The Scientific Foundations of Kirlian Photography as a Medical Diagnostic Tool

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ABSTRACT

An analysis is made of a general gas discharge between dielectric-covered electrodes at small gap separations to reveal all the essential conventional physics involved in light generation. This is extended to the case of one biological electrode and one inert electrode to reveal the key factors involved in light pattern and light intensity generation for a finger pad electrode. A very good correlation between theoretical prediction and experimental observation is found for finger pad electrodes.

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Introduction

A form of high-voltage photography called Kirlian photography has recently triggered considerable interest. First developed by the Soviet scientist Seymon Kirlian, who studied the technique for more than 30 years[(1-3)], psychologists, psychiatrists, biologists and physicists began to look at the technique as a unique way of observing energy states associated with living systems. Some investigators in the U.S. even initiated attempts to use it as a diagnostic tool to monitor the psychological and physiological conditions of their patients.

Early statements pointing to this technique as being able to photograph the "aura," seen heretofore only by clairvoyants, created a flurry of excitement in parapsychology. Even more extravagant claims have been made about the process based upon little first-hand information and some wishful thinking by a few not-so-careful experimenters. On the one hand, the intensity and character of the energy emissions seemed to depend strongly on the mental, emotional and physical health condition of the subject being photographed and this prompted some people to postulate new types of energy emission from the body (called bioplasmic energy by some of the Soviets). On the other hand, the process itself seemed clearly associated with ane electrical discharge and looked, on the surface, like a corona discharge effect. This prompted other people to relegate the entire phenomenon to a category of fairly familiar, and thus uninteresting, electrical discharge effects.

The Soviets claimed to obtain their best results by working in the frequency range 70 kHz - 3 MHz, although others[4,5] have found no significant effects in this range. In fact, no significant difference at 200 kHz was noted between discharge from a finger on a living subject, a finger on a cadaver and a plastic finger replica[4]. Likewise, photographs of live (anesthetized), transected (unanesthetized) and dead salamanders were essentially identical using a 60 Hz pwoer supply[6]. In addition, foreleg amputation resulted in no characteristic luminous effect and the Kirlian photographs were found to merely mirror the moisture content and geometry of the subject. More extensive, yet similar, observations attesting to the importance of tissue moisture content have been provided by Pehek et al.[7]. On the other hand, clear evidence has been provided by Bowerman and Golub[8] that the size of the discharge halo increases about the finger of a subject during transcendental meditation relative to the before or the after states. Statistical evidence has also been given that the discharge halo size and intensity from finger pads is influenced by the emotional state of the subject[9]. From a large body of data, it has also been observed that pathological development in an individual correlates with the presence of a fragmented and patchy halo about the finger pad. In spite of poor technique by a number of investigators and a very complex process, some definite physiological effects have been observed in drug, alcohol and illness Healing studies.

Much data indicates that there is a conventional energy channel functioning in Kirlian photography and it is quite possible that there is an unconventional one functioning as well. However, until the former is quantitatively understood, it will not be possible to separate out and clearly discriminate any unconventional part of the total signal. In this paper we shall focus our attention on the former portion.

General Gas Discharge Analysis

When a voltage pulse train is applied to a small air gap, of spacing d cm and pressure p torr, with dielectric-coated electrodes, an electrical corona begins to develop in the gas space when the gap voltage exceeds the Paschen's law value. Of course, because of the capacitive voltage drop across the dielectrics, the applied voltage, V_a, must be correspondingly larger. The electron flow produces excitation and ionization of the gas molecules, while recombination and deexcitation produces the emission of EM radiation. Air gives a blue emission (from nitrogen), hydrogen gas gives red, helium gives green, neon gives orange, etc., and the gas discharge current deposits charge on the surface of the dielectrics.

