someone supposed that the part of the TS covering the back side of the human body, was too long and therefore it was turned up to cover the feet under the upper side of the TS. Nevertheless, this hypothesis does not explain the gradual lack of image visible in correspondence of the frontal RS feet, because a double folding should have let a clean sign of separation between image and non-image.*

thick, is chemically altered whereas the inner cellulosic layer is not. In the same way, the blood could also be not damaged.

During the CD experiments, the temperature increase was measured in correspondence to the corona glow by means of an optical pyrometer and the temperature remained relatively low (50-150 °C). If the supposed burst of energy was sufficiently brief (probably fractions of a second), these effects were not, therefore able to degrade the blood very much.

In any case some kind of degradation in the bloodstains can be detected and this phenomenon seems to be more intense than that related to the effects simply caused by aging. Using Raman analysis, G. Moscardi (2008) detected the limited presence of Bilirubin in red crusts coming from the TS, but also detected the presence of iron oxides such as hematite and goethite in them. She came to "suppose that the blood present is ancient and consistently degraded, perhaps as a consequence of a prolonged exposition to light, radiation or heating that could accelerate the production of iron oxides from the hemoglobin structure."

In addition, C. Goldoni (2008) did experiments with human blood samples (Figure 15) and found that samples previously exposed to UV light show a particular redness similar to the one detected on the TS blood: it is known that CD produces UV light and these facts could be related to each other.

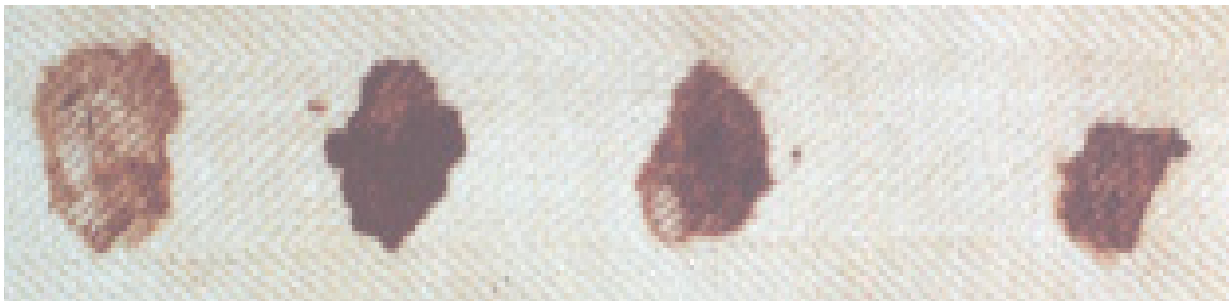

Figure 15. Experiments with UV light on bloodstains made by C. Goldoni to reproduce the specific redness of the TS bloodstains.

5.9 Image resolution

In Ray Schneider's SSG message #10673 he writes,: "*I don't think that it [CD] can convey resolution except over relatively small distances. I'd like to see a CD image created say by putting a cloth over a full scale human bronze bust and generating one."*

G. B. Judica Cordiglia (1986) used a live human body to form an image of hands on a linen sheet by means of CD (Figure 16). The resolution of this experimental test has not yet been measured, but at a first sight it appears to be of the same order, if not better than that of the TS hands shown in Figure 17.

