Particle Transport, Deposition, and Removal in Xerography

NSF CRCD Project Lecture

November 29, 2004

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Wilson Center for Research & Technology

Xerox Corporation

Webster, NY

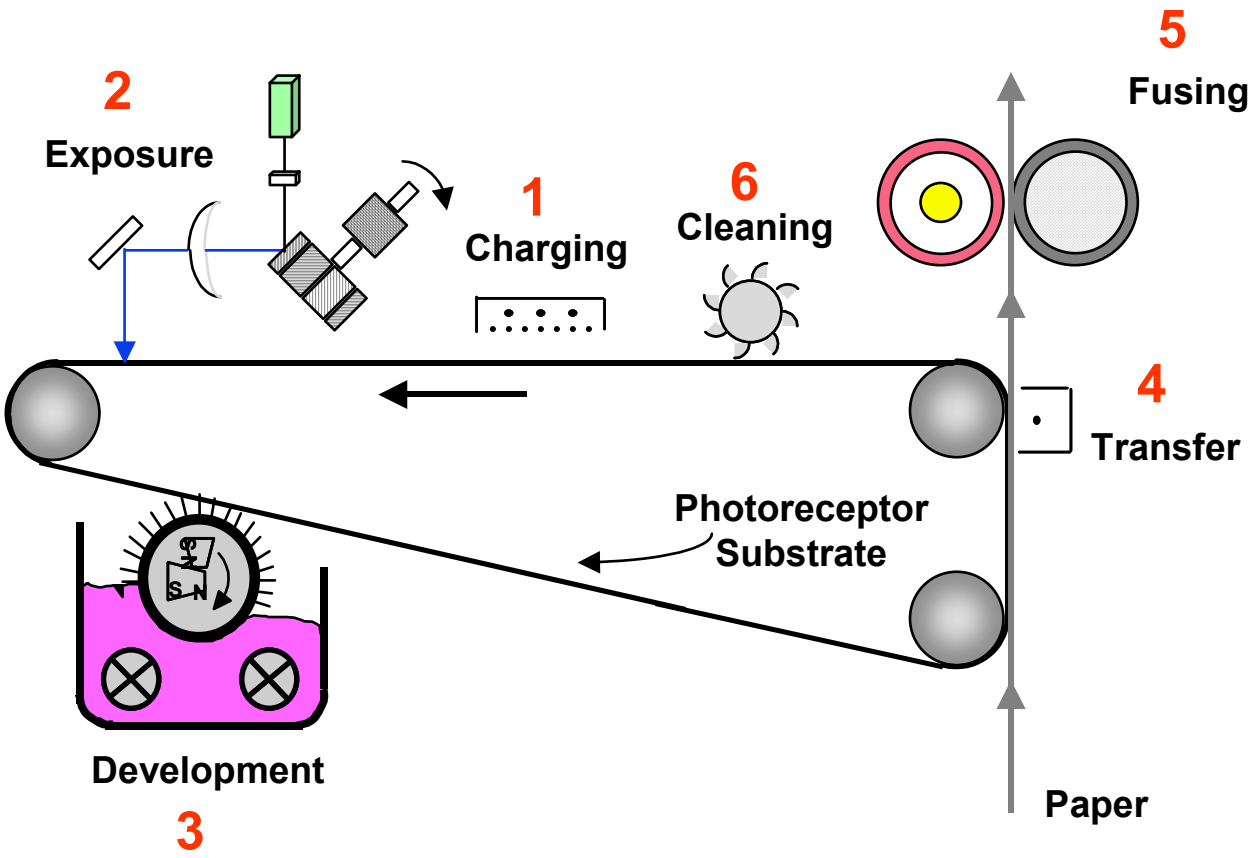
http://chester.xerox.com/innovation/wcrt.html

Outline of the Lecture

- **General Overview of Xerography**
- **Transport, Adhesion/Cohesion and Removal of Fine Particles (Toner) in Xerography**
  Measuring Toner Charge --- Cage Blowoff, Charge Spectrograph
  Electrostatic Adhesion, Detachment of Toner Particles
  Measuring Toner Adhesion --- Atomic Force Microscopy (AFM), Centrifuge Detachment, Electric Field Detachment
  Measuring Cohesion --- Fluidized Bed
- **Modeling of Electrostatics in Subsystems (in MAE Seminar 4:00-5:00pm today)**
- **Q&A**

Acknowledgements:
S. Chang, C. Duke, D. Hays
N. Goodman, H. Mizes

Xerographic Process



C. Duke, J. Noolandi, T. Thieret, "The surface science of xerography," *Surface Science*, 500, p. 1005, (2002)

Xerox Phaser 7700 Color Desktop Laser Printer

22 prints/min, full-color

Xerography is a versatile technology that scales from desktop, to office, to production machines; black-and-white, hightlight color, and full color.

DocuColor 40 Pro Color Office Multifunction Machine

40 prints/min, full-color

DocuTech 6180 Production Publisher

180 prints/min
Black-and-White

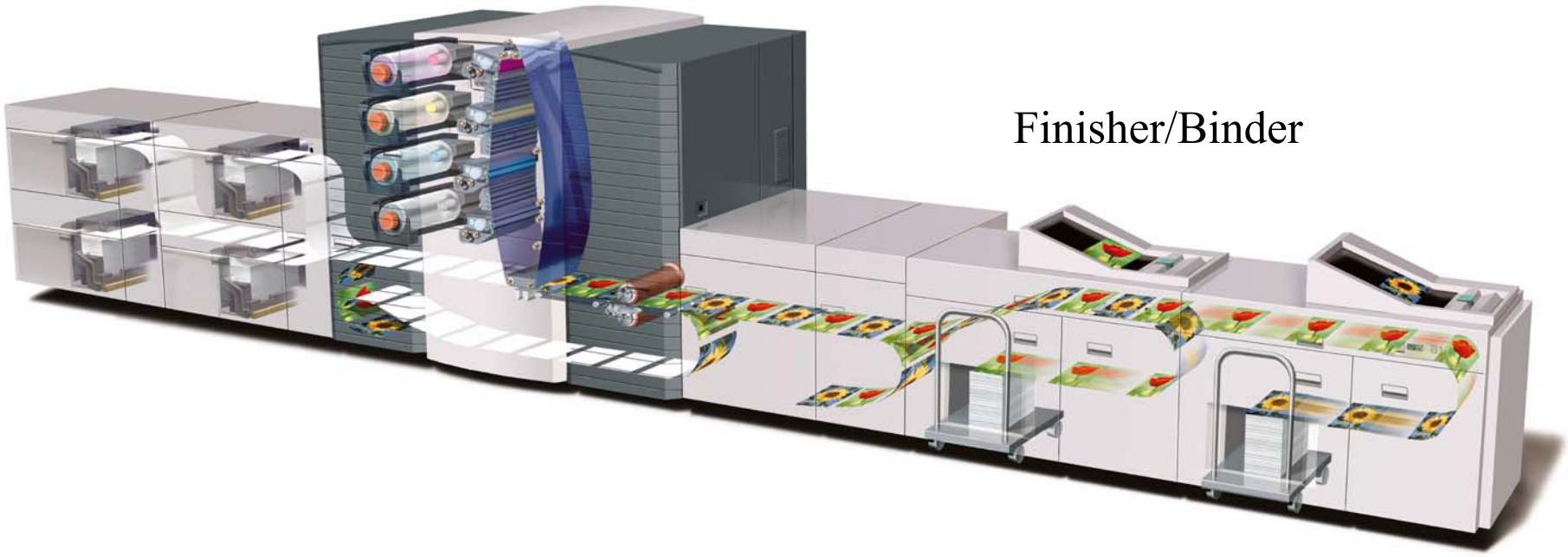
DocuColor iGen3 Digital Production Color Press

100 prints/min, full-color

iGen3

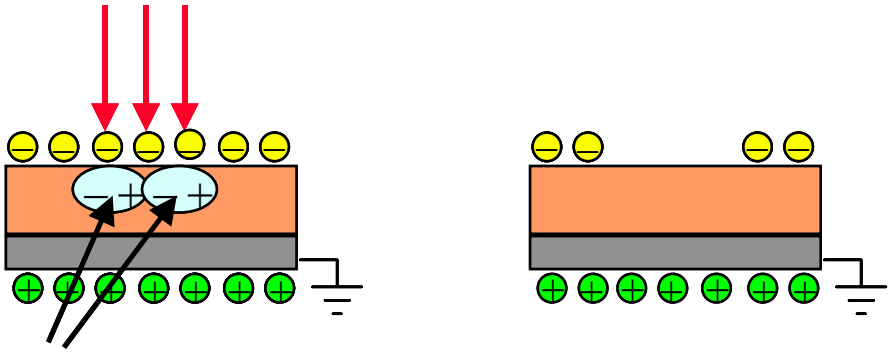
Xerographic Unit

Finisher/Binder

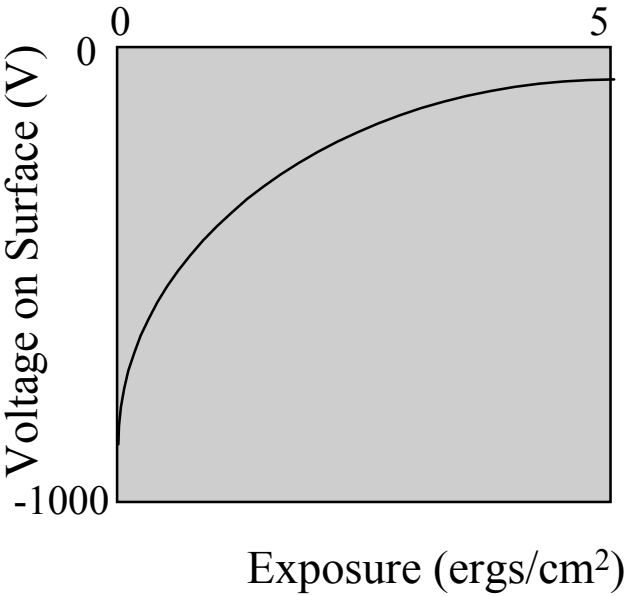


Photoreceptor

- A semiconductor whose conductivity is a strong function of light exposure.

