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Feasibility Study of a Direct Electron Recording System

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EXPERIMENTAL HYPOTHESES

General Collateral Hypothesis

Spatial and/or temporal electron image relationships can be permanently recorded, by the direct electron exposure of an energy sensitive system, through the dependency of spatial physical changes in the system, brought about by chemical changes initiated by spatial and/or temporal changes in the electron density.

Refined Collateral Hypothesis

Spatial and/or temporal electron image relationships can be permanently and directly recorded, by the direct electron exposure of a solid state system, in an oxidized state, so that the impinging electrons will promote a reduction of said system with the appearance or disappearance of paramagnetic resonance, thus creating a visual difference between the initial oxidized state and the reduced state; also, that this difference will correspond, in some manner, to the original electron image relationship.

Substansive Hypothesis

The above refined, collateral hypothesis is true and is feasible in terms of application to:

A. recording electron patterns, presently done primarily by scanning of a kinetic-luminance energy transducer and photographing the latter.

B. continous data computer storage by electron write.

C. general photographic application through the utilization of light-electron transducers such as photocathode surfaces.

Operational Hypothesis

Electrons are emitted, thermionically, from a tungsten filament and may be accelerated under the influence of a suitable electrostatic field.

The accelerated electrons may be exited from the vacuum condition, necessary for acceleration, by kinetic passage through a thin mica window, with a slight increase in energy distribution and a slight decrease in the mean kinetic energy.

The exited electrons will introduce an excited state to a solid state target thus initiating a reduction reaction that; 1. may continue on a self-sustaining basis through the release of the energy of formation; 2. may be promoted on an incident energy excess principle; 3. may be promoted under the influence of an electrostatic field.

The reduced state of the solid state system will be visually differentiable from the initial oxidized state and that said visual difference may be quantitatively expressed by non-visual densitometric means.

Finally, the visual change should be permanent, be completed under a dry enviroment over a short interval of time and constitute some dependency on the electron parameters which comprise the factors of this experiment.

PROBLEM ANALYSIS

Let:

E ≡ electrons emitted, accelerated and exited
S_o ≡ oxidized state of the solid state system
S_1 ≡ reduced state of the solid state system
V ≡ visual difference between states S_o and S_1.

Through apparatus design, construction and calibration, it must be asserted that E is true. The selection of the specific solid state system will be made so that S_o denotes the sample target in the higher oxidized state, and S_1 denotes the same target in a lower oxidization state with a visual difference, V, between the two states. Thus, the selection of the system will guarentee the following biconditional implications:

$$V \leftrightarrow S_1 \quad (1)$$
$$V \leftrightarrow \sim S_o \quad (2).$$

In accordance with the operational hypothesis, the energy, in the form of accelerated electrons and incident upon the solid state system, will produce a reduced state in the target system. Thus,

$$E \cdot S_o \longrightarrow S_1 \quad (3).$$

These proposistions represent the truths as stated in the operational hypothesis. Converting the truth proposistions into Boolean form:

$$S_1 \left[E \cdot S_o\right] = S_1 \quad (4)$$

$$S_1 = V \quad (5)$$

$$S_o = (\sim V) \quad (6).$$

Under the operational hypothesis, the reduced state of the solid state system appears and is visually (and densitometrically) different from the oxidized

state. Is it valid to state that the occurance of response, V, is the result of electron exposure?

The proposistion under test is:

$$V \rightarrow E \cdot S_o \quad (7)$$

converted to the Boolean form:

$$[E \cdot S_o] \cdot V = V \quad (8)$$

from equation (6):

$$(\sim S_o) = V$$

substituting in equation (8)

$$[E \cdot S_o] \cdot (\sim S_o) = V$$

but

$$S_o \cdot (\sim S_o) = 0 \text{ value of truth,}$$

therefore:

$$[E \cdot S_o] \cdot V = 0 \ .$$

Thus, it is a logical fallacy to say that a detectable change in state is a consequence of electron exposure. The experimental design will have to be such as to render the proposistion (7) biconditional; ie.

$$V \leftrightarrow E \cdot S_o \ .$$

This may be done through the utilization of the proper control factors.

A solid state system will be feasible for application or further study if:

A. it shows a response, V, on one or more of the main factors of investigation. Also:
   1. this response shall be detectable by densitometric means within the visible spectrum, and:
      a. it shall be possible to obtain a spectral density difference $\Delta D_s \geq |0.30|$ at the maximum absorbtion peak for that system, or:
      b. a change, $\Delta D_s \geq |0.30|$ in any other resonance band within the region

of visible wavelengths (dependence upon Beer's law is not implied).

2. The change, V, does not take place upon exposure of the system to ambient electromagnetic radiation (see condition D to follow).
3. The changes, V, implies exposure to electrons.

B. No post exposure chemical treatment, wet or dry, is necessary to amplify a latent change in the system; ie. V occurs to completion or equilibrium under one or more of the principles outlined under the operational hypothesis.

