INFORMATION STORAGE AND IMAGE REPROGRAPHY ON LOW VOLTAGE, CRYSTALLINE PHOTOCONDUCTORS

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Abstract: The storage of digital information by optical means on low voltage, anisotrophic photoconductors leads to high packing densities through the utilization of differential voltage/density levels and acutance of edges; both features are equally suitable for reproducing high resolution images of wide dynamic range both in black and white as well as color.

Discussion

With the introduction of low voltage, high charge density electrophotographic materials it has become possible to create new applications for xerographic techniques both for digital and analog imagery products. These applications are characterized through sub-micron resolution capability and high edge acutance.

To maintain resolution in the 5,000 Angstrom - 10,000 Angstrom domain with meaningful contrast, it is necessary to have a photoconductor which -- while featuring exceptionally high lateral surface resistivity -- allows a selective, easy discharge to zero volts of the initially deposited charges. This results in a latent electron image featuring sharp voltage increments above zero background which, when toned, produce optical density levels which are clearly machine readable as well as visually recognizable (Figure 1).

Modern liquid toners can discern voltages of 1/4 volt with particles of 1000 Angstrom size and thus permit the reproduction of five volt increments with great ease. The accurate rendition of the respective densities, for example eight levels spread over two bits, extends the binary storage capability in a vertical direction thus increasing the information density dramatically.

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A typical low voltage film such as KC-Film consists of crystallites of approximately 500 Angstrom diameter and 5000 Angstrom height. Considering each crystallite an information storage element, we calculate

$$n = \left(\frac{10^8}{500}\right)^2 = 4 \cdot 10^{10} \text{ crystallites/cm}^2 \qquad (1)$$

The charge (q) per crystallite with 10V/1000 Angstrom voltage acceptance and $K = 1 \cdot 6 \times 10^{19}$

$$q = \frac{Q}{n} = \frac{C \cdot V \cdot k}{n} = 250 \text{ electrons/crystallite} \qquad (2)$$

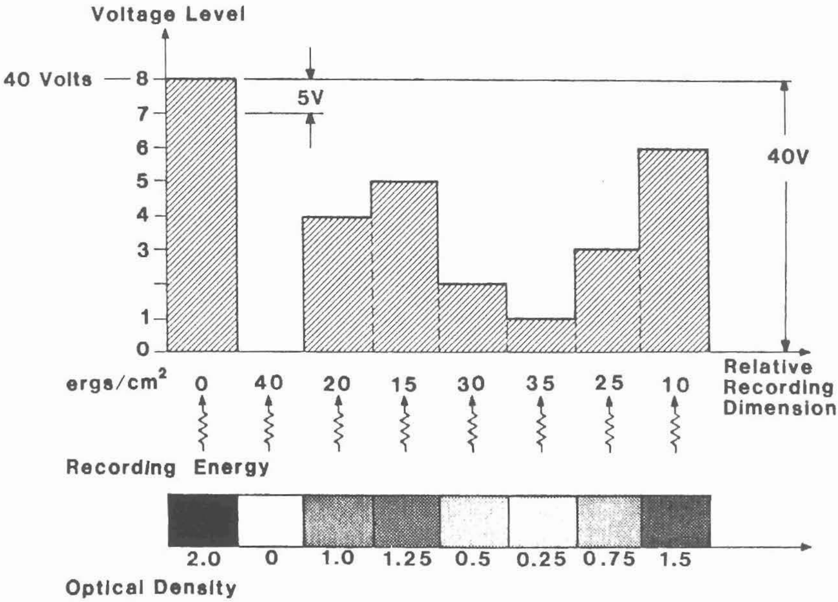


Figure 1. Interrelation of voltage, density, and recording energy

The theoretical information storage capacity, ignoring for the moment the problem of how to "find" the information again, yields the product of $n \cdot q$

$$i_{max} = 4 \cdot 10^{10} \cdot 250 = 10^{13} \text{ electrons/cm}^2 \qquad (3)$$

If we are not counting electrons but are looking for storage of optical information, then 10 million bytes/cm^2 should be achievable with suitable techniques.

The surface of KC-Film differs chemically from the bulk through deliberate oxidation in the manufacturing process. This feature, apart from the crystalline, highly oriented structure, Figure 2, plays three essential roles:

a. it provides the traps for storing charge electrons;

b. it renders the surface very resistive ($\sim 10^{20}\ \Omega/\square$) and thus prohibits lateral charge migration;

c. it makes the surface exceptionally abrasion resistant.

