



Particle Transport, Deposition, and Removal in Xerography

NSF CRCD Project Lecture

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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**

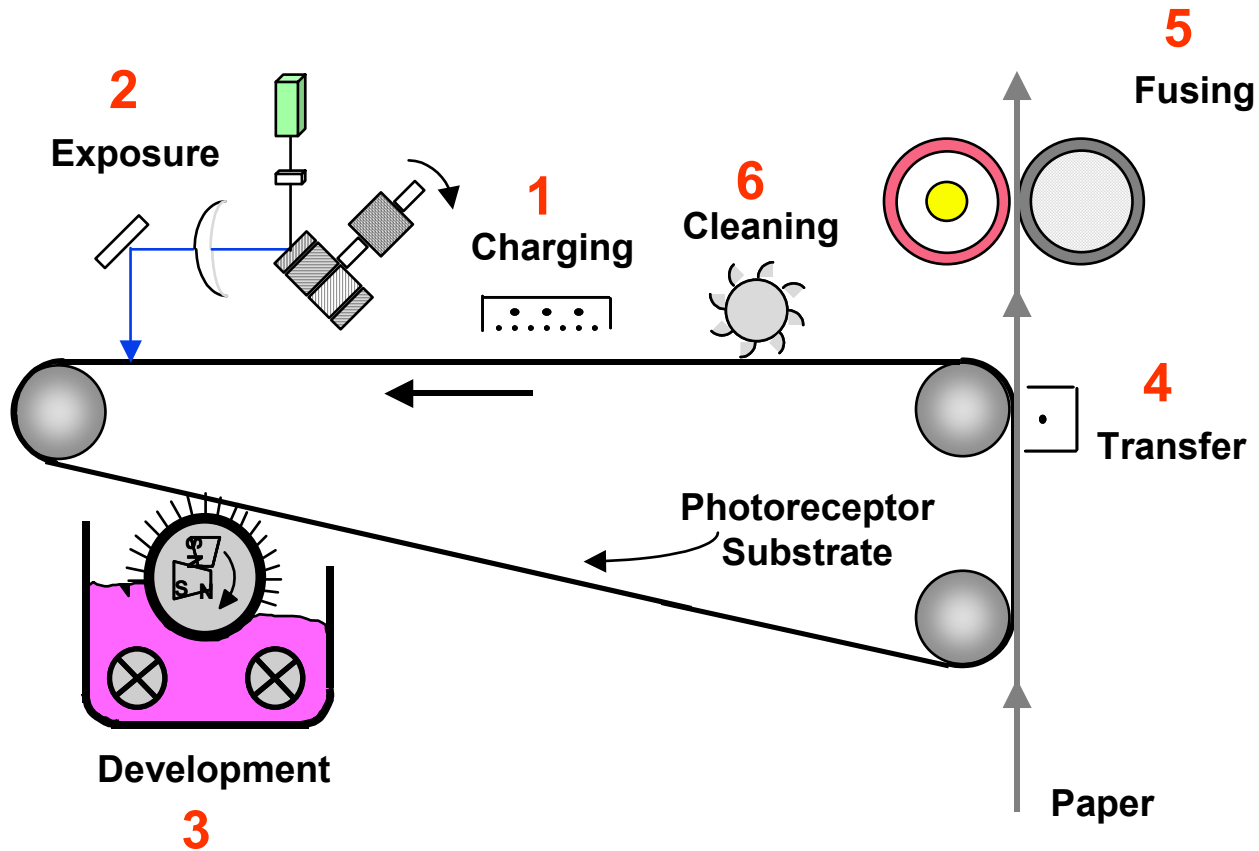
Acknowledgements:

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, highlight 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