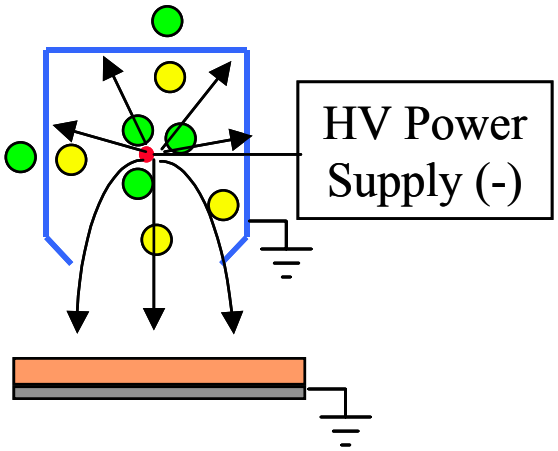


Electron/hole pairs

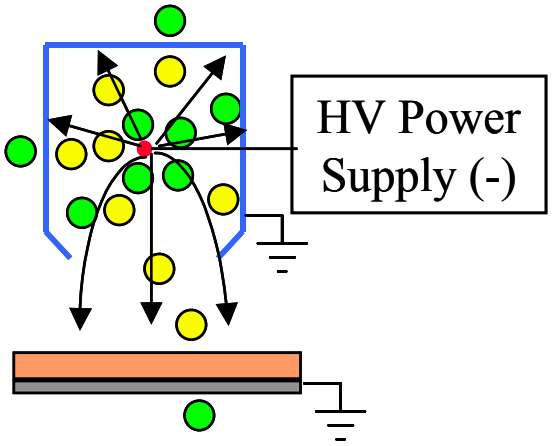


- Requirements
  - Insulator in the dark.
  - Conductor when exposed to light
  - Builds up enough voltage.
  - Uniform properties

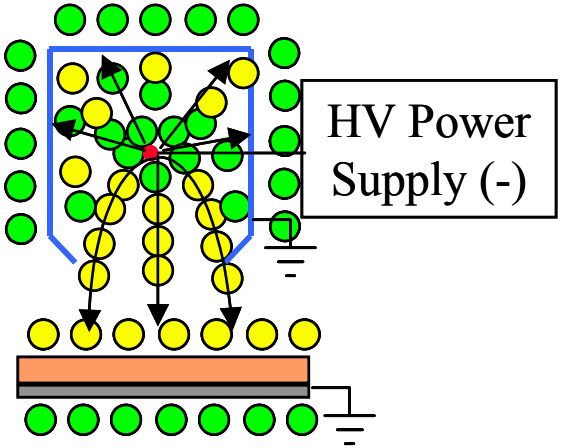
Charging Subsystem



Free ions are attracted to wire; Free electrons are repelled. Counter-charges build up on grounded surfaces.



Rapidly moving electrons and ions collide with air molecules, ionizing them and creating a corona.



Electrons continue to follow Electric Field lines to Photoreceptor until uniform charge builds up

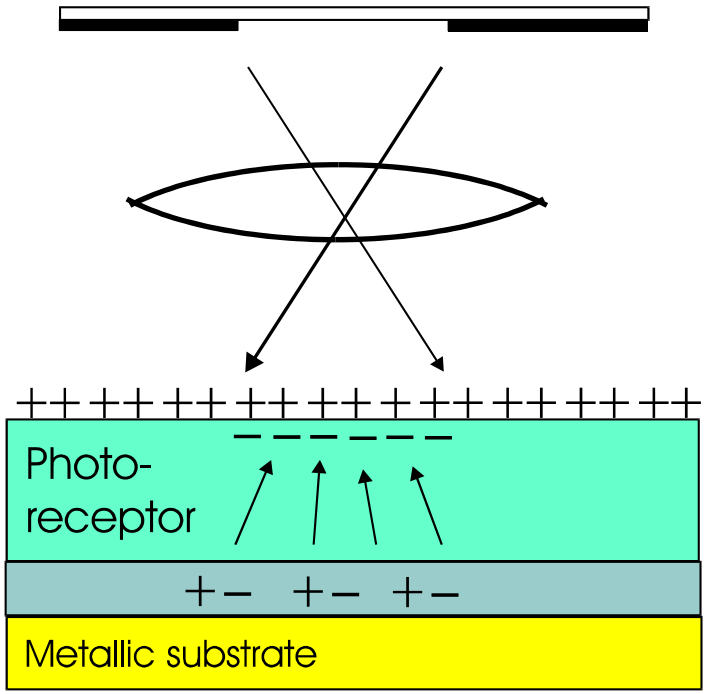
- Positive Ions
- Electrons

Imaging/Exposure

Selectively discharge a photoreceptor using light

The camera technique

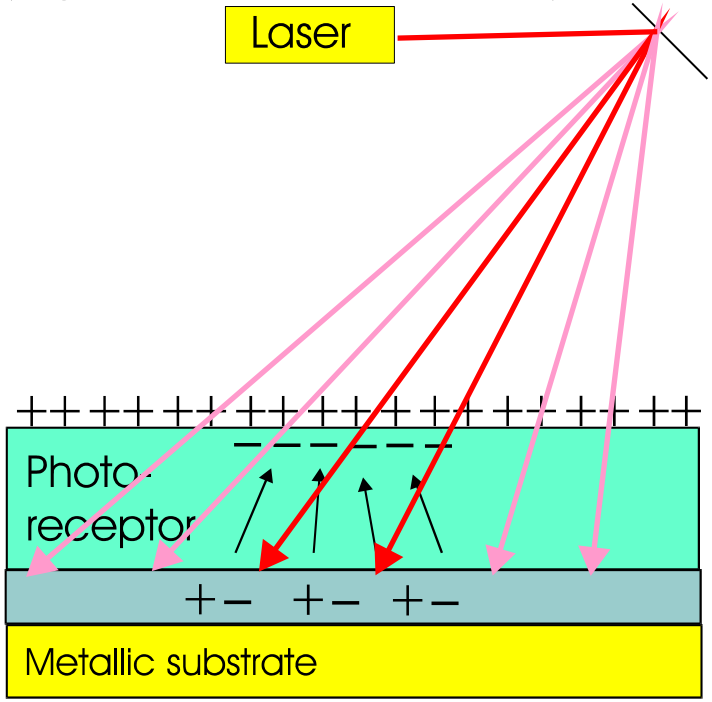
(analog, the past)



Traditional Analog Copier

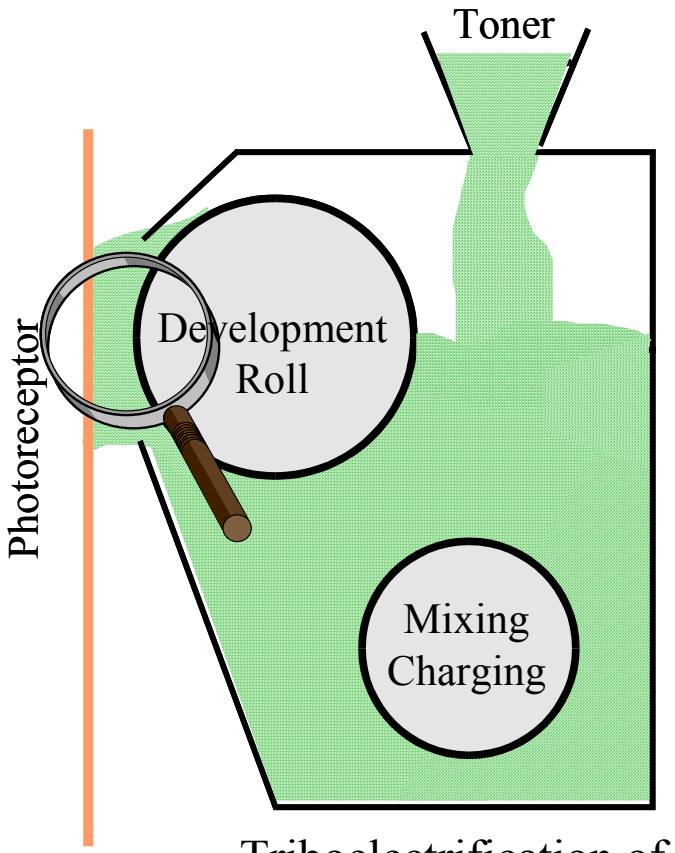
The television technique

(digital, the present & future)