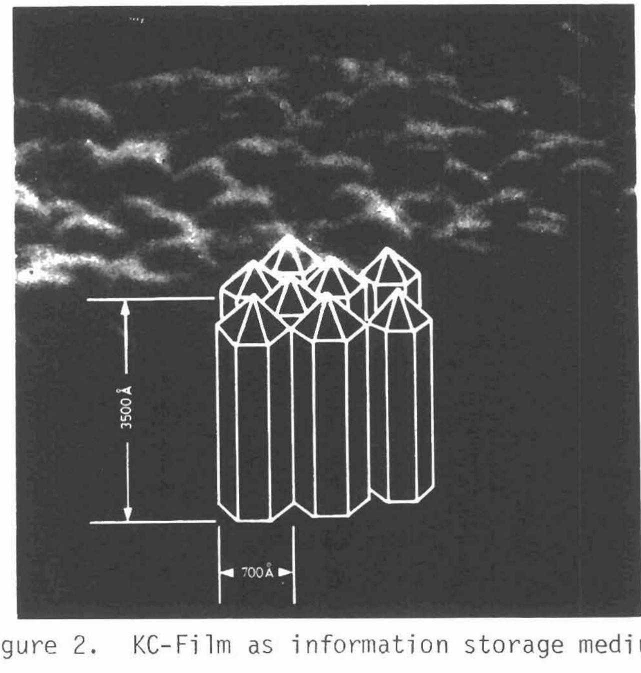
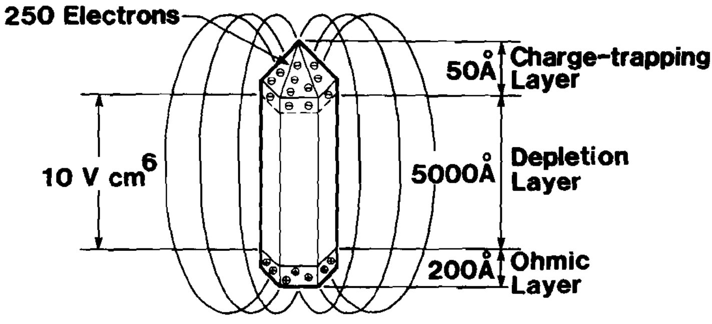


Figure 2. KC-Film as information storage medium

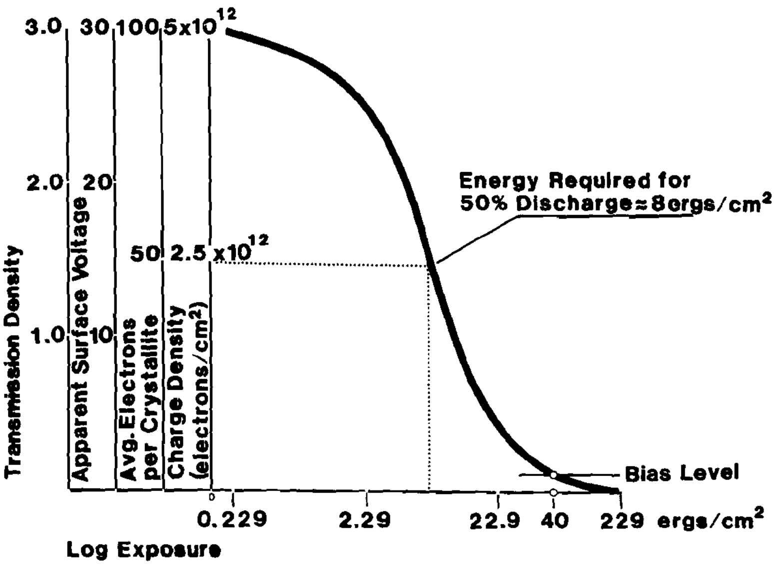
The individual crystallites, Figure 3, act as independent field domains due to the aggregation of charges near the crystal tip. The field lines close along the boundaries between the crystallites. The bulk between the surface and the conductive base is totally depleted (Shockley depletion layer) when the surface is fully charged.



The Crystallite as discrete information storage element

Figure 3. The crystallite as discrete information storage element

The relationship of exposure, voltage, and Coulombic charge can best be displayed in a multi-coordinate diagram, Figure 4. Here the partial linearity of the process becomes evident. Furthermore, the effect of electrical bias during "information conversion via toning" becomes obvious: the exposure can be shifted more than a decade and light sensitivities of ASA 50 - 100 can be achieved with suitable toners.



Voltage/Exposure relationship of KC-101 material

Figure 4. Voltage/exposure relationship of KC-101 material

Neither the toner nor the photoconductor care much whether visually unintelligible dot patterns are recorded for digital memories, or whether aesthetically arranged dot patterns are produced to represent an analog, meaningful image to the human observer. Indeed, resolution, contrast, and acutance can be identical in both cases, Figures 5 and 6.

Figure 5. KCY transfer image with approximately 120 steps of grey

The ability to produce high quality imagery has lead to the digital reproduction of color images of wide tonal range, Figure 7.

Digital reprographic techniques permit precise control over gama, Dmax, and highlights while carrying colorimetric values in the data stream from beginning to end.

The degree of predictability and accuracy makes low voltage, crystalline, high charge density films ideally suitable for producing machine-readable and human-readable patterns.

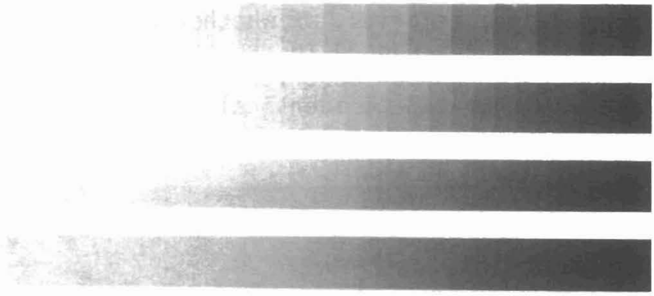


Figure 6. Half-tone grey scale recorded
on KC-Film with argon laser

Figure 7. Digitally recorded
gravure simulated image

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