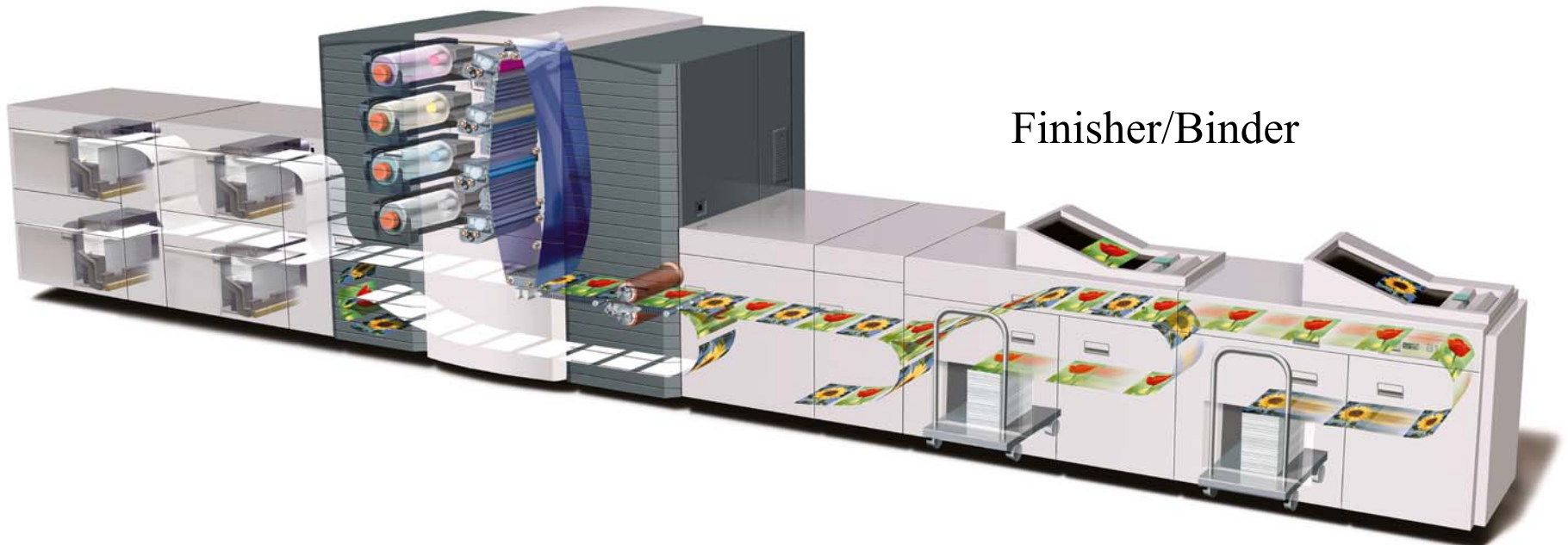




iGen3

Xerographic Unit

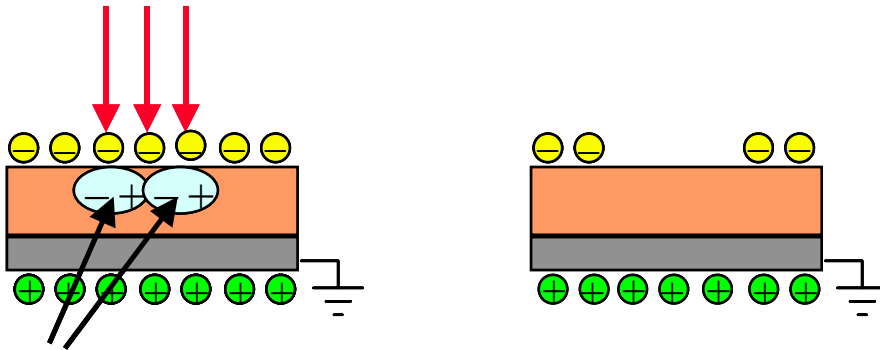
Finisher/Binder



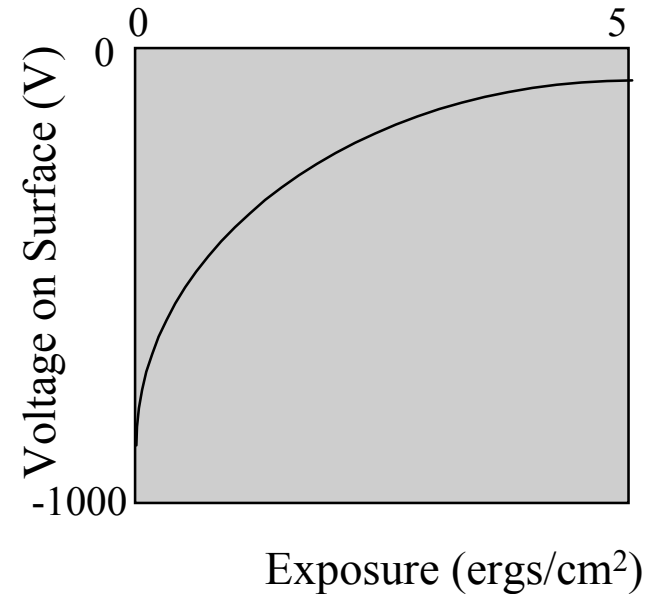


Photoreceptor

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



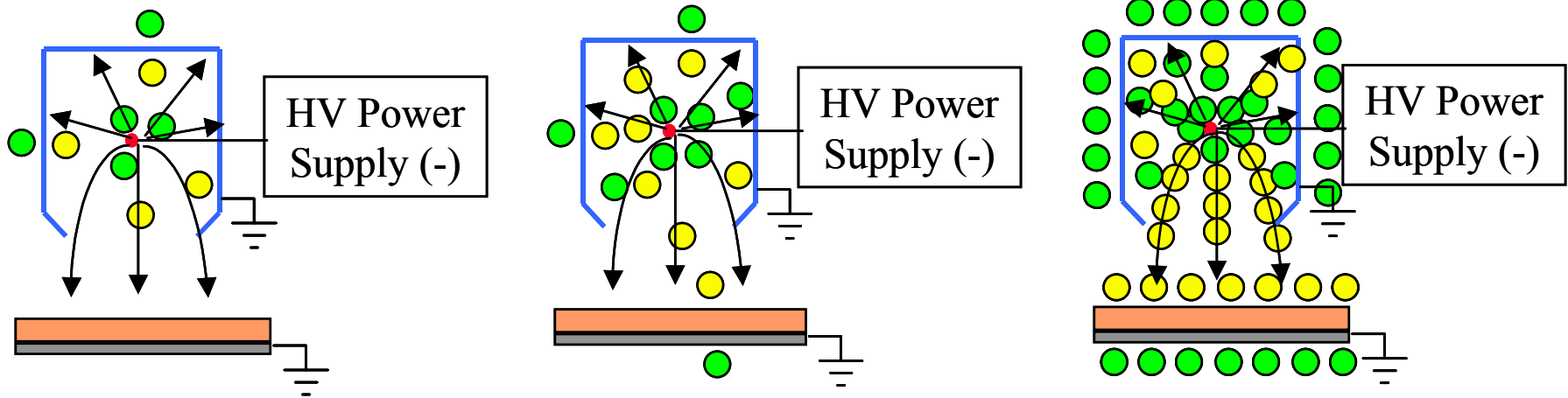
Electron/hole pairs



- 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

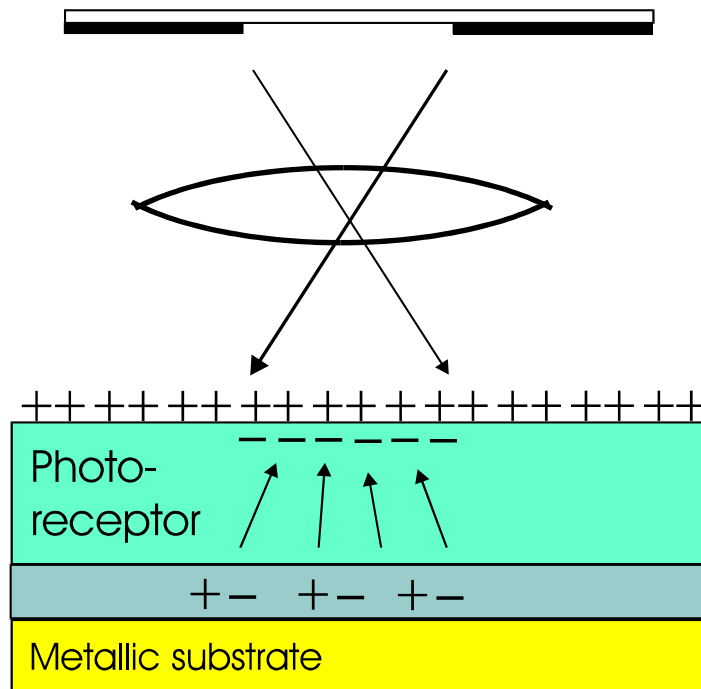


Imaging/Exposure

Selectively discharge a photoreceptor using light

The camera technique

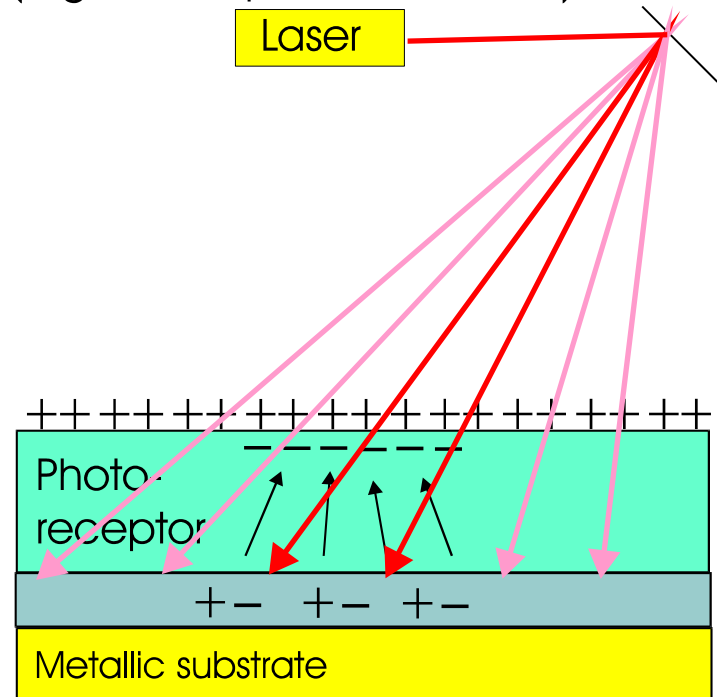
(analog, the past)



