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Introduction to Photographic Science

Course Outline

1. Basic Sensitometry

- Characteristic curve and components
- Interpretation of contrast
- Derivation of film speed

2. Film Emulsion

- Gelatin
- Silver halides
- Manufacturing process

3. Latent Image

- Light absorption
- Image nuclei
- Crystal imperfections
- Photoconductivity
- Gurney-Mott Theory
- Modifications of the G-M theory
- Spectral sensitization

4. Exposure Effects

- Reciprocity
- Clayden
- Solarization
- Hershel

5. Development Mechanisms

- Energy of Activation
- Catalytic-electrode theories
- Initiation of development
- Charge effect

6. Development Reactions

- Classification
- Ionization
- Reaction Equations
- Developer components

7. Development Kinetics

- Development rates
- Concentration
- Alkali
- Sulfite
- Temperature
- Synergism

8. Fixation

- Solution product
- Reaction equations
- Rate
- pH

9. Image Structure (Optional)

- Graininess and Granularity
- Resolution and Acutance
- MTF

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Process Reactions

1. Production of silver bromide:

$AgNO_3 + KBr \Rightarrow AgBr + KNO_3$ Manufacture

2. Unexposed negative emulsion:

AgBr and gelatine (ratio 40% / 60%) Pre-exposure

3. Effect of light on silver bromide:

$Br^- + h\upsilon \Rightarrow Br + e$
$Ag^+ + e \Rightarrow Ag$ Exposure

4. The latent image:

Ag^+Br^- **with Ag specks** Pre-development

5. Effect of the developing agent (hydoquinone) on silver bromide grains containing latent image silver specks.
Production of image silver:

$C_6H_6O_2 \Rightarrow C_6H_6O_2^=$ Ionization

$C_6H_6O_2^= + 2Ag^+ \Rightarrow C_6H_6O_2 + 2Ag + 2H^+$ Development

6. Solvent action of the thiosulfate ion on the silver bromide.

$Ag^+Br^- + Na_2S_2O_3 \Rightarrow NaAgS_2O_3 + NaBr$
$NaAgS_2O_3 + Na_2S_2O_3 \Rightarrow Na_3Ag(S_2O_3)_2$ Fixation

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<u>Electromagnetic Energy</u>

General Reaction:

$Br^- + h\upsilon \Rightarrow Br + e$
$Ag^+ + e \Rightarrow Ag$

Consider: The term 'hυ' specifies the energy of light quantum (or photon).

$\phi = h\upsilon$ where h = Planck's constant (6.63×10^{-34} Joules-sec)
υ = frequency of light
ϕ = quantum energy

$\lambda = c/\upsilon$ where c = speed of light (3×10^8 m/sec)
λ = wavelength of light

Combining the two equations by the common term 'υ' where:

$\upsilon = \phi/h$
and
$\upsilon = c/\lambda$

we then have:

$\phi/h = c/\lambda$
or
$\phi = hc/\lambda$

The above equation shows that the energy of the light quantum is inversely proportional to the wavelength (note that c and h are constants). Therefore, as the wavelength of light <u>increases</u> the energy of the light quantum <u>decreases</u>.

Example:

Calculate the amount of energy in a mercury vapor light source and determine if it is sufficient to produce a photographic effect. The wavelength of the mercury vapor light is 4.4×10^{-7} m.

We are interested in determining ϕ, therefore:

$\phi = hc/\lambda$ where:

$h = 6.63 \times 10^{-34}$ Joules-sec
$c = 3 \times 10^{8}$ m/sec
$\lambda = 4.4 \times 10^{-7}$ m

$$\phi = \frac{(6.63 \times 10^{-34})(3 \times 10^{8})}{4.4 \times 10^{-7}} \qquad \frac{(\text{Joules-sec})(\text{m/sec})}{\text{m}}$$

$\phi = 4.52 \times 10^{-19}$ Joules

If 1.602×10^{-19} Joules = 1eV (electron-volt) then

$\phi = 2.79$ eV

The critical energy required to excite a silver bromide electron is 2.5 eV, thus mercury vapor light sources provide sufficient energy to produce a photographic effect.