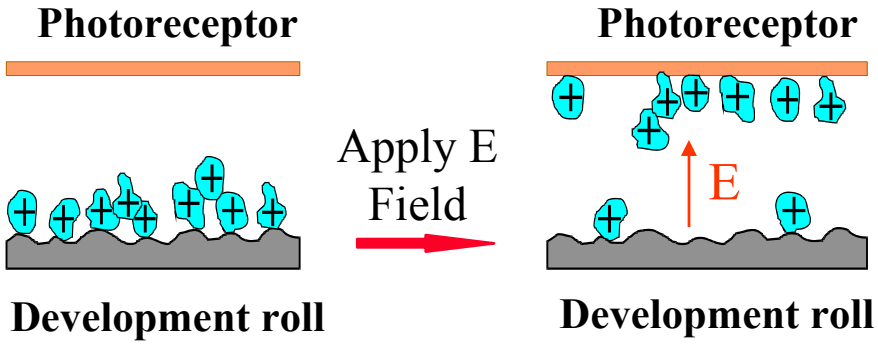


Laser Printer

Development



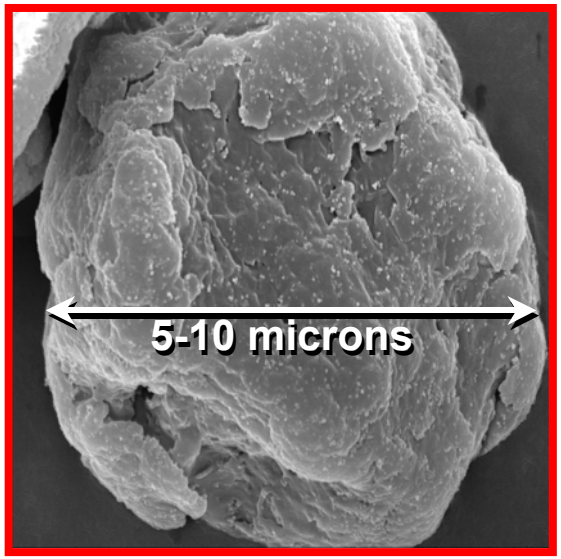
Triboelectrification of toner particles and carrier beads



- Charge particles triboelectrically
- Electric field moves particles from developer roll to photoreceptor

Toner

- Charging
- Adhesion/cohesion
- Powder flow
- Rheology
- Color - hue and density
- Pigment dispersion

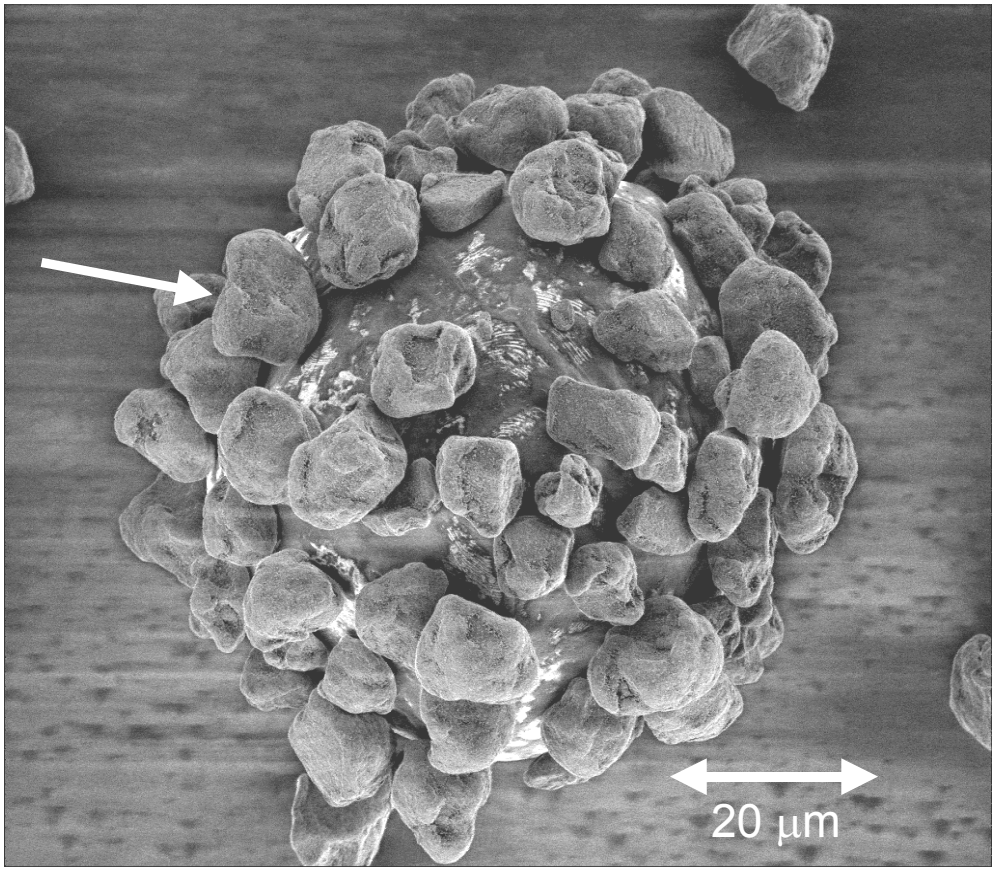


Toned Carrier Bead

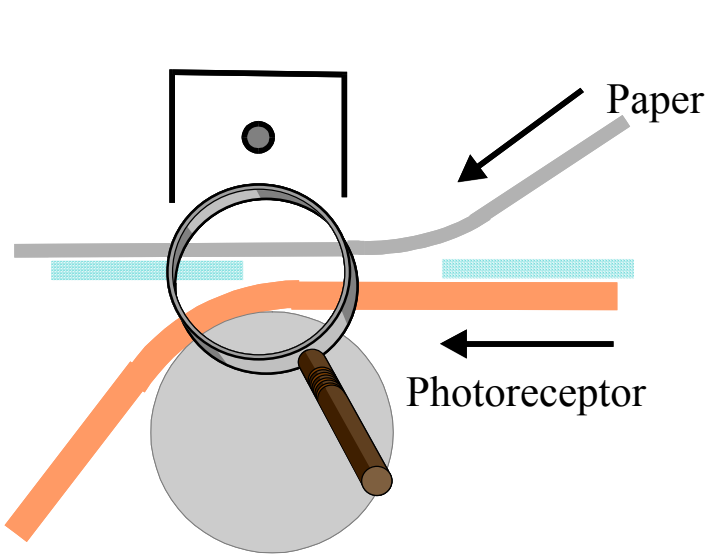
$q \cong 2 \times 10^{4}$ e

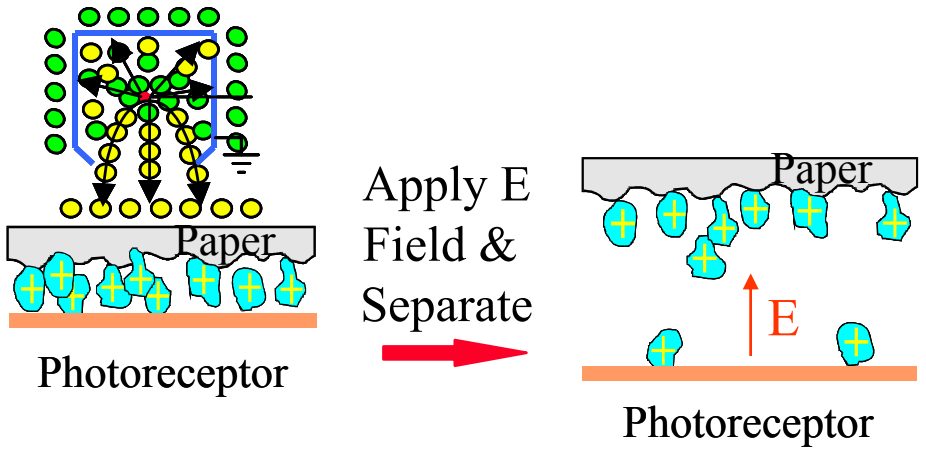
$m \cong 2 \times 10^{-10}$ gm

$q/m \cong 16$ μC/gm



Transfer



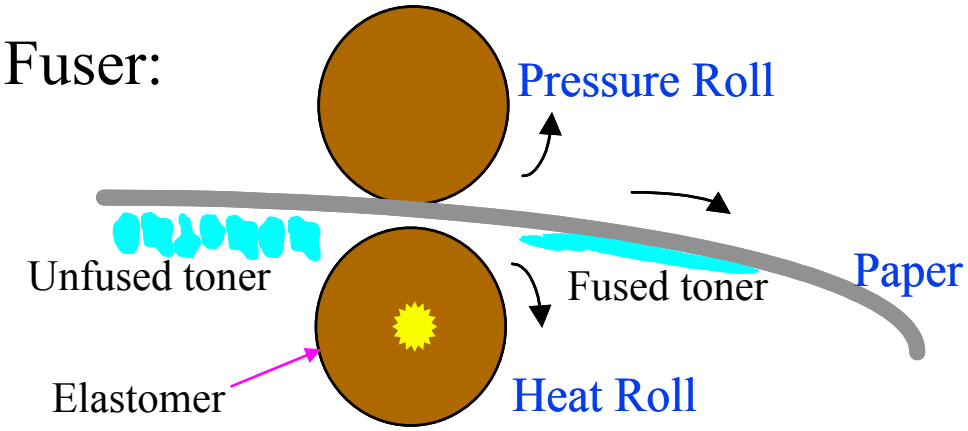


- Electric field moves particles from photoreceptor to paper or transparency
- Detachment field must overcome toner adhesion to photoreceptor