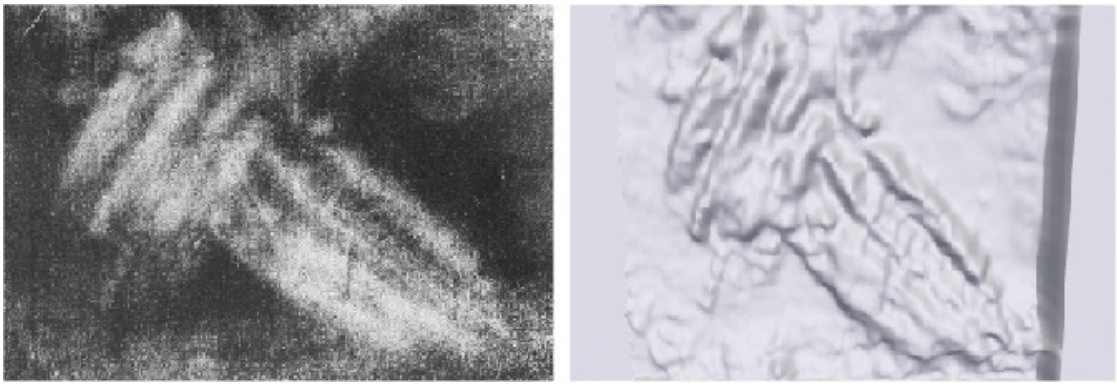

Figure 16. CD experiments done by G. B. Judica Cordiglia; the resulting image of hands obtained from a live body (negative image on the left – courtesy of G.B. J.C. - and corresponding 3-D processing on the right), similar to the TS image, is well resolved, has 3-D characteristics and appears very elongated.

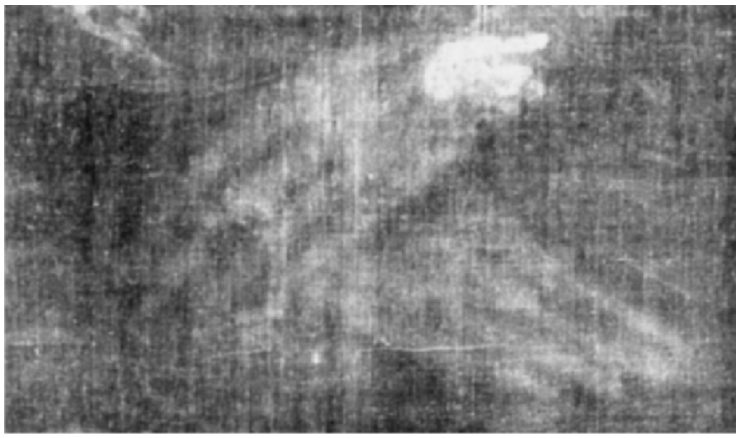

Figure 17. Negative image of the TS hands to be compared with those in Figure 17.

5.10 Hair position

Other SSG messages note that it in Figure 1 of G. Fanti et al. (2005) paper, here reported as Figure 18, a person, touching an high voltage conductor, has his hairs stand up in all directions, but nothing alike can be seen on the TS-image. In addition they note that if the whole event took only some milliseconds the hairs had no time to stand up.

This is an interesting note because it points out a fact about the TS image that is not frequently discussed, perhaps because no one has explained it very well yet: the soft hair (including the beard and moustache). We can assume that the TS Man's hair was mixed with blood and sweat and anointed, but results from experimental tests show that although the hair should have been packed, it was not.

A possible explanation of the TS image of face, Figure 19, can come from the CD effects: the hair of a man in contact with a high-voltage electrostatic field tends to straighten. It must also be added that, when there is CD, there is a charge concentration in correspondence with the tips and highly curved surfaces such as the very thin cylindrical surfaces of hair; for this reason the image intensity of the hair, beard and moustache is higher than in other parts of the human body. A possible explanation of the TS hair image can therefore be related to the fact that the packed hair became softer as a consequence of a CD.

Figure 18. Hair disposition if a man (O. Scheuermann) is in contact with the high-voltage electrostatic field produced by a Van de Graaff generator.

Figure 19. TS Face showing soft hair.

And now it is possible, at least in part, to answer the observations. The TS hair is soft, but not straight, as can be seen in Figure 19. This is probably for two reasons: the first one is perhaps due to the very limited time interval in which the TS body image formed to let the hair dispose along straight lines; the second one is due to the fact that some object, such as flowers for example, put on the sides of the TS Face, may have prevented the hair from moving as it would have.

No clear answer can be furnished, however, about the duration of time of the various events because studies have yet to reach this level of definition. As is stated in this paper, not all the TS body image process has been clarified, nor has the cause of the CD generation; the consequence is that very little can be discussed about the related time intervals.