If we consider the AC voltage in the pulse train, V_a, to have an amplitude V_m, discharge is initiated shortly after the gap voltage, V_G, exceeds the threhold value, V_{th}, for transition between a Townsend discharge and a normal glow discharge. The degree of overvoltage on the gap will depend upon the value of the statistical time lag, τ, for forming the first avalanche and upon the rate of wall charging $\dot{V}_w$. The charge building up on the dielectric surface lowers V_G compared to V_a and, depending on the relative rates of $\dot{V}_a$ and $\dot{V}_w$ (proportional to current density), V_G eventually drops below the minumum sustain voltage, V_n, after some time τ^* and the discharge ceases. However, V_a is usually still increasing and it eventually reaches a value sufficiently high that V_G again exceeds V_{th} and a new corona discharge develops and more light is generated. This particular discharge event continues until the new collected wall charge is sufficient to drive V_G below V_n and this discharge is again extinguished. This process may repeat itself several times during the rise of V_a to V_m.

At some point during the second quarter cycle, V_a has fallen sufficiently far below the wall voltage, V_w, that V_G again exceeds V_{th} but now in the opposite direction. Once again a discharge is initiated, wall charge of the opposite sign is deposited and light is emitted until V_G falls below V_n and the discharge is extinguished. This process keeps repeating itself in a very regular way so that a large number of time-separated microdischarges occur each cycle. The greater is the ratio V_m/V_{th}, the more microdischarges occur and the greater is the light output generated per cycle. For a D.C. voltage, microdischarges would occur only during the rising portion of the voltage and would then cease thereafter, so the only light generated would be that developed during the initial rise time. For a unipolar A.C. signal, erase voltage discharges may occur during alternate quarter cycles so more light output may be generated. For bipolar A.C. signals, even more erase microdishcarges will occur and much more light output is generated. As one increases the frequency of V_a, the light output per unit time increases up to some limit where self-priming occurs and the space charge in the gas does not have time to develop so that V_n is increase, V_{th} is decreased and the average current and thus light output per microdischarge begins to be greatly reduced. This situation is very analogous to memory margin considerations in A.C. plasma display panels[11].

The above describes the time-separated microdischarges; let us now mention the space-separated microdischarges. Depending on the value of d, the discharge may be uniform over the entire electrode area or it may consist of a close-packed set of parallel microchannels, each of cylindrical shape, extending between the electrodes and ~ 10μ - 100μ in diameter with separation distance ~ 100μ[12]. At small air gaps, one can readily observe the discrete set of microchannels via the generated light pattern. This provides a heterogeneous distribution of wall charge so that, as V_a increases, V_{th} is soon exceeded in the regions between the initial set of discharge channels and a new set of parallel microchannels of discharge develop. Subsequent repetitions of this process spreads a relatively uniform distribution of wall charge on the electrodes (for low frequency V_a) and the time-averaged light emission in the air gap appears to be uniformly distributed. Thus, the time-variation of light output from a unit area of surface is expected to consist of a sequence of main pulses per cycle (depending upon V_a/V_{th}) with each of these composed of a set of micropulses due to the wall charge filling-in process.

The presence of electron-attaching molecules in the gas (like O_2,H_2O,

C_2, etc.) slows down the development of the critical avalanche process for a self-sustaining discharge so that an appreciable overvoltage develops (E_G/p increased where $E_G = dV_a/dx$) and altered light output can occur with respect to both intensity and pattern. Overall, the current generated and the light output developed depends on the magnitudes of 3 important coefficients: (1) α, the Townsend primary ionization coefficient for the gas, (2) γ, the Townsend secondary ionization coefficient for the gas/surface combination and (3) η, the electron attachment coefficient for the gas.

If one of the electrodes was not coated with a dielectric but was bare metal, the process would be qualitatively the same but quantitatively altered. It is the total rate of buildup of wall charge and thus wall voltage that is important to the quantitative picture. If one of the electrodes is flat and the other electrode is curved, the field in the vicinity of the curved surface will increase as the curvature, K, increases so that electrical discharges can occur in the vicinity of these points ($V_{th}(k) < V_{th}(0)$) before they would for planar electrodes ($V_{th}(0)$). In addition, depending upon the electrical polarity of the curved electrode (negative point/positive plane vs. positive point/negative plane), the character of the electrical discharge is uniquely different[13].