Traditional Analog Copier

The television technique

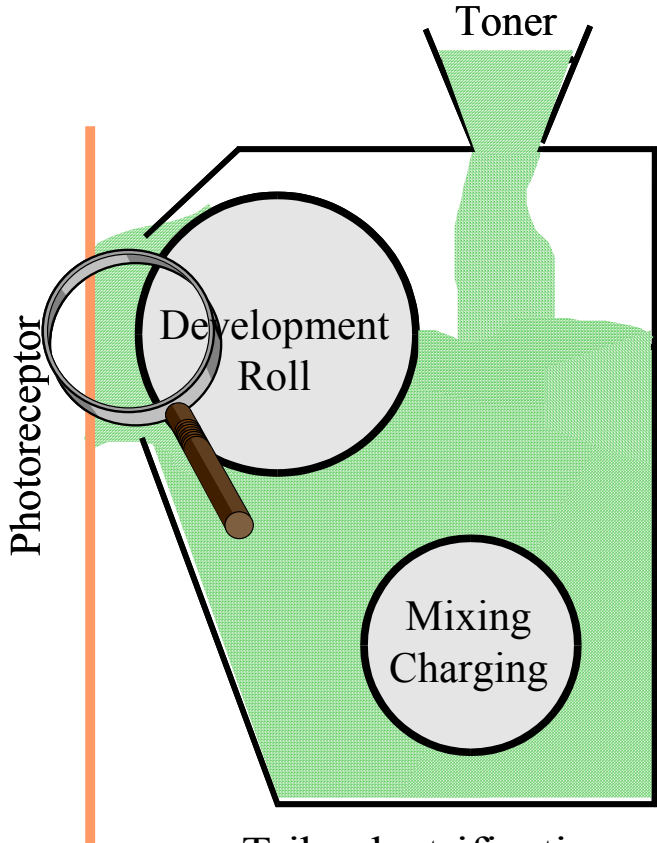
(digital, the present & future)



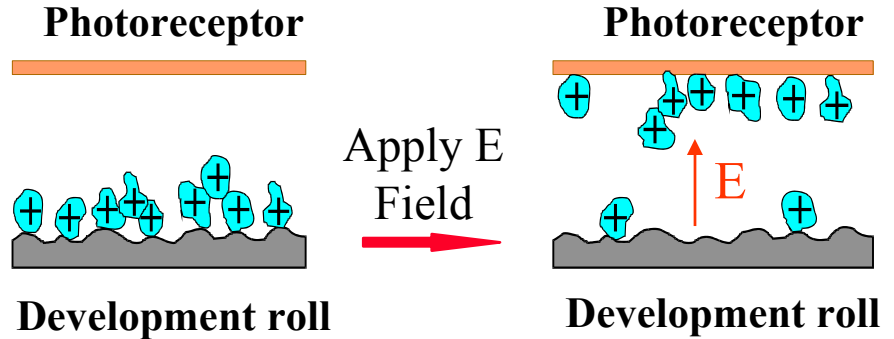
Laser Printer



Development



Triboelectrification of toner particles and carrier beads

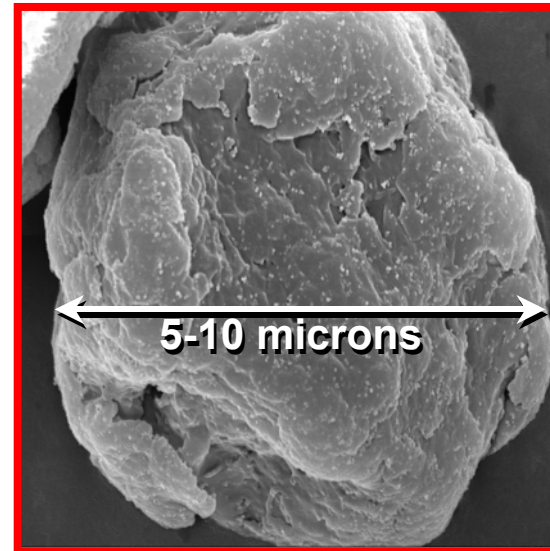


- Charge particles triboelectrically
- Electric field moves particles from developer roll to photoreceptor



Toner

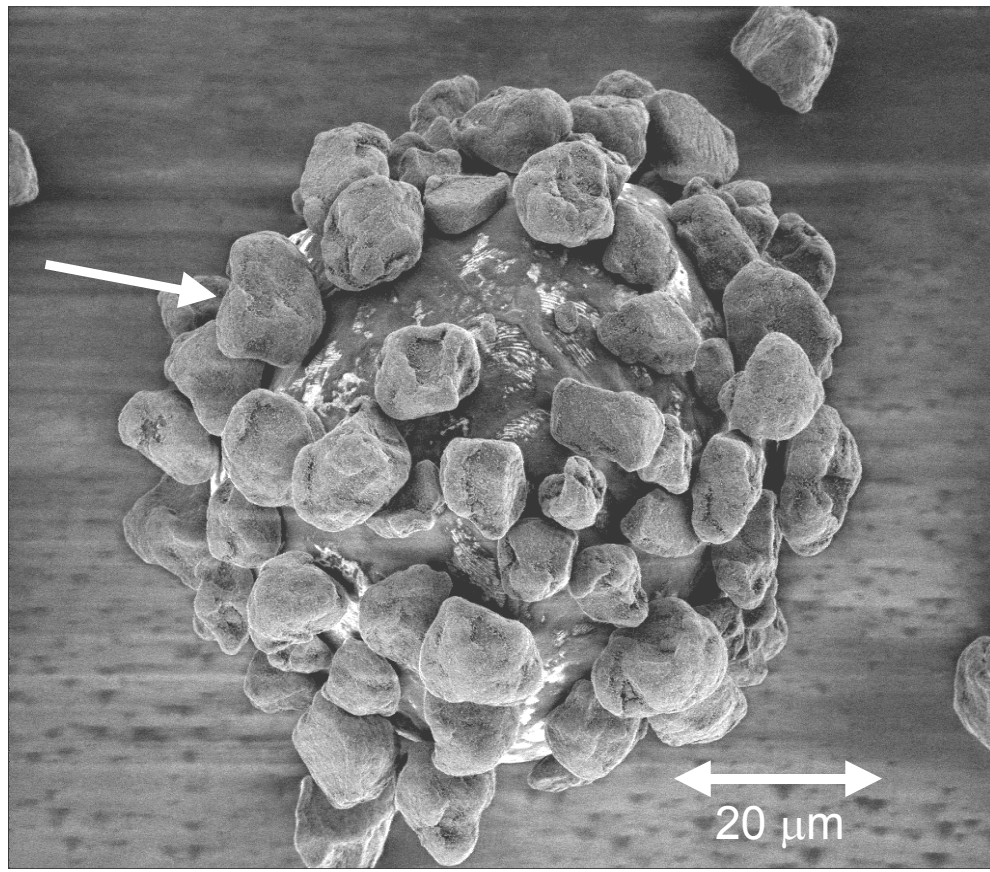
- Charging
- Adhesion/cohesion
- Powder flow
- Rheology
- Color - hue and density
- Pigment dispersion