5.11 Wall effect on the electric field

In Gerardo Ballabio's SSG message #14003 he writes, : "*... [the Holy Sepulchre] was a very narrow place, only a couple of meters wide…. I guess that the corona discharge could flow more easily horizontally between the walls, than vertically between pavement and ceiling. Of course in that case an image such as that on the Shroud couldn't have been obtained.*"

First of all, it must be observed that the CD is not only connected with the wall distance but, more importantly, with the electric field lines. Suppose, for example, that a perfectly vertical field acts on a sepulchre, perhaps due to an underlying compressed quartziferous layer. In this case, no discharges develop horizontally because the two vertical walls have the same voltage.

In any case, the possible wall effect must not be forgotten because perhaps the TS Man was put on a tombstone in proximity of a wall (see the electric field reported in Figures 5 and 10). In this case the electric lines are deviated towards the side of that vertical wall.

Therefore, we should expect to have a non-symmetric body image with one side better defined than the other: if we look at the TS Face in Figure 19, we see that the left hair is better impressed than the right hair. Other parts of the left Face are better impressed as well. This fact does not demonstrate that it was CD that formed the image because other hypothesis such as non-symmetric enveloping can be formulated. Nonetheless, it does not work against the CD hypothesis either.

5.12 Fiber coloration

Some scholars have doubts about fiber coloration with CD perhaps because it is not simple to experimentally obtain an image on a linen sheet using CD. However, the following characteristics of CD are worth pointing out.

- Very low CD energy causes no coloration on linen fibers.
- Low CD energy causes latent coloration of the topmost fibers of a linen fabric. The coloration can be enhanced by further "aging" (heating). The resulting color is similar to that of the TS (Di Lazzaro et al., 2008).
- A narrow band level of CD energy causes a direct coloration of the topmost fibers of a linen fabric and, as in the TS, without coloring the inner cellulosic medulla.
- Higher CD energy causes ablation without any evident image or burning; prolonged exposition to this energy causes holes in the fabric without traces of burning (Figure 20) because they are eliminated by ablation.

An interesting finding on a TS fiber is in agreement with the fact that higher CD energy causes ablation without an image and it is also an important fact in favor of the hypothesis that the TS was subjected to a CD.

Figure 21-1 shows a TS linen fiber coming from the buttocks area having the same characteristics of fibers exposed to prolonged CD (Figure 21-2). The fiber shown in Figure 21-1 has no color and though this may not appear to be particularly significant, some considerations are in favor of the importance of this finding.

- The C area is very limited having a length of about 40 μm; it is not easy to obtain such a result if localized electrical discharges are not used. For this reason, this evidence cannot be related to a non-localized phenomenon such as the 1532 Chambéry fire that damaged the TS.
- It is easy to think that the electric charges formed during the TS body image formation may have found some preferential paths between the human body enveloped in the TS (perhaps imbibed with some conductive liquid) and the tombstone forming some localized sparks that may be responsible for the result in Figure 21.1.

- To confirm the previous consideration, different TS fibers 'dried' showing ablation signs have been found in correspondence with the buttocks area, but not other locations where it must be assumed that there was not the proximity of the human body with the tombstone.

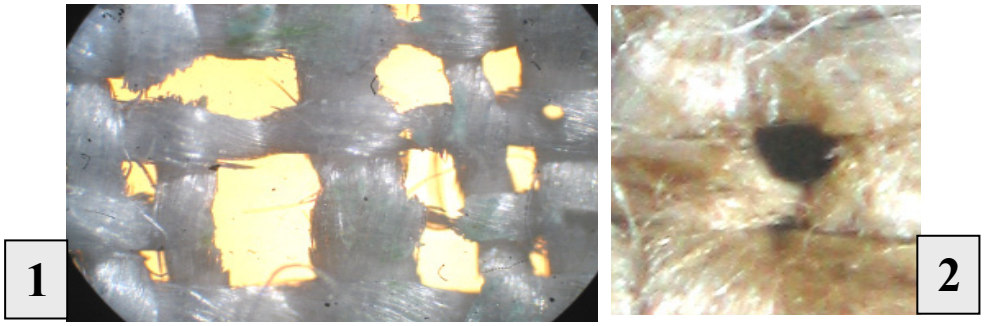

Figure 20. Effects of prolonged expositions of linen sheets to CD (for about 30 minutes). 1) Ablation and 2) a hole appears without burnings or image traces.