Fusing Subsystem

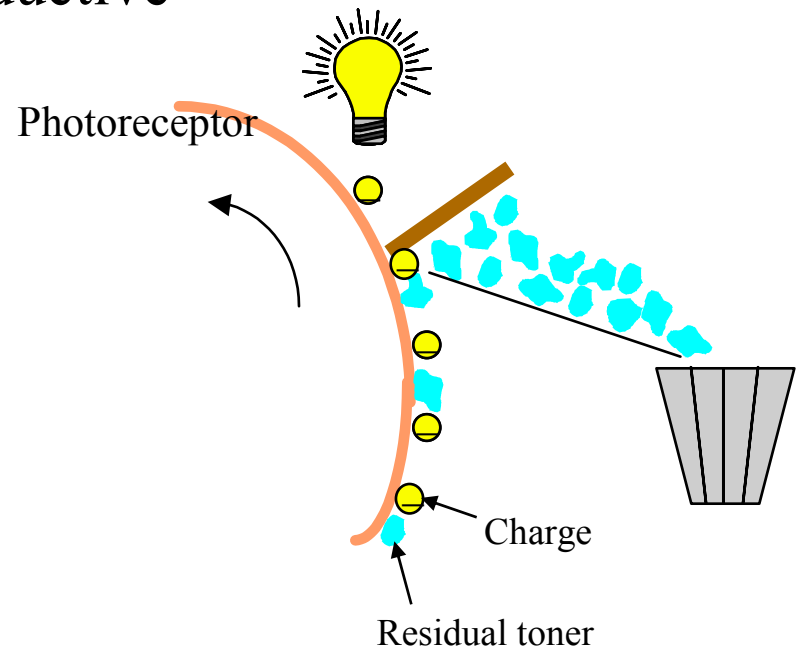
- Permanently affix the image to the final substrate
  - paper of various roughnesses and surface treatment
  - transparency (plastic)
- Apply heat and/or pressure

Hot Roll Fuser:

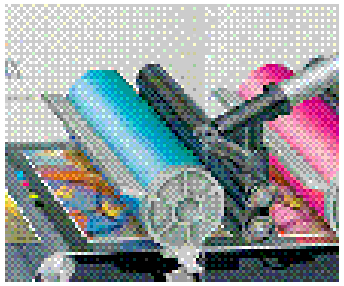


Cleaning and Erase

- Removes unwanted residual toner and charge from photoreceptor before next imaging cycle
  - Physical agitation removes toner (blade or brush)
  - Light neutralizes charge by making entire photoreceptor conductive

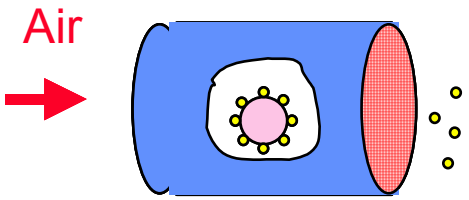


Transport, Adhesion/Cohesion and Removal of Fine Particles (Toner) in Xerography

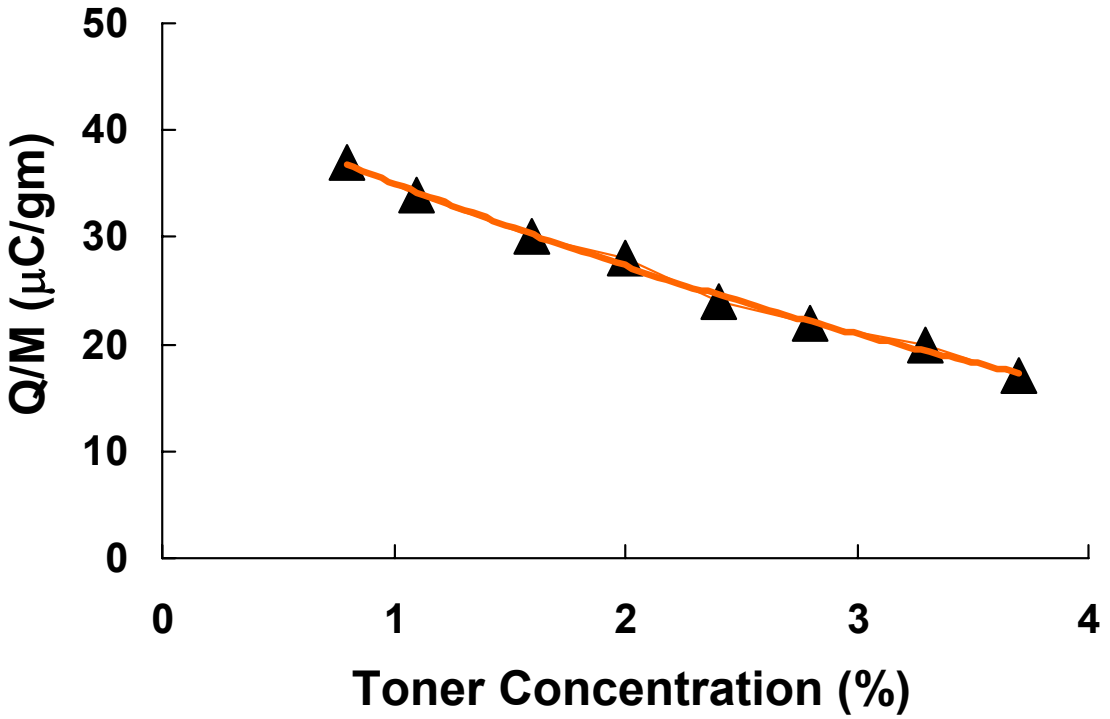


Toner Charge Measurements

Blowoff Tribo

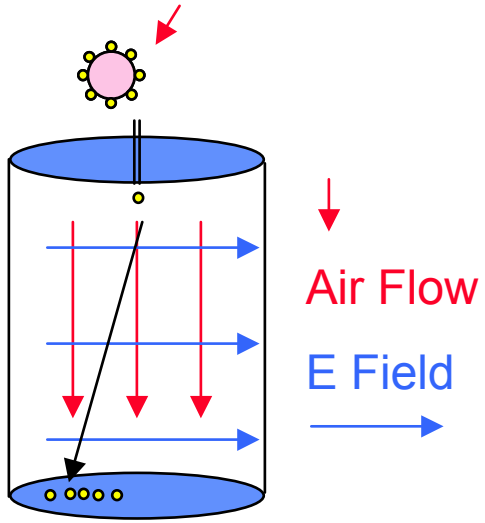


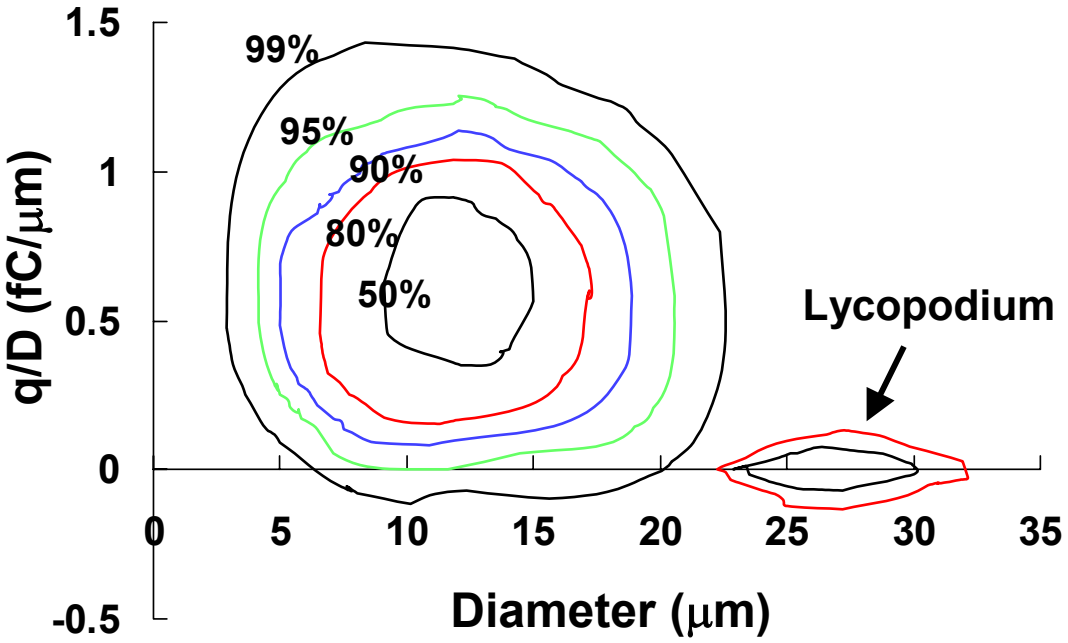
- Blow toner from toned beads in cage
- Measure charge & mass difference
- Calculate average Q/M