Kirlian Discharge Analysis

In Kirlian photography, using a skin electrode and a transparent insulating electrode, all the foregoing processes occur and, to observe physiological effects in the subject associated with inner state changes, physiological changes in the skin electrode must be sufficient to modulate the gas discharge to such a degree that the light output is altered in intensity and/or in pattern. This can occur via one or more of five unique but generally coupled information channels[14]: via changes in the electrical impedance of the skin (affects V_G/V_a ratio), (2) via changes in the skin chemistry with respect to electronegative species (affects η), (3) via changes in the dielectric constant of the skin (affects $\dot{V}_w$); (4) via changes in the surface potential of the skin (affects $\dot{V}_w$) and (5) via changes in the electron emission from the skin (affects γ and τ).

Using the discharge mode of a skin electrode plus a metal electrode covered by a dielectric isolator and a sheet of film, additional factors can enter the process. Electric stress in the air gap can cause the film to flutter allowing a discharge to occur at the back side of the film between the film and the dielectric isolator and/or between the dielectric isolator and the metal electrode. This will generate a very different pattern of colors compared to a front side discharge[12,15]. This condition also appears to correlate with the presence of a high skin dielectric constant (moisture).

If one was to use a different information registration medium like a fluorescent screen sensitive to electrons rather than to light, then one would detect the same, or closely similar, patterns. This occurs because it is the electron and ion microchannel distribution and the microchannel current density that gives rise to the details of the light patterns in the first place.

Correlation with Experimental Data for Finger Pads

Let us model the finger pad as a sphere for simplicity so that we shall be considering a type of point to plane discharge but with a small curvature point (large radius). The air gap width d for a microdischarge channel will increase with radial position, R, on the film away from the region of contact. The value of d^d/dR will depend upon the size of the sphere and the pressure with which it contacts the film. As V_a increases, the microdischarge channels begin to develop first at small R and increase to larger R as V_a increases towards V_m. The larger is V_m for a given Paschen curve, the greater will be the ultimate halo size R^* developed on the film; in fact, R^* should be linear with V_m.

A change in the basic Paschen curve may occur under at least two different circumstances. If electonegative species vaporize from the skin causing η to increase, V_{th} is increased so that, for a given V_m, R^* will be reduced and so will the light intensity. If the electronic surface states in the skin membranes change so that γ increases or decreases, then V_{th} for a self-sustaining discharge decreases or increases, respectively, and R^* will increase or decrease, respectively. Changes in the statistical time lag, τ, for electron emission would be expected to change light intensity rather than R^*. Since during transcendental meditation, the skin electrical impedance is known to increase[16], the voltage drop across the skin during a discharge will decrease the effective V_m across the gap and one might expect R^* to decrease just as it does if an external load resistor is placed in the circuit and its value increased to simulate TM. However, the experimental observation is that R^* increases and this can only be accounted for by a significant increase of γ as a consequence of TM. Such changes in γ with surface treatment of the dielectric has been observed to markedly change the Paschen curve in MgO coated Plasma Display Panels[17].

If the skin has a large electrical impedance at a given frequency, then R^* is reduced for a given V_a, but small internal state changes that alter this impedance can be readily detected. At high frequencies ($w > 10$ kHz), the skin impedance is so low that any changes that do occur cannot modulate the discharge sufficiently to be observed. This is why the high frequency work observed no life factor variations[4,5].

Because of electrical leakage through the skin to neutralize surface charge, the rate of buildup of wall charge, $\dot{V}_w$, can be much reduced over that of an inorganic dielectric of the same permittivity so that the overall light output can be greatly increased at high leakage rates (high skin conductance). Of course, at quite low frequencies ($w \quad 10^2$ Hz), the skin leakage rates may be sufficiently high that there is no observable $\dot{V}_w$ effect which can be modulated by an internal state change. This could account for the lack of distinction in the Marino et al.[6] studies.

As the water content of the skin increases, its dielectric constant increases so that $\dot{V}_w$ decreases, which means that the gap overvoltage will increase and the light output will increase. Since the electric stress-induced film flutter increases as V_G^2, this could explain the correlation with back-side discharge.

Finally, we need to ask why it is that one can develop a patchy finger-pad halo containing regions of no discharge at the relatively high values of V_m/V_{th} in common practice. This would require either an extremely high electrical impedance for that region of skin or an extremely low value of γ. These would have to be considered as pathological conditions.

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