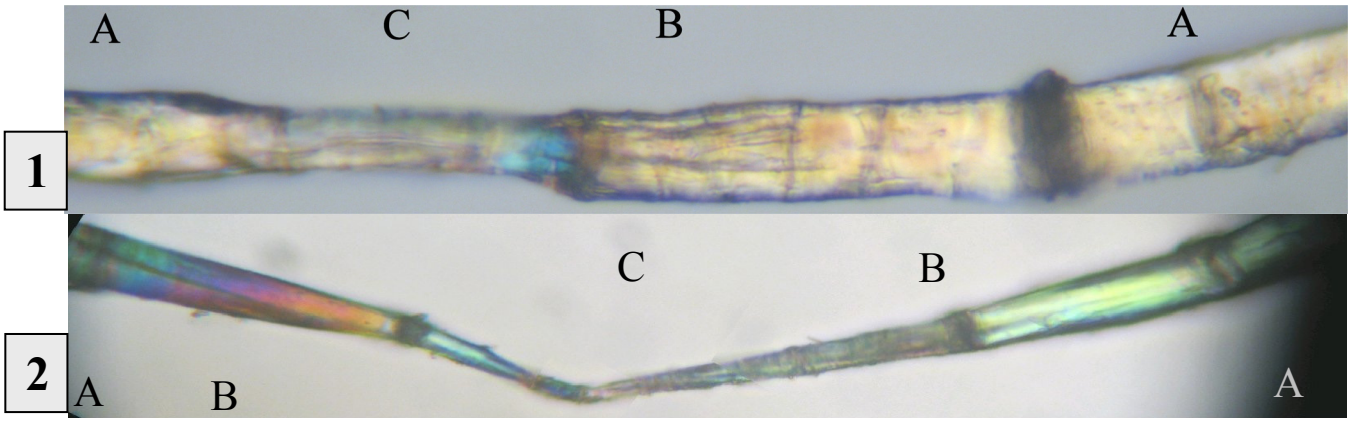

Figure 21. 1) TS linen fiber coming from Filter "h" of G. Riggi di Numana (Fanti G., Basso R., 2008) corresponding to the buttocks area in polarized light. The shape of the fiber 14 µm thick can be subdivided into 4 areas:
- A, where the typical characteristics of a linen fiber are shown;
- B, where some longitudinal crevices lead to the assumption that shrinking was probably caused by the exsiccation caused by a CD source;
- C, where the local reduction in diameter to 8 µm, which was probably caused by a local ablation following an exposition to CD, is evident.
2) Linen fiber in polarized light, taken from the fabric shown in Figure 20-1 in which a reduction in diameter is detected after exposition to CD.

6) DISCUSSION

It could seem that all is explained and that the TS body image was formed during an energy emission connected with CD. Even if in the author's opinion the hypothesis based on CD is the most probable one, there are many facts that must be still explained before reaching a certain conclusion, and these facts are not easy to reproduce in a laboratory.

What we can say is that the TS body image can easily be explained by an intense source of energy, such as a ball of lightening, but this is a great experimental difficulty because it is almost impossible to reproduce in laboratory. Therefore, we can scientifically discuss what is detected on the TS, but base the conclusions only on what can be reproduced in minimal part.

It is well known that some difficulties come up when the working model goes into details; in the present case, these difficulties appear with the lack of comparative experimental results.

For example, the statement of a paper (G. Fanti et al., 24 authors, 2005) reports: "A5) … the color of the image-areas has a discontinuous distribution along the yarn of the cloth: striations are evident. The image has a distinct preference for running along the individual fibers making up a yarn, coloring some but not others" it has not been well clarified. A working hypothesis to explain this fact can still make reference to CD and be formulated as follows. An electric field was generated in the human body by neutrons that came out. The free electrons were then attracted by the linen fabric. The TS fibers acted as 'optical fibers' or 'light pipes' (in a manner first proposed by K. Moran in 1999), and let the electrons generated by the human body run along their length, not as supposed by K. Moran 'in' the fiber but 'outside' them, along their thin external layer. Some colored fibers are, therefore, posed side-by-side to non-colored fibers because these were not involved in electron interaction, as they were a bit more distant from the electron source. This hypothesis needs to be verified by experiments that are not easy to perform.