Toner Charge Measurements

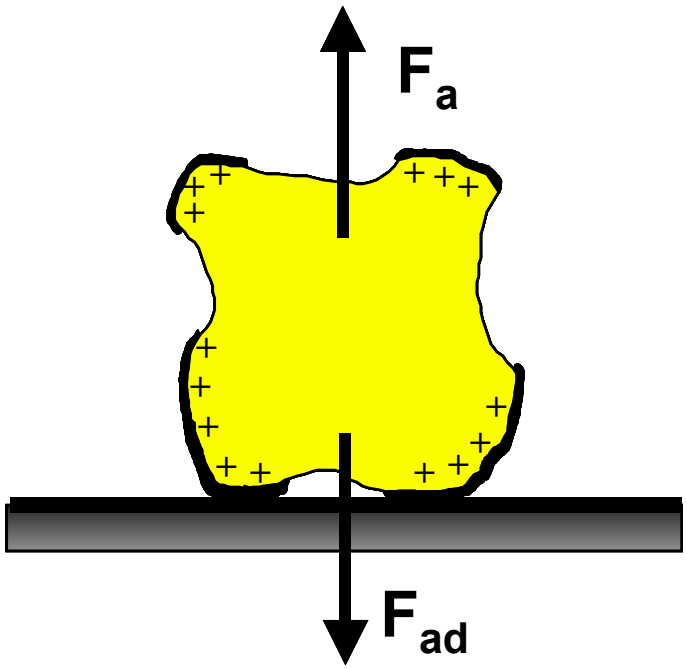
Charge Spectrograph





- Inject toner
- Displacement ∝ q/D
- Measure position & size of particles

Toner Adhesion Forces



Particle adhesion depends on:

- **Size, shape, & roughness**
- **Materials**
- **Flow agents**
- **Charge**
- **Surface charge distribution on particle**

Detachment when $F_a > F_{ad}$

Electrostatic Image Force Model

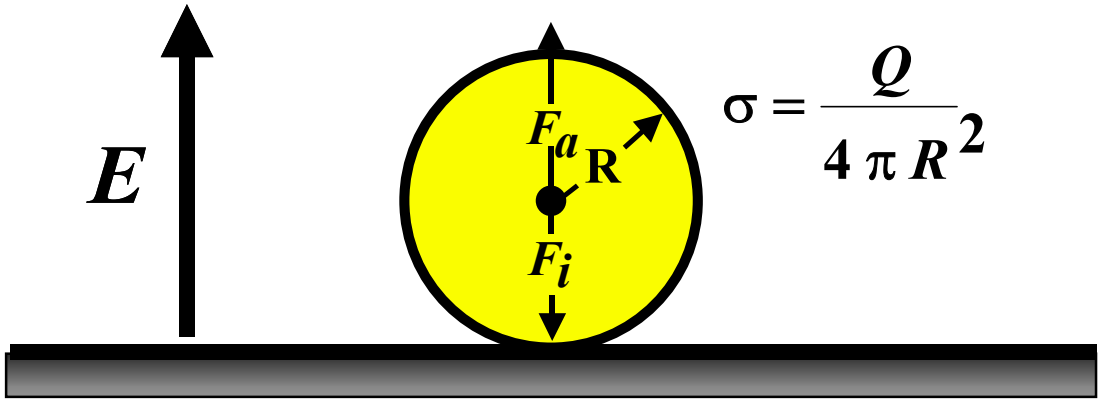


Image Force

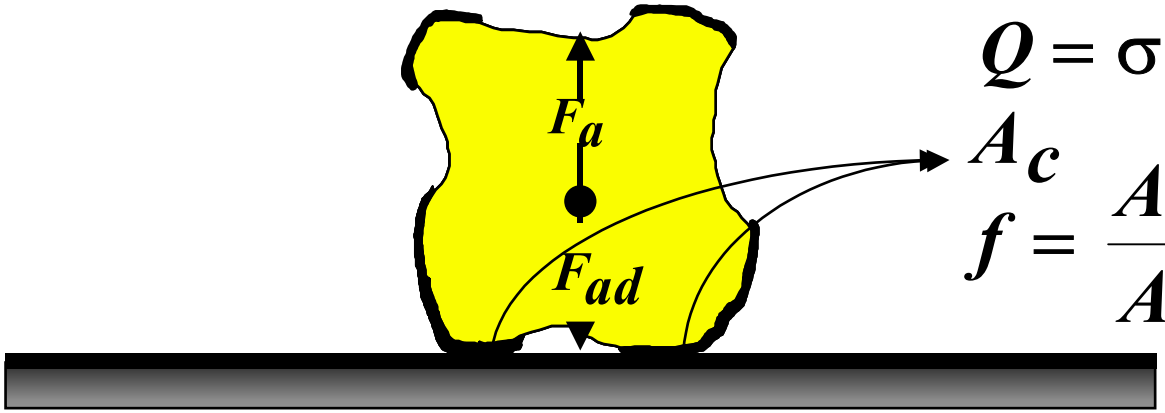
$$F_i = -\alpha \frac{Q^2}{16\pi\varepsilon_o R^2}$$

Applied Force

$$F_a = \beta QE - \gamma \pi \varepsilon_o R^2 E^2$$

$$E_d \cong \frac{\alpha Q}{\beta 16 \pi \varepsilon_o R^2} \approx 1 \ \ \mathrm{V/\mu m}$$

Charge Patch Adhesion Model



$$Q = \sigma A_t$$

$$A_c$$

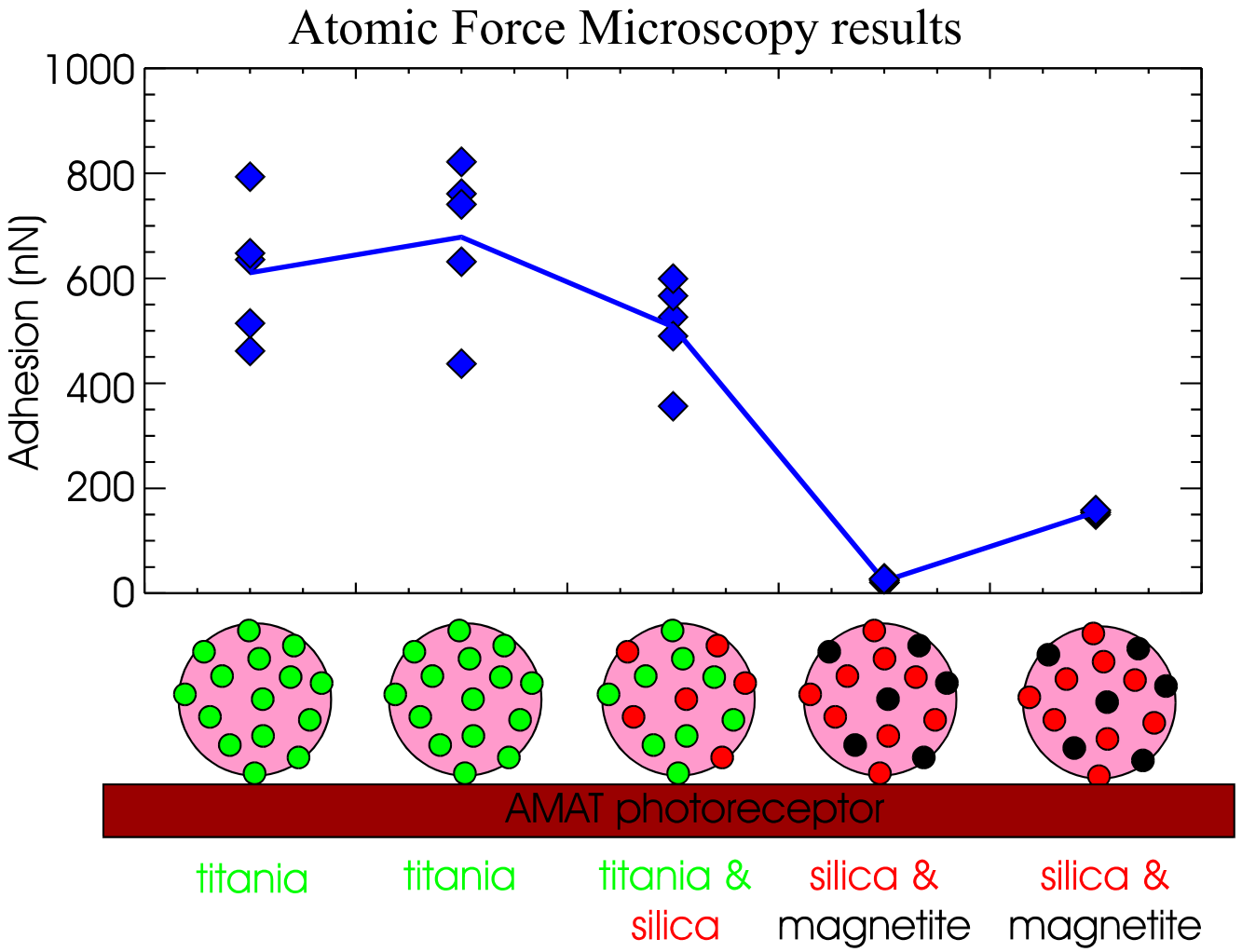
$$f = \frac{A_c}{A_t}$$

$$F_{ad} = -\frac{\sigma^2}{2\varepsilon_o} A_c - W A_c$$

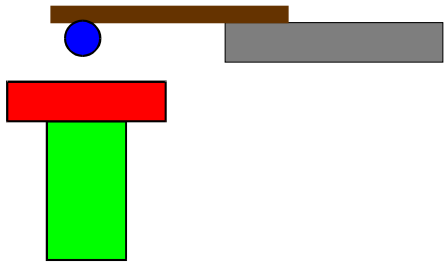
$$= -Qf\left(\frac{\sigma}{2\varepsilon_o} + \frac{W}{\sigma}\right)$$