Table showing eV quantum energy associated with wavelength λ (in nanometers)

4.14	300	1.94	640	1.27	980
3.88	320	1.88	660	1.24	1000
3.65	340	1.83	680	1.22	1020
3.45	360	1.77	700	1.19	1040
3.27	380	1.72	720	1.17	1060
3.10	400	1.68	740	1.15	1080
2.96	420	1.63	760	1.13	1100
2.82	440	1.59	780	1.11	1120
2.70	460	1.55	800	1.09	1140
2.59	480	1.51	820	1.07	1160
2.48	500	1.48	840	1.05	1180
2.39	520	1.44	860	1.03	1200
2.30	540	1.41	880	1.02	1220
2.22	560	1.38	900	1.00	1240
2.14	580	1.35	920	0.99	1260
2.07	600	1.32	940	0.97	1280
2.00	620	1.29	960	0.96	1300

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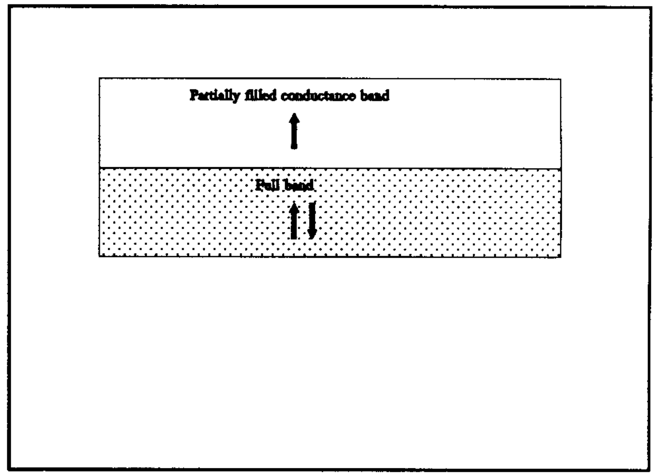
Conductance

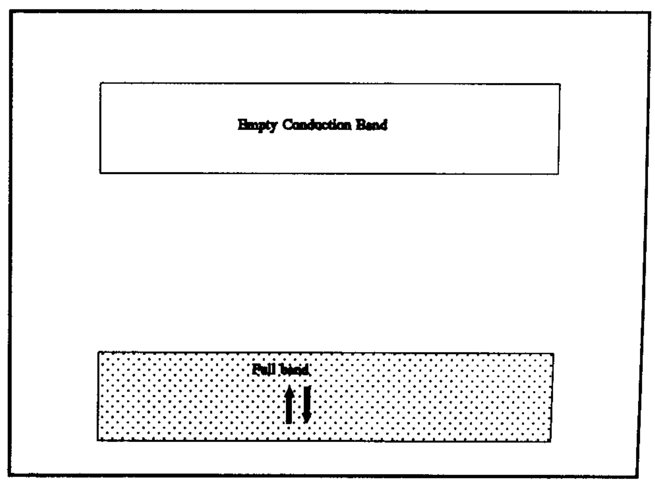
1. A conductor

A metal has its conduction band only partially filled. The elctrons which occupy the band are free to move around the band structure and are therefore set in motion if a potential difference is applied to the metal. This is electricity. Conducting metals include iron, copper, gold, etc.

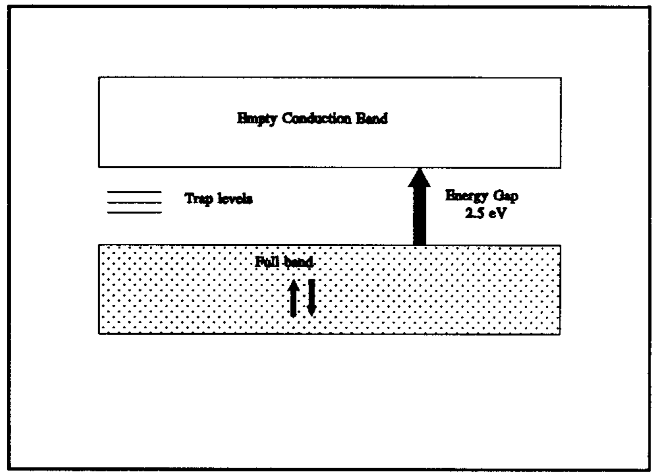


2. An insulator

An insulator is characterized by a large energy gap between the conduction band and the filled valence band. With no free electrons in the conduction band, any potential applied to such a material would produce no electron movement thus no current. Materials which display these characteristics are asbestos, wood, etc.