Ray Schneider (October 2008) observed: *"On the CD issue I'm mainly skeptical because it requires high voltages, but also because the man of the shroud is enshrouded in an insulator so that even if there were voltages present from some unknown source it is unclear how they connect to the body in such a way as to produce an image."*

This comment gives evidence to the real difficulties in interpreting how the TS body image formation occurred. Many body image formation hypotheses (R. Basso, G. Fanti, 2007) have been formulated, but all the hypotheses based strictly on scientifically reproducible mechanisms have failed; on the other hand, the hypotheses that make reference to intense sources of energy can be accepted, but they have great difficulties to be scientifically verified from an experimental point of view. Among the latter, we find the CD hypothesis that, as the paper has shown, can be experimentally verified in many details, but not in its entirety.

If we leave strictly scientific aspects for a moment, we can find a more general, metaphysical answer connecting the image formation with the Resurrection of Jesus, but if we want to stay within scientific limits, a complete explanation becomes more difficult. This is also why, as was stated in Note 2 (*Some facts are considered and discussed in this paper trying only to find a scientific explanation to what can be detected*) the paper does not discuss how the TS formed, but rather only what source of energy may have been involved in the creation of this scientifically impossible image.

Another problem raised by the observation of R. Schneider is related to the explanation of how the human body, which was a corpse, enveloped in more or less insulating cloth (perhaps also wetted of oils that are non conductive), could have generated such intense energy. As stated in Note 2, this problem goes beyond the scope of the present paper because perhaps a non-scientific hypotheses, such as a miracle, may have been involved and because of the lack of experimental results. For the moment, the following causes can be considered: a possible electric contact (across the TS) between the human body and an electric source, a ball of lightening, a supernatural phenomenon[5].

[5] *It can be added – out of a strictly scientific domain - that the problem can be that of being able to separate scientific aspects from theological ones; this is not always simple. For the author, the following issues must be considered.*

7) CONCLUSION

The present paper has been written to better clarify some points that came up after discussions at the SSG level in reference to a paper on CD, published by G. Fanti, et al. (2005). After the presentation, in the details of the hypotheses, some TS aspects such as the radiation direction, 3-D effects and their mathematical representation, the image resolution, the double draping configurations of the TS and the color on the linen fibers, are here considered and discussed. Some new evidence is also presented, such as the exsiccation of limited parts of linen fibers coming from the TS, that is in favor of a radiation related to the CD hypothesis.

Many results obtained with CD tests have been compared with those of TS body image and they show no appreciable chemical-physical differences from the image features of the TS.

An additional working hypothesis was also discussed to better understand how the body image was perhaps impressed on the most important Relic of Christianity, but up to now no sure conclusions can be reached about the mechanism that really formed the body image because it is not possible to experimentally reproduce the sources of energy necessary to obtain an experimental copy of the TS image.

In agreement with R. Schneider (2008) we can, therefore, conclude in reference to the TS, "... the enduring character is the mystery, since whether authentic or inauthentic the mystery remains. If it is actually Jesus and Jesus is God, then a miraculous account cannot be ruled out. If it is representative of Jesus, but made in some way, then the mystery in not removed, in fact I think it is deepened because then a miraculous account ... is ruled out, and then we have an unheralded genius who created the most convincing image of Jesus ... I think that is a deeper mystery and harder to explain than authenticity."

ACKNOWLEDGEMENTS

The author wants to thank the ShroudScience Group (especially F. Lattarulo, A. Whanger, G. Ballabio and B. Wiech) which, through discussions about CD, allowed the author to clarify some details relative to this very complex hypothesis. A particular thanks is addressed to R. Schneider who, also through private correspondence, offered some very interesting details that help shed light on the problem.