Additives Control Adhesion

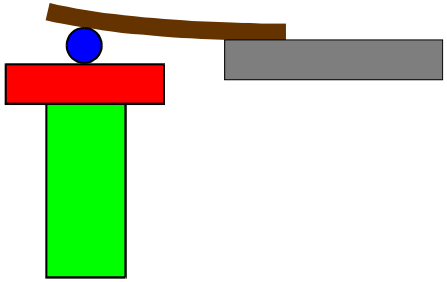
Changing type of additive modifies adhesion



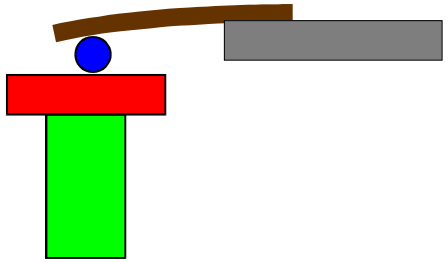
Atomic Force Microscopy (AFM)



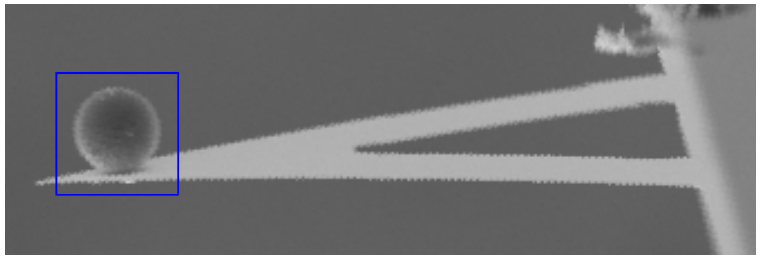
Bring toner
near surface



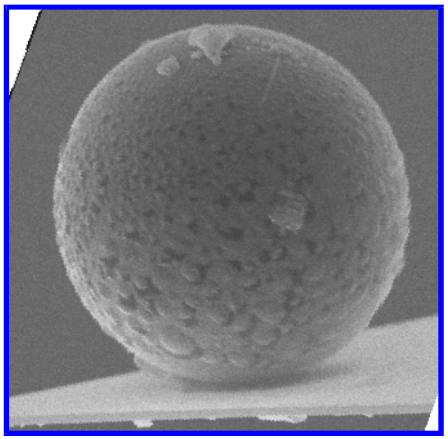
Push toner
against surface



Retract toner until
probe releases

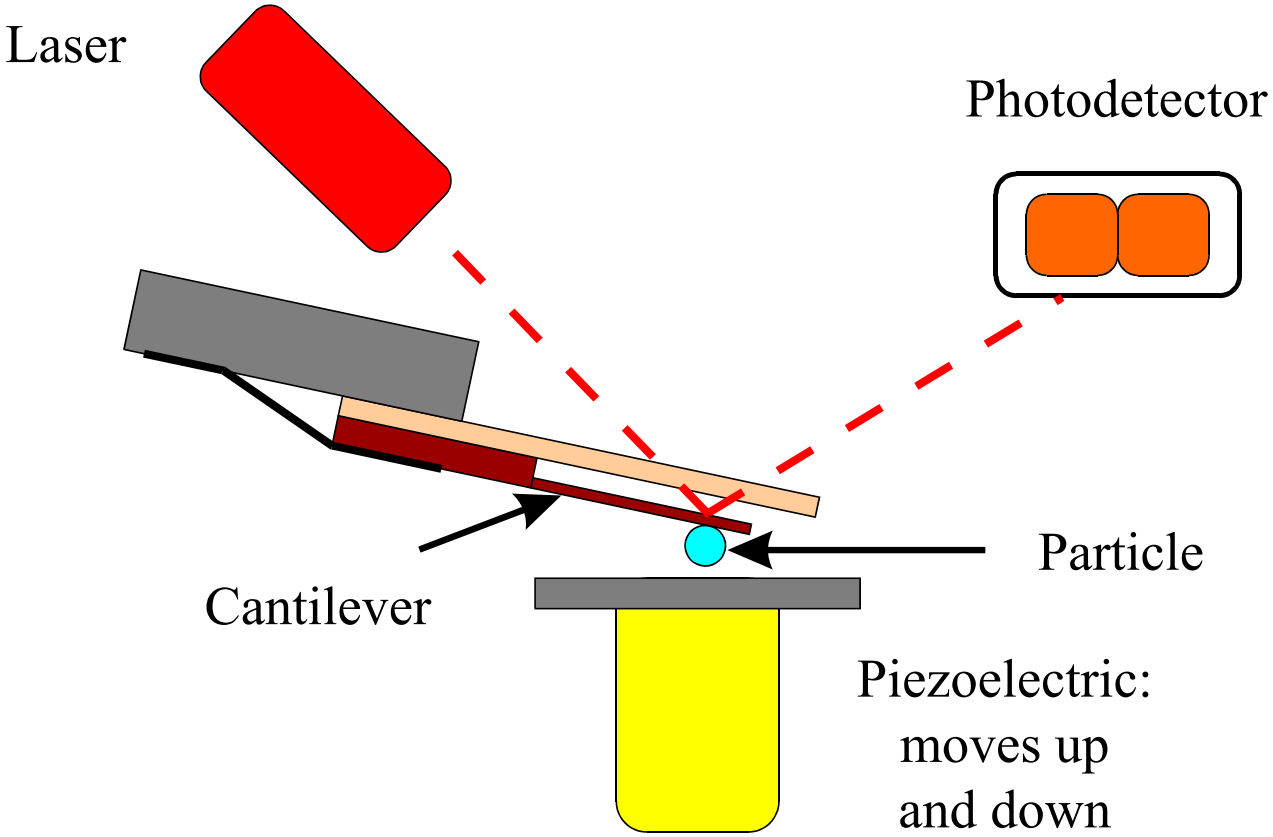


200 μm



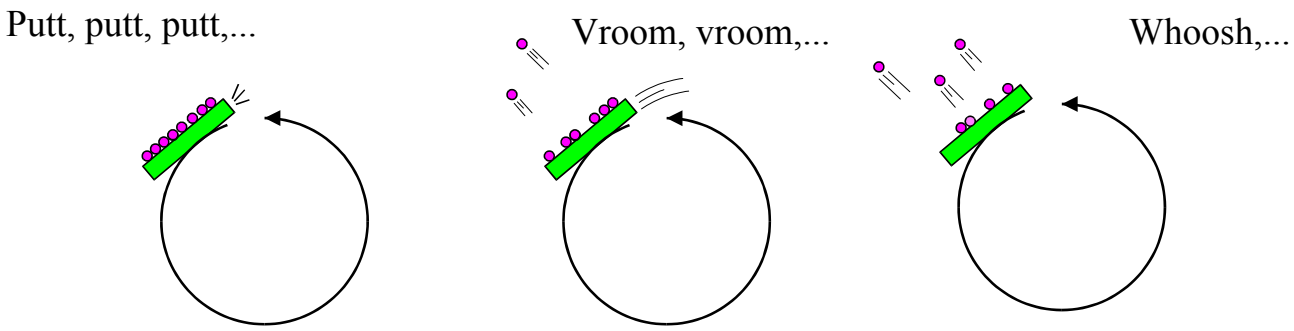
20 μm

Measure Single Particle Adhesion

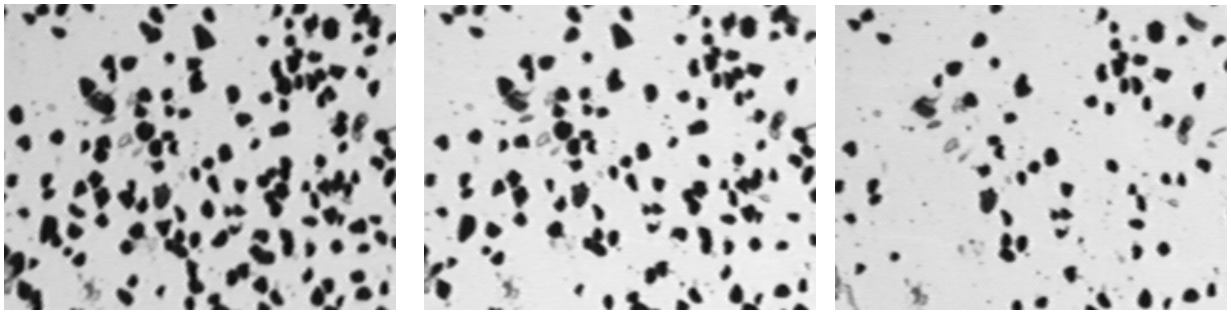


Centrifuge Detachment