C. The change, V, occurs for a maximum exposure energy of 30 KeV.

D. A spectral density change $\Delta D_s > |0.03|$ does not occur (this density to be measured in a like manner to the electron response density) when the initial system is exposed to electromagnetic energy, at a wavelength equal to that of maximum adsorbtance of the sample in the higher oxidization state. The exposure conditions to this wavelength will be 1,000 times the maximum electron exposure (joules/cm^2).

Possible response variables that will not be considered at this time are: electron resolution and scattering, stability and permanance of the system (long term) in either state, absolute system reaction times, densitometric response of the system of high energy electromagnetic radiation (short uv, X-rays) and also long term thermal effects. Although these will not be investigated, realization of the presence of these variables will influence the design of experimental controls.

FACTORS

The experimental design will be constructed around three variable, main factors. The levels, will be controlled, in magnitude and/or duration, by apparatus currently being constructed.

Acceleration Potential

The acceleration potential is applied to the accelerator tube through a linear voltage divider network of total resistance 315.9×10^6 ohms. The acceleration potential will be applied to the end of the network, opposite the gun. The ground point will be at the emission source and will be an earth ground.

High voltage will be supplied to this network by a high voltage supply featuring variable regulation and output from 0 to 30,000 volts at a current not exceeding 1 ma. This is an oscillator type supply utilizing a single high voltage step up coil. The high voltage (AC) thus obtained is half-wave rectified and filtered before it is supplied to the divider network as positive DC high voltage.

Exposure Time

Determined by grid cut-off, the exposure time is controlled by a pulsed grid or gating supply. This supplies an inverted square wave, of variable negative voltage and duty cycle, in either a monostable or astable mode.

Target Current

The magnitude of this factor is not presently known. This factor will be dependent upon the other two factors of cut-off volatge, ie. exposure time, and acceleration potential. The main control of this factor is in the power supplied to the tungsten filament which is being used as a thermionic emission source. The target current may be determined only by end to end calibration of the entire working system.

Factor Combinations

The factors thus far listed may be mathematically manipulated at their respective levels to give values for:

single electron exposure energy in joules
relativistic electron mass in kgm.
relativistic electron velocity in m./sec.
relativistic electron momentum in kgm.m./sec.
electron wavelength in angstoms
electron wave number
power density at target in watts/ sq. cm.
number of electron directed into the target
electron exposure or energy density in j./sq.cm.

It is necessary to realize the presence of two other factors which are not primary factors under investigation , but may influence the experimental results. These are:

exposure of the solid state system to quanta of electromagnetic energy,
exposure of the system to an electric field without exposure to accelerated electrons.

The first factor as listed, enters into the question of system feasibility. The second may be investigated in a seperate experiment or it may be randomized within the primary factors.

Implicit in the above statements are the control conditions necessary to this experiment, so that a change in density in the target sample may be related to the electron exposure and not to uncontrolled factors producing the same response.

EXPERIMENTAL OBJECTIVES:

To determine the densitometric effects (within the range of the visible spectrum), of a direct exposure by electrons accelerated to a maximum energy of 30 KeV, on a selected solid state metallic oxide system.*

To determine the feasibility of the utilization, of a solid state system that produces a densitometric response to said exposure, as a permanent recording media for phenomena which beams of accelerated electrons are; 1. used to monitor, 2. because of the nature of a proposed solid state system, may be used to monitor.

CONDITIONS

These objectives are to be fulfilled under the limiting conditions listed under the operational hypothesis and control conditions therein implied. The sole operating factors shall be electron energy, target current , exposure time and mathematical extensions thereof.

In this preliminary search, rejection of a responsive system on the basis of not being feasible, is of greater danger than the acceptance of a system whose response is not due entirely to electron exposure. The psychological effects of refutation of a system may over-shadow any positive aspects of such a system that may be brought to light through further investigation. Thus the permissible risk of acceptance may be large, whereas the risk of rejection, will of necessity , be small.

*specific, proposed systems are listed in appendix A.

The null hypothesis in all experiments shall be that of no change in the system, when exposed. The rejection risk, in this case, must be large and shall arbitrarily set at $\alpha = 0.10$

The response variable shall be limited to densitometric measurements on the target sample. These measurements may be spectral in nature, within the visible electromagnetic spectrum.

APPENDIX A

Metallic Oxide, Solid State Systems*

Oxide	Color	Reduced State	Color	H (kcal)
CeO_2	white	CeO	black	
Cr_2O_3	green	CrO	black	128.2
MoO_3	white	MoO_2	gray	50.3
Pb_2O_3	yellow	Pb_2O	black	14.1
SnO_2	white	SnO	black	69.8
Ta_2O_5	white	Ta_2O_4	black	255
TiO_2	white	TiO	black	192.0
V_2O_5	yellow	V_2O_4	blue	29.0
WO_3	yellow	WO_2	brown	64.6
BaO_2	black	BaO	white	18.60
BiO_5	black	Bi_2O_3	yellow	18.60
Co_3O_4	black	CoO	green	152.8
CuO	black	Cu_2O	red	74.84
Mn_2O_3	black	MnO	green	266.7
Ni_2O_3	black	NiO	green	140.1
Rb_2O_3	black	Rb_2O	yellow	43
Tl_2O_3	brown	Tl_2O	yellow	78.1
TeO_3	gray	TeO_2	white	74.85

*Robillard;Jean,J., "New Approaches in Photography," Photographic Science and Engineering, (January-February,1964), p.30.