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- From a scientific point of view, the TS image cannot be explained. We are only trying to hypothesize something as close as possible to what we see and CD is able to explain many of the characteristics of the TS image.
- From a religious point of view, the author thinks that the TS is "proof" of the Resurrection that God wanted to give us as both a present and to help people believe in his way. The TS does not impose itself with its facts, but it does propose a lot. Like S. Thomas, also the author and many others wish to touch in order to believe and ... our Lord gave us the opportunity to ’touch’ the TS!
- From a personal point of view, joining scientific with religious aspects, the author thinks (at least until the contrary will be shown) that the Resurrection (probably the dematerialization of the Body) caused as a by-product a burst of energy connected to CD to form the TS body image.

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APPENDIX: Electrochemical-mechanical analogy

Sometimes a complex problem can be easily solved using a proper analogy; here it is considered the electrical-mechanical analogy that poses the following correspondences:

- strength variable: to voltage V corresponds force F or pressure P;
- flow variable: to electrical current I corresponds; velocity v;

A chemical-mechanical analogy is added to represent the effect of the chemical energy due to CD acting on the polysaccharides of the linen fibers: the rupture of the double C=C bond is here represented by nails that damage a smooth surface when hitting on it.

The dotted box of the scheme represented in Figure 5 and that of the plasma-ball experiment of Figure 6 can therefore be transformed in the scheme of Figure A1; Table A1 shows the correspondences.

The stiff open box of Figure A1 represents a capacitor modeled as a chamber with flexible plates in it separating the input on the bottom from the output on the top.

The following characteristics are evidenced.

- A constant gas flow (having velocity v, corresponding to current I) does not have great effect because it does not pass through the elastic wall; the floe only deflects it.

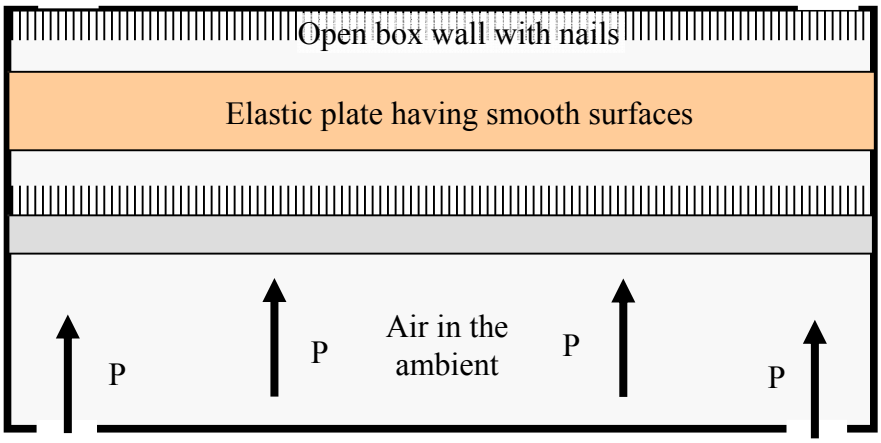

Figure A1. Stiff open box representing the ambient in which the CD happens.
- The TS human body or the ionized gas inside the plasma ball are represented by the lower air in the ambient of the box in which there are high voltages V, and then high mechanical pressures P (force per unit area).
- The Elastic plate having nails on one surface represents the TS human skin or the glass sphere which does not allow the electric current to pass (flow of velocity v) but they allow the action of the voltage V (velocity v); the nails correspond to the chemical energy capable of breaking the polysaccharides C=C bonds of the linen fibers .
- The Elastic plate having smooth surfaces corresponds to the TS or to the linen fabric used in the experiments.
- The box wall with nails represents the CD in ambient external to the TS or external to the experiments in which still there is a voltage which causes a smaller force acting between the wall and the elastic plate (not represented in the scheme).

- A transient pulse or alternating gas flow can transmit the elastic energy (and then the electric one) necessary to make the wall to vibrate.
- An overpressure results in the wall bursting, analogous to dielectric breakdown.
- The typical characteristic of a capacitor to have relatively high electric voltages *V* without transmitting high currents *I* corresponds to the box characteristics to have the possibility to furnish relatively high velocities *v* of the walls due to their flexion, without the possibility to transmit gas pressure *P*.
- The input pressure *P* on the bottom corresponds to the capacitor's voltage *V*.