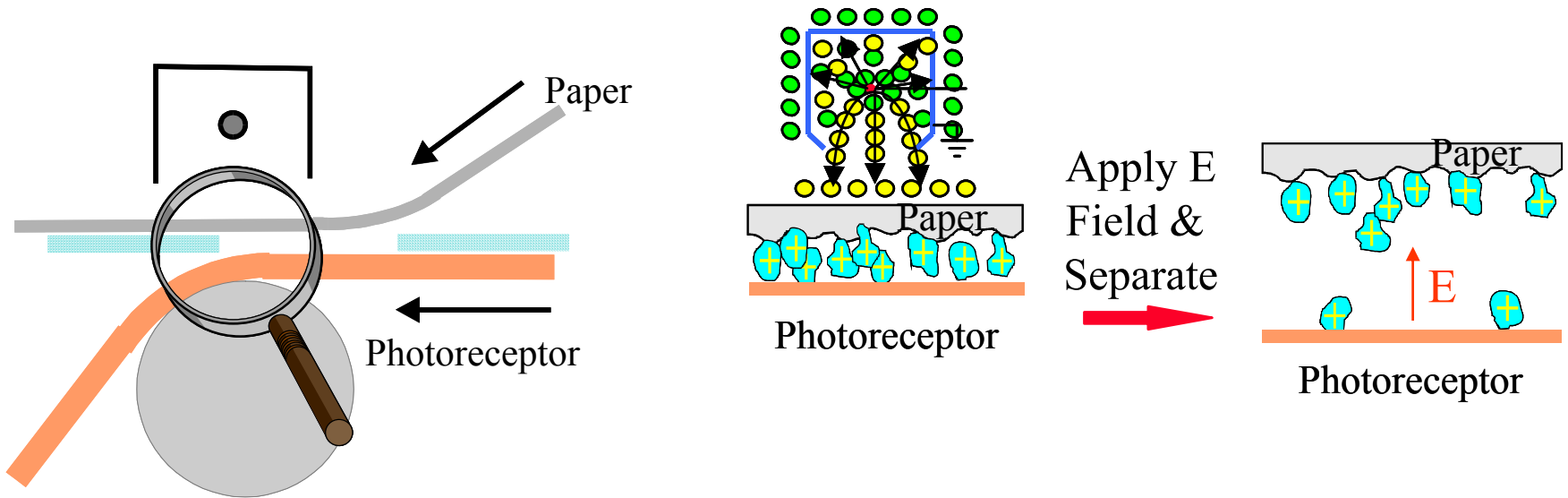
Toned Carrier Bead

$q \cong 2 \times 10^4 e$
 $m \cong 2 \times 10^{-10} \text{ gm}$
 $q/m \cong 16 \mu\text{C/gm}$





Transfer



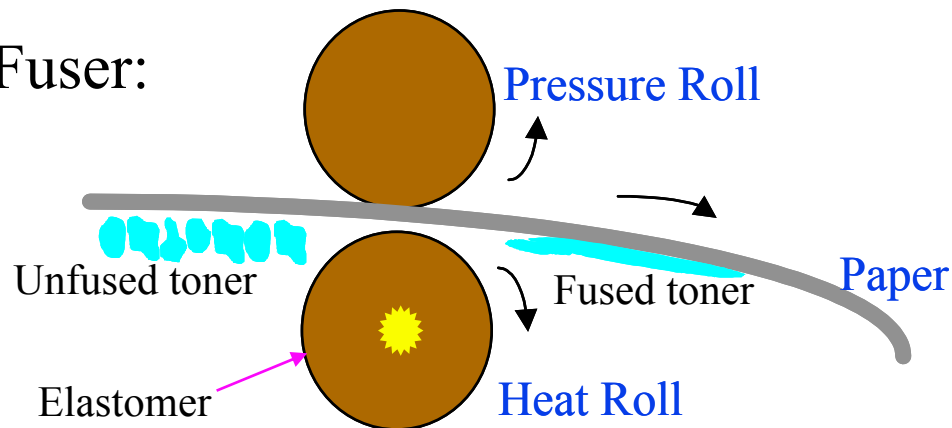
- Electric field moves particles from photoreceptor to paper or transparency
- Detachment field must overcome toner adhesion to photoreceptor



Fusing Subsystem

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

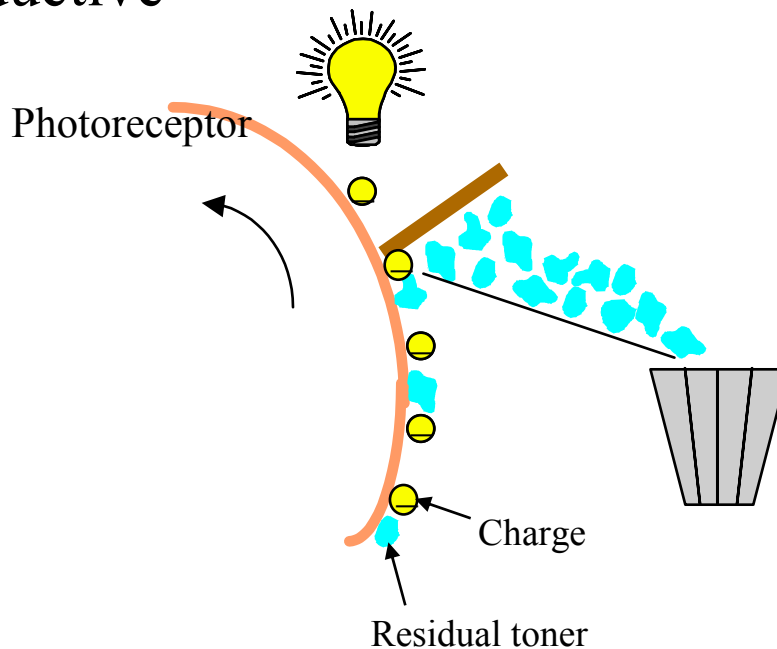
Hot Roll Fuser:





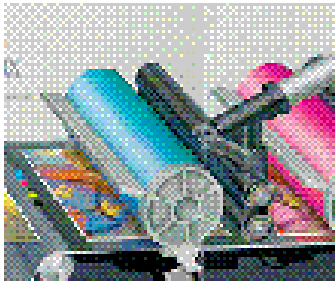
Cleaning and Erase

- 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





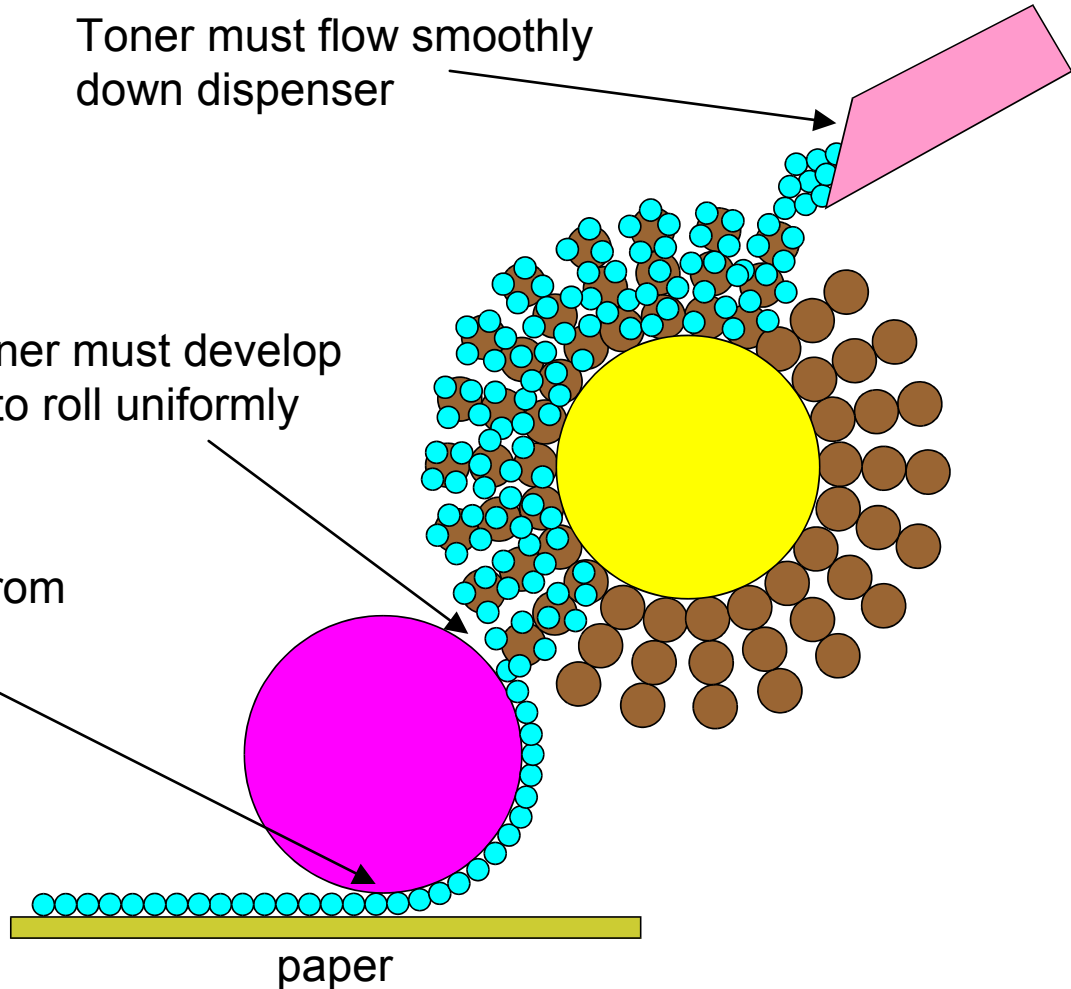
Transport, Adhesion/Cohesion and Removal of Fine Particles (Toner) in Xerography



Toner must flow smoothly down dispenser

Toner must develop onto roll uniformly

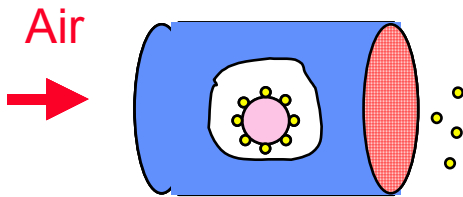
Toner must transfer from roll to paper



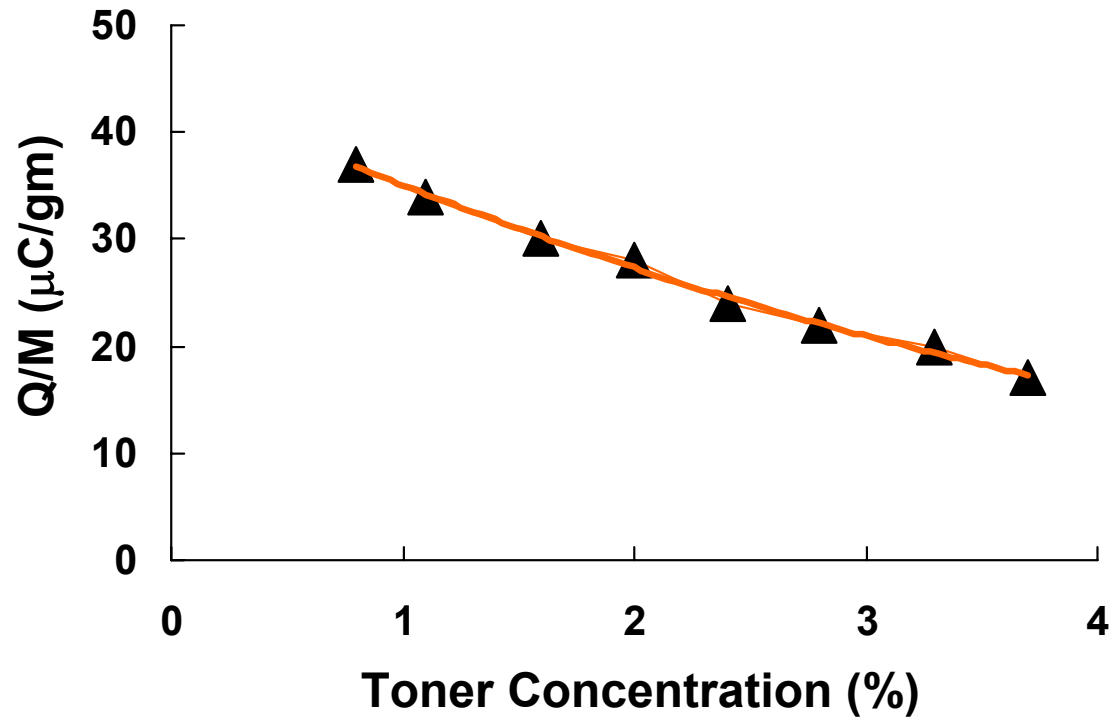


Toner Charge Measurements

Blowoff Tribo



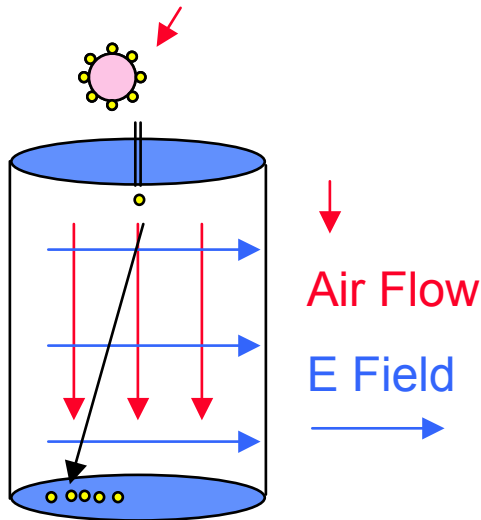
- Blow toner from toned beads in cage
- Measure charge & mass difference
- Calculate average Q/M