Experimental Design 1

Operational Hypothesis:

Equipment operation asertained under calibration will be true during target bombardment.

Response Variable:

$D_\lambda = D_{2\lambda} - D_{1\lambda}$ where: $D_{1\lambda}$ = pre-bombardment spectral density
$D_{2\lambda}$ = post-bombardment spectral density
λ = for CCl, 619-630mu.

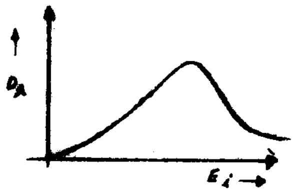
Factors: Bombarding particle; electron

Electron Energy:

Levels: $E_1, E_2, E_3, \ldots, E_n$
where $n = 6$

Effect: $D = f(E_i)$
and
$f'(E_i) = 0$ in the interval
$0 \leq E_i \leq E_n$

expected curve shape;



Electrostatic field across target sample, parallel but opposite to the acceleration field.

Levels: $B_1 = 0$
$B_2 = (\frac{V_1}{1}, 180^\circ)$

where: V_1 = acceleration voltage associated with E_1
1 = support target thickness

acceleration field vector origin at target and direction 0°.

Constants:

N = total number of electrons striking sample

T = electron exposure time

T_r = time sample is exposed to electrostatic field B

1 = total target support thickness

T_d = target system density

attempt will be made to keep exposure of the target system to electromagnetic radiation, at a minimum , after electron exposure.

Composition: styrene-butadiene copolymer (Pliolite S·7, Goodyear) solution weight; 50 grams.
dry copolymer weight; 43.9 grams = W_{cp}

KBr .20 mole 23.8 grams = T_w

$$T_d = \frac{T_w}{W_{cp}} = 0.00456$$

Form: Condensed phase system of KBr crystals dispersed in a copolymer continuous phase.

Reaction Substansive Hypothesis:

1. Bombardment of target system with accelerated electrons will produce free electrons and negative ion vacancies in the KBr crystal phase. Trapping of a free electron in a negative ion vacancy will give rise to F centers. Presence of F centers will be noted by an increase in optical absorption with a peak at 610-630 mu.[a]

2. Presence of an electrostatic field during bombardment will promote seperation of the F center and a free negative ion thus retarding the bleaching of the F center by electromagnetic radiation in the F band absorption peak.

[a] Dekker Adrianus J. Solid State Physics. Englewood Cliffs, N.J. Prentice-Hall, Inc. (1957). pp366-395.

Experimental Design No. 1-CCL

Math model:

$$\overline{X} = \mu + E_h + B_l + (E \times B)_{hl} + e_{k(hl)}$$

Analysis: Effect E_h Method: Std. Anova

H_{o_1}: $\sigma_{e_h}^2 = 0$

H_1: $\sigma_h^2 \neq 0$

B_l

H_{o_2}: $\sigma_l^2 = 0$

H_{1_2}: $\sigma_l^2 \neq 0$

$(E \times B)_{hl}$

H_{o_3}: $\sigma_{hl}^2 = 0$

H_{1_3}: $\sigma_{hl}^2 \neq 0$

Expected Results: H_1, H_2 Sig. @ $F_{\alpha 0.50, \nu_1, \nu_2}$

H_{o_3} Not Sig. @ $F_{\alpha 0.50, \nu_1, \nu_2}$

Constants	Electron Energy / Target Field	E_1	E_2	E_3	E_4	E_5	E_6
N T T_r l T_d	B_1	$e_1 b_1 r_1$	$e_2 b_1 r_1$	$e_3 b_1 r_1$	$e_4 b_1 r_1$	$e_5 b_1 r_1$	$e_6 b_1 r_1$
		$e_1 b_1 r_2$	$e_2 b_1 r_2$	$e_3 b_1 r_2$	$e_4 b_1 r_2$	$e_5 b_1 r_2$	$e_6 b_1 r_2$
	B_2	$e_1 b_2 r_1$	$e_2 b_2 r_1$	$e_3 b_2 r_1$	$e_4 b_2 r_1$	$e_5 b_2 r_1$	$e_6 b_2 r_1$
		$e_1 b_2 r_2$	$e_2 b_2 r_2$	$e_3 b_2 r_2$	$e_4 b_2 r_2$	$e_5 b_2 r_2$	$e_6 b_2 r_2$