Measure Many Particle Adhesion



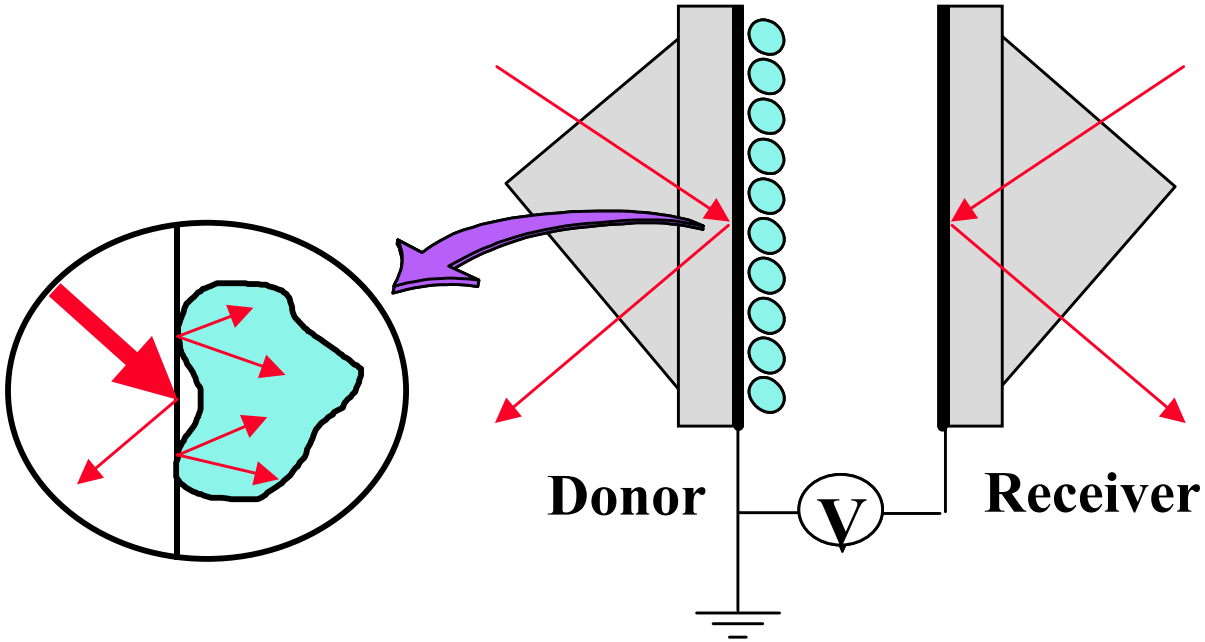
Observe Donor Plate after Each Spin



H. Mizes, "Adhesion of Small Particle", Electro. Soc. Amer.
Univ. of Rochester, 6/23/95

Electric Field Detachment

Measure Many Particle Adhesion

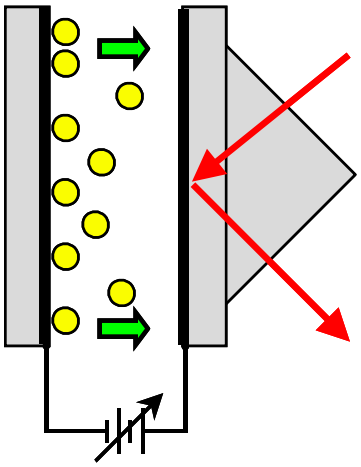


transparent conductive electrodes

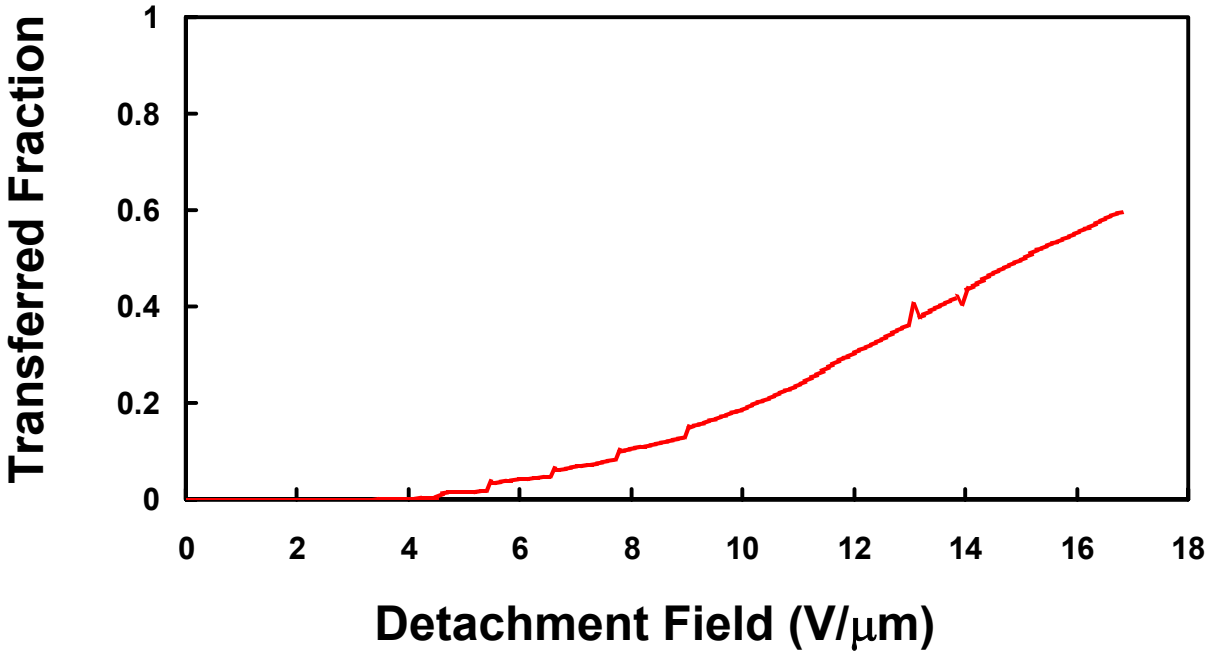
E. Eklund, W. Wayman, L. Brillson, D. Hays, 1994 IS&T Proc., 10th Int. Cong. on Non-Impact Printing, 142-146

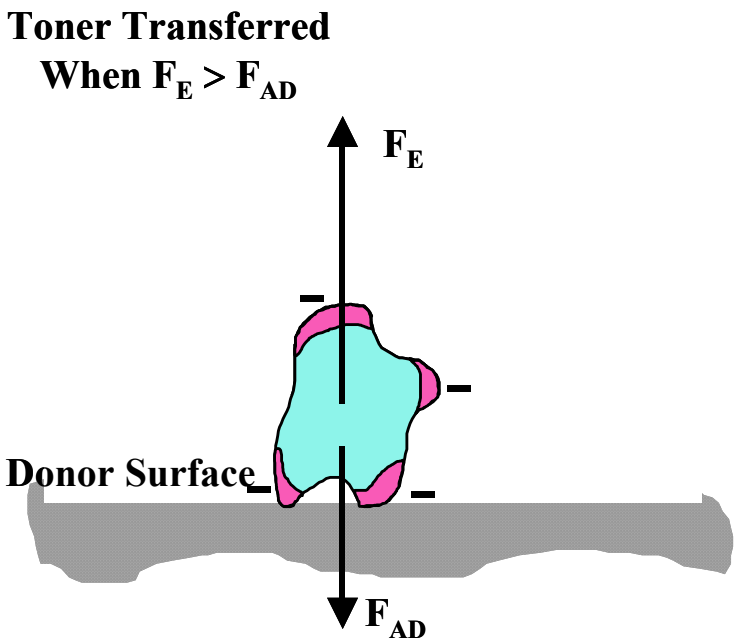
Electrical Field Detachment of Charged Toner