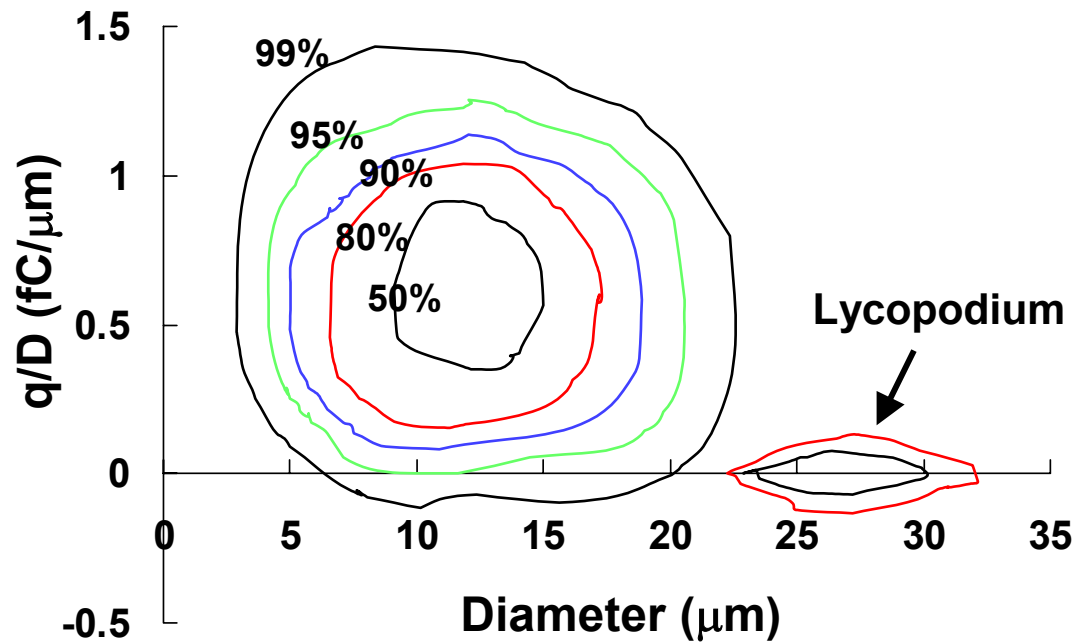


Toner Charge Measurements

Charge Spectrograph

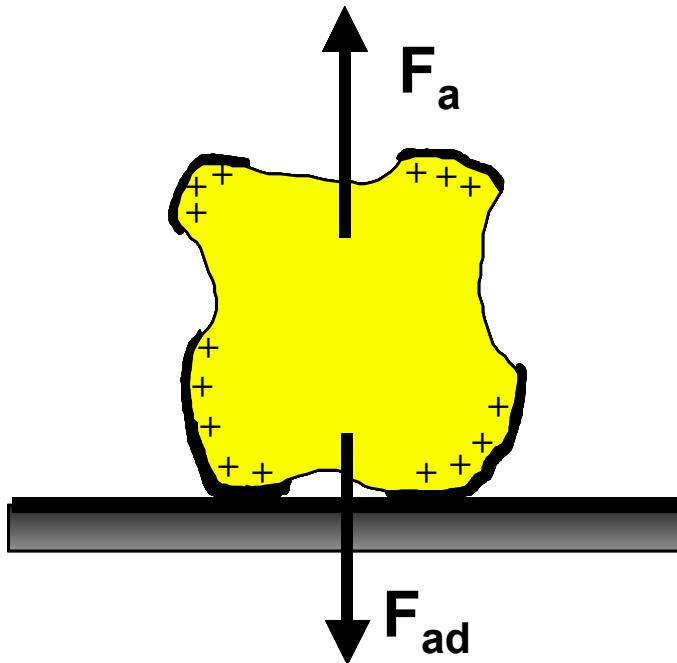


- Inject toner
- Displacement $\propto q/D$
- Measure position & size of particles





Toner Adhesion Forces



Detachment when $F_a > F_{ad}$

Particle adhesion depends on:

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



Electrostatic Image Force Model

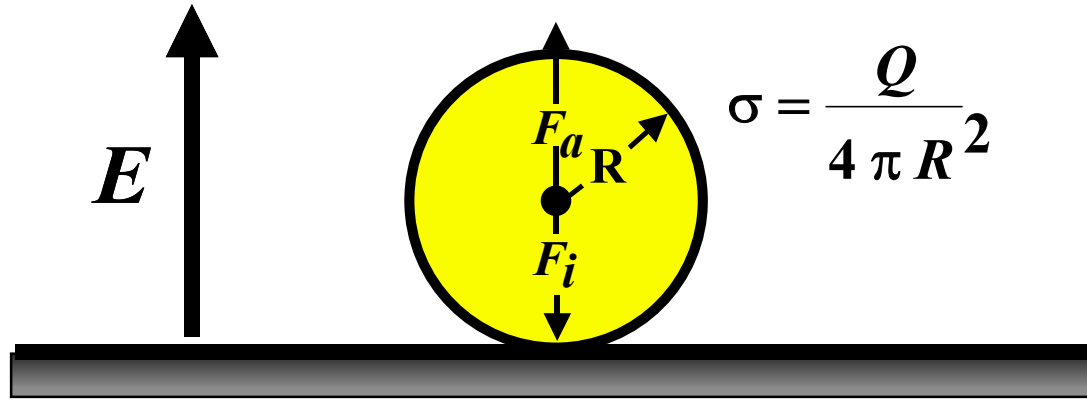


Image Force

$$F_i = -\alpha \frac{Q^2}{16\pi\epsilon_0 R^2}$$

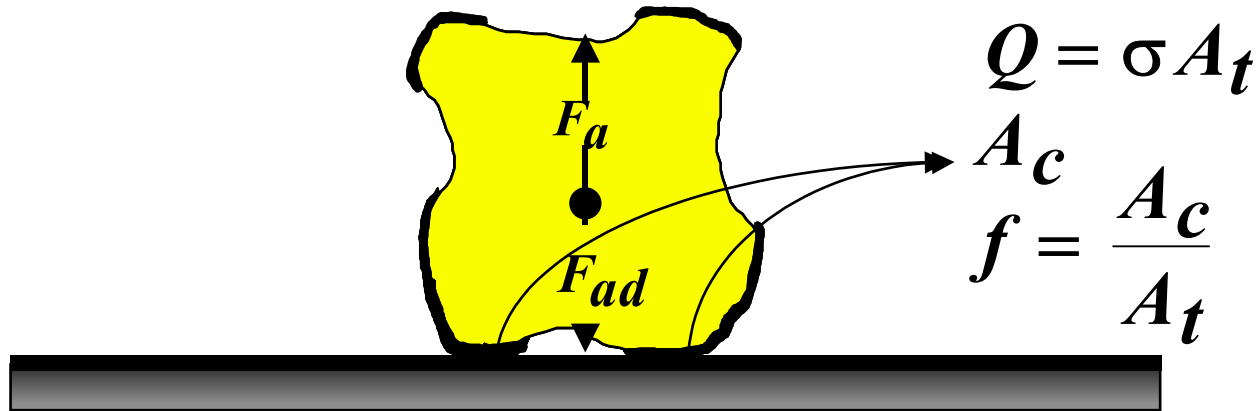
Applied Force

$$F_a = \beta QE - \gamma \pi \epsilon_0 R^2 E^2$$

$$E_d \cong \frac{\alpha Q}{\beta 16\pi\epsilon_0 R^2} \approx 1 \text{ V} / \mu\text{m}$$



Charge Patch Adhesion Model

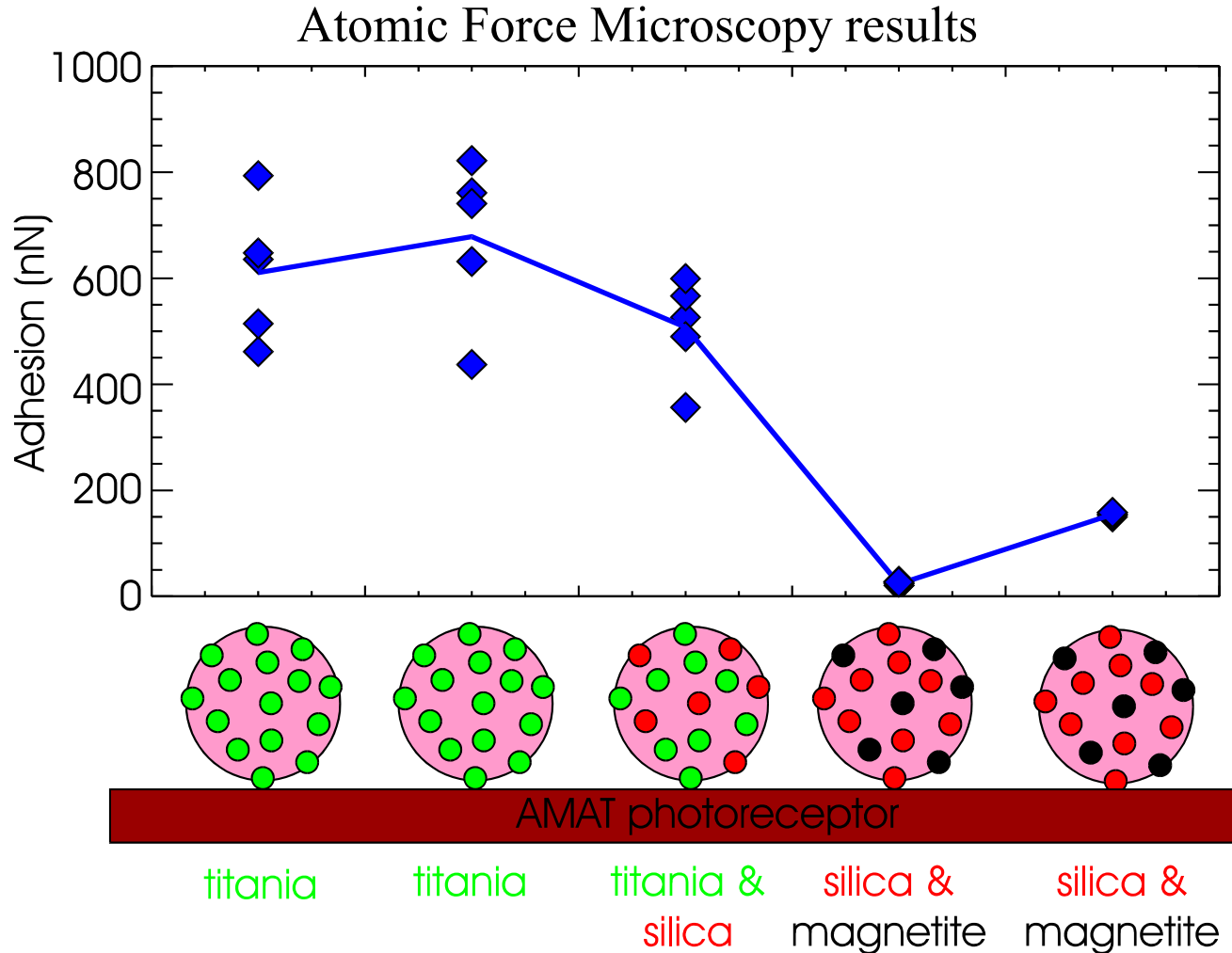


$$F_{ad} = -\frac{\sigma^2}{2\epsilon_0} A_c - W A_c$$
$$= -Qf \left(\frac{\sigma}{2\epsilon_0} + \frac{W}{\sigma} \right)$$



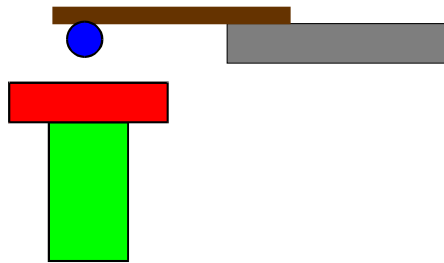
Additives Control Adhesion

Changing type of additive modifies adhesion

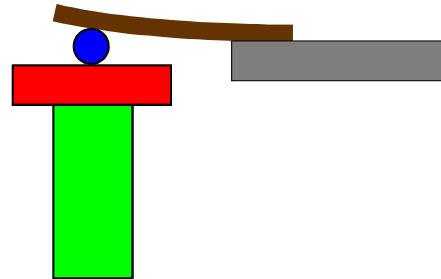




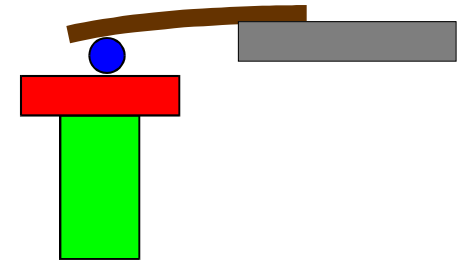
Atomic Force Microscopy (AFM)