3 Semi-conductors



Semi-conductors are essentially a cross between conductors and insulators. These materials are normally insulators in that a significant energy gap exists between the empty conduction band and the filled valence band. The material may gain enough energy through light quanta or through thermal sources to **excite** an electron or to raise it to a higher energy level. If enough energy is gained, then the electron may be raised to the conduction band energy level where its mobility enables it to migrate freely. These mobile electrons would be the essence of electricity if a potential difference would be applied.

The silver bromide crystal displays these characteristics. It is normally an insulator except when 2.5 eV is absorbed by the crystal in which case it becomes a conductor and enables the free electrons to migrate throughout the structure.

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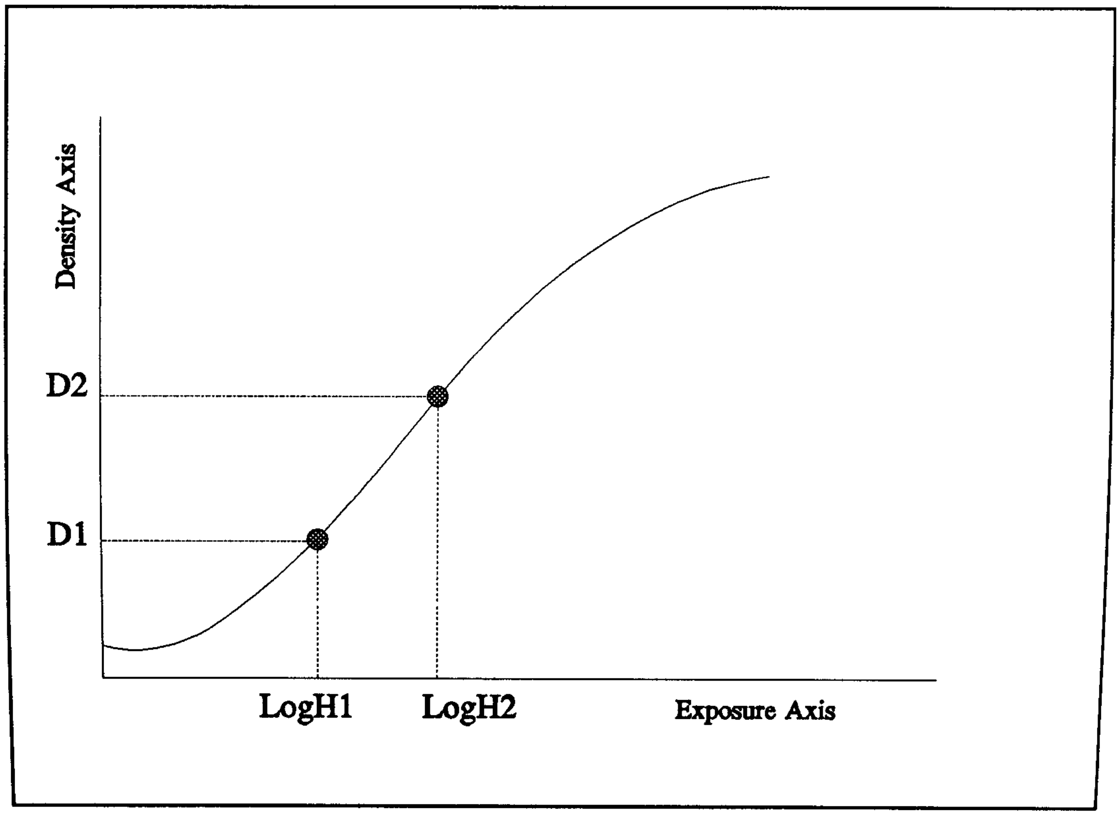
Sensitometry: Deriving Gamma and Film Speed

1. Gamma

Gamma is an indicator of the photographic contrast of the processed film material. It is derived by calculating the slope between two points on the straight line portion of the characteristic curve.