Table A1: correspondences of the proposed analogy.

Dotted box of the scheme represented in Figure 5	Plasma-ball experiment represented in Figure 6	Analogue system proposed
Human body *(I)*	Ionized gases in the glass sphere of the plasma-ball *(I)*	Air in the ambient *(P)*
Human skin with CD *(V)*	Glass sphere with CD *(V)*	Elastic plate having nails on one surface *(v)*
Turin Shroud *(V')*	Linen fabric *(V')*	Elastic plate having smooth surfaces *(v')*
CD in external ambient (air)	CD in external ambient (air)	Box wall with nails
CD energy capable to break the C=C bonds	CD energy capable to break the C=C bonds	Nails

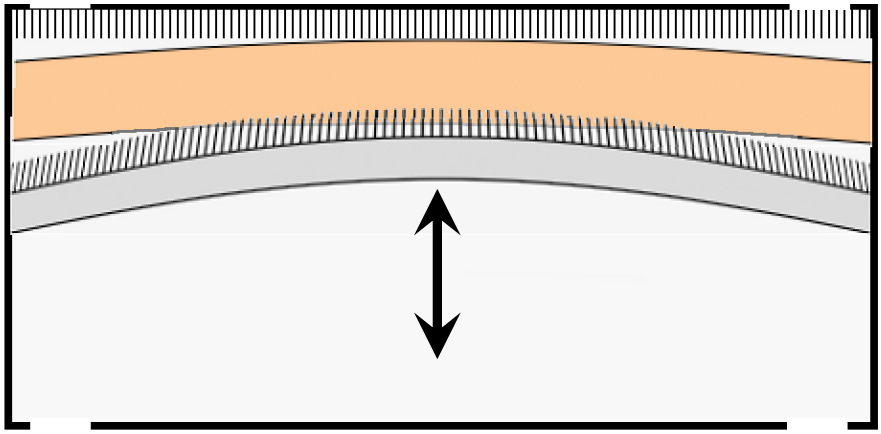

Figure A2. Open stiff box subjected to the influence of the pressure P and of CD: the elastic plate having nails on one surface vibrates under the action of the pressure P corresponding to the voltage V oscillating at high frequency (in the plasma ball case) or corresponding to the impulsive voltage (in the TS case). As a consequence, an "image" forms on the Elastic plate having smooth surfaces which in turn is excited; therefore it hits the Box wall with nails forming a second "image" on its back surface. As in the TS case, both the external surfaces are damaged (C=C bonds broken) but there is no damage along the plate thickness.

After the definition of the electrochemical-mechanical model we can document the corresponding effects of CD on the TS imaging, see Figure A2. In reference to the plasma-ball experiments, we have a high-frequency current *I* corresponding to a high-frequency vibration *v* of the "Elastic plate having nails on one surface" that touches in some points the "Elastic plate having smooth surfaces" which in turn vibrates at a lower velocity *v'*. This motion causes the hitting of this last plate against the box wall. Therefore, both the sides of the "Elastic plate having smooth surfaces" are damaged by the nails that form an "image" on both the surfaces, one more evident on the lower side and one less evident on the opposite side, also in agreement with Fanti and Maggiolo (2004).

This analog model has shown how it is possible to obtain images on a linen sheet using a simple plasma-ball, but in the case of the TS, things are a little different. From the CD experiments some image can be obtained on the linen sheet if it is in the proximity of the glass sphere (not distant more than few millimeters). Instead, in the case of the TS we have images on the linen fabric corresponding to anatomical parts distant up to about 100 mm.

To simulate this characteristic in the analog model, we must increase both the distance among the elastic plates in the box and their distance from the upper wall. To obtain images on the "Elastic plate having smooth surfaces" it is now necessary to drastically increase the wall flexion and then the relative pressure *P* acting on the wall (that corresponds to very high electric voltage *V* of the order of one hundred million volts, see Note 1).

This can be reached by using a very high-frequency vibration or more simply by an impulsive loading (corresponding to a burst of electric energy) that deforms the "Elastic plate having smooth surfaces" in such a way that both the nails of the two adjacent plates are able to damage the smooth surfaces.