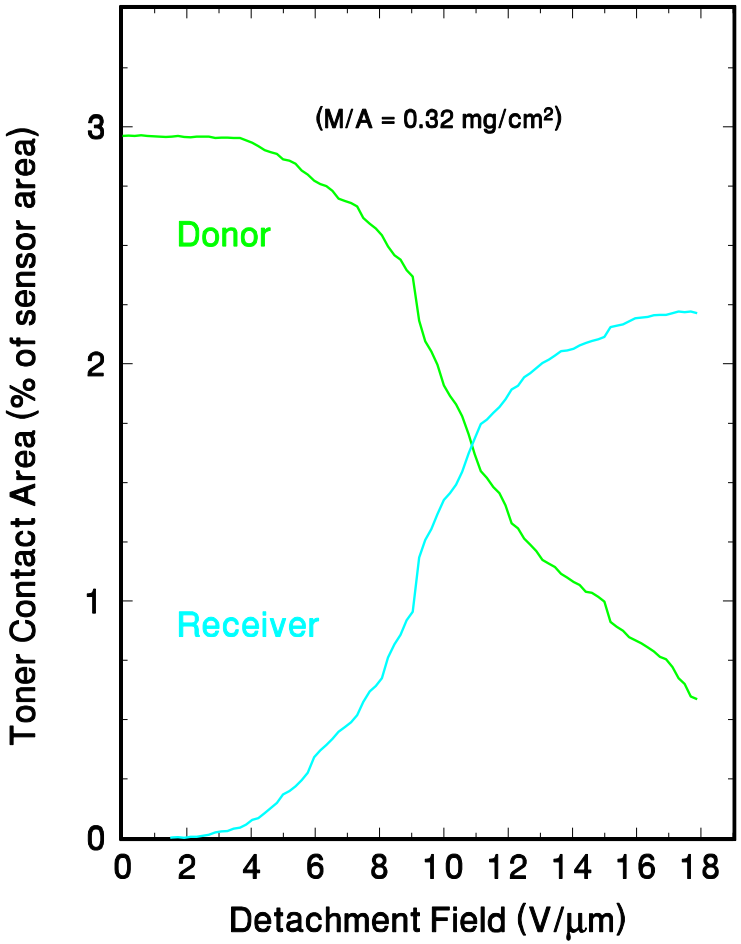
Detachment Cell



Adhesion of Triboelectrically Charged Toner



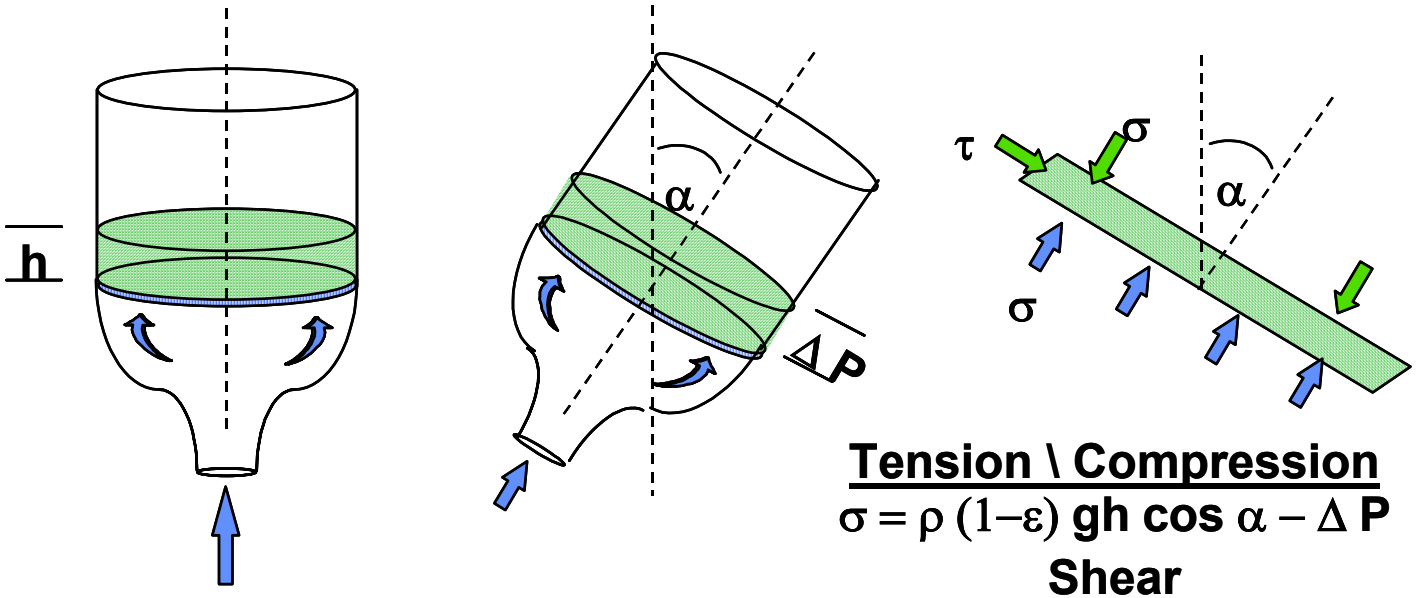




E. Eklund, W. Wayman, L. Brillson, D. Hays, 1994 IS&T Proc., 10th Int. Cong. on Non-Impact Printing, 142-146

Fluidized Bed

Measure Powder Cohesion



Stresses on the toner bed

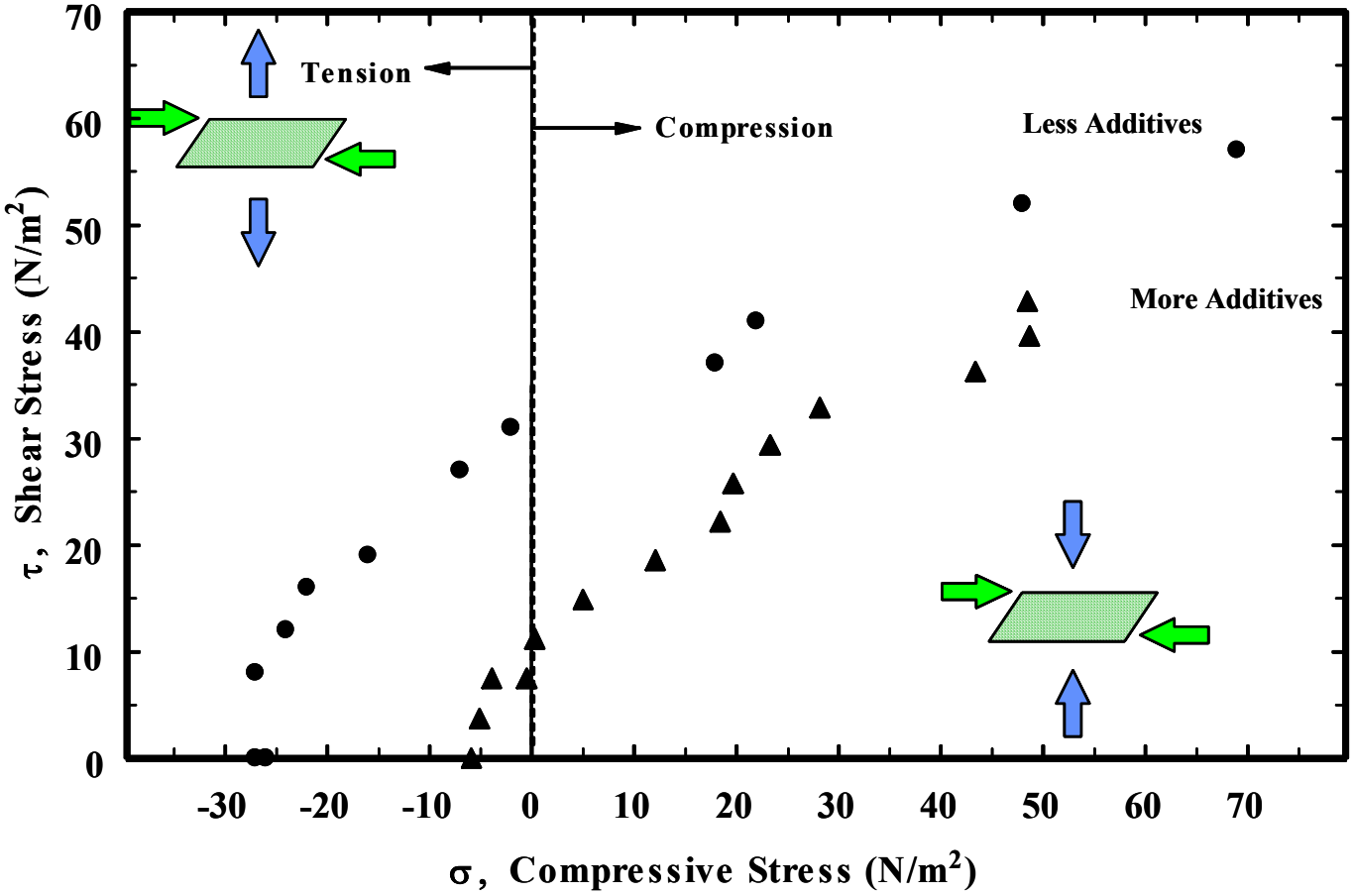
Tension \ Compression

$$\sigma = \rho\,(1-\varepsilon)\,gh\cos\alpha - \Delta P$$

Shear

$$\tau = \rho\,(1-\varepsilon)\,gh\sin\alpha$$

P.K. Watson, "Yield Locus of Cohesive Granular Materials", Workshop on Dynamics of Granular Materials: Understanding & Control, Univ. of Chicago, 5/11/95


Tension
Compression
Less Additives
More Additives
τ, Shear Stress (N/m²)
σ, Compressive Stress (N/m²)
70
60
50
40
30
20
10
0
-30
-20
-10
0
10
20
30
40
50
60
70

Q&A