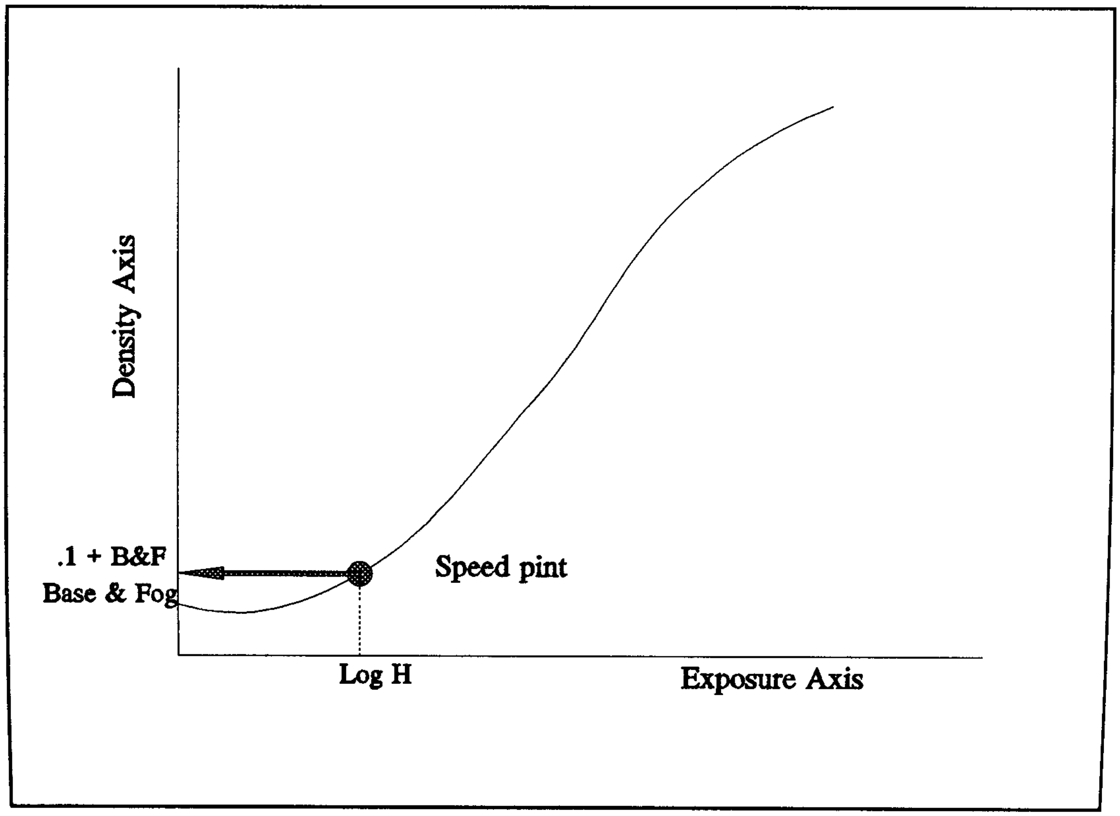
$$\text{Gamma } (\gamma) = \frac{D_2 - D_1}{\text{LogH}_2 - \text{LogH}_1}$$

2. Film Speed

Film speed as measure by the ISO standard is also derived from the characteristic curve. The variables which must be known are:

a) the base plus fog density value: this is the density value of a clear section of processed film.

b) the speed point: this value is derived by adding the base plus fog value to .1 and locating the sum value on the characteristic curve. The LogH value is then determined on the Exposure axis and is used in the calculation.



$$\text{ISO Speed} = \frac{.8}{\text{Log } H_{.1+BF}}$$

Note: You must convert the Log H value to an arithmetic number before using the equation. For example, a Log H value of -2.37 converts to approximately .0043. The log of .37 (the mantissa) is .43 and the -2 (characteristic) signifies a displacement of the decimal point 2 place to the left.

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2. James and Higgins
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3. Katz
   Photographic Analysis

Quantum Mechanics and the Latent Image

1. Mott and Gurney
   Electronic Processes in Ionic Crystals

2. Seitz
   The Physics of Metals

Photographic Chemistry

1. Mason
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2. Eaton
   Photographic Chemistry

Professional Journals

1. Society for Photographic Science and Technology (U.S. based)

2. Journal of Photographic Science (U.K. based)