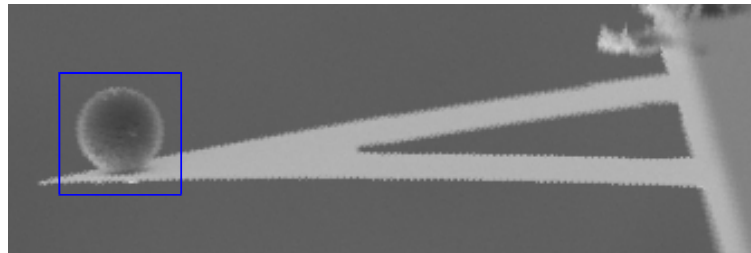
Bring toner near surface



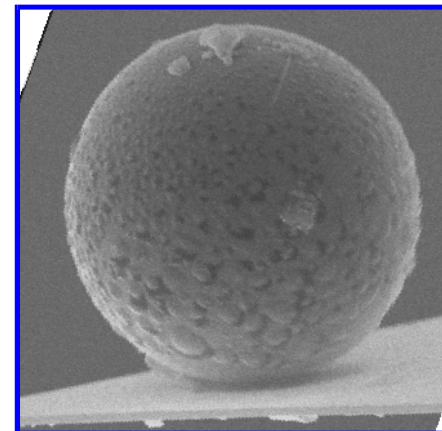
Push toner against surface



Retract toner until probe releases



200 μm

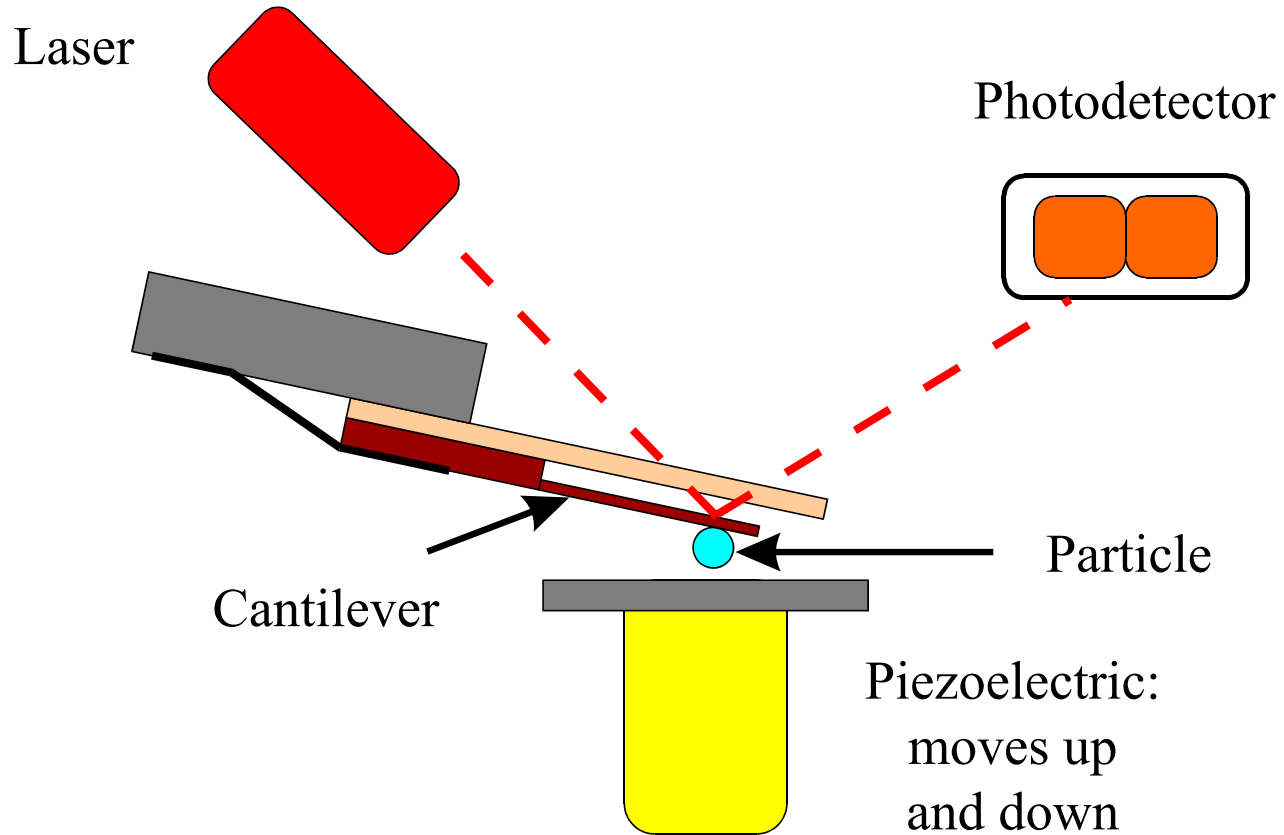


20 μm



AFM

Measure Single Particle Adhesion

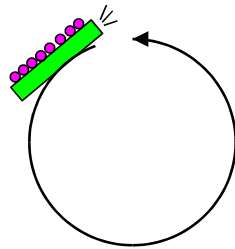




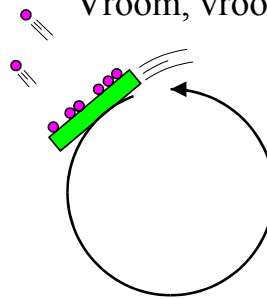
Centrifuge Detachment

Measure Many Particle Adhesion

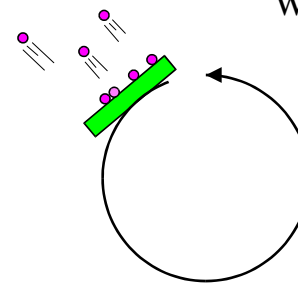
Putt, putt, putt,...



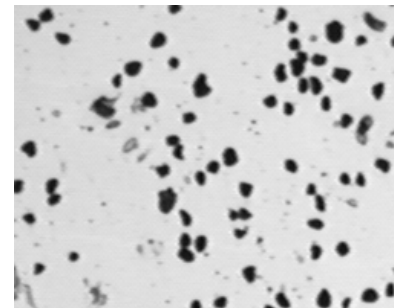
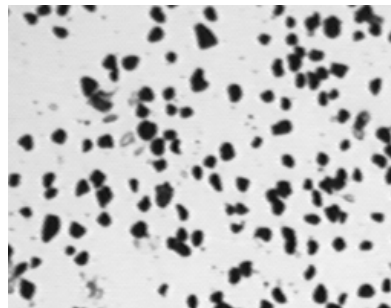
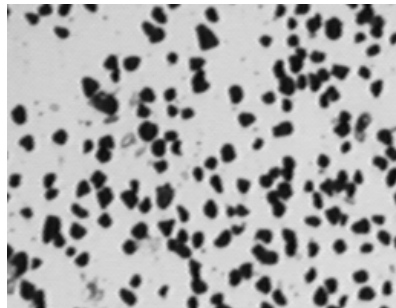
Vroom, vroom,...



Whoosh,...



Observe Donor Plate after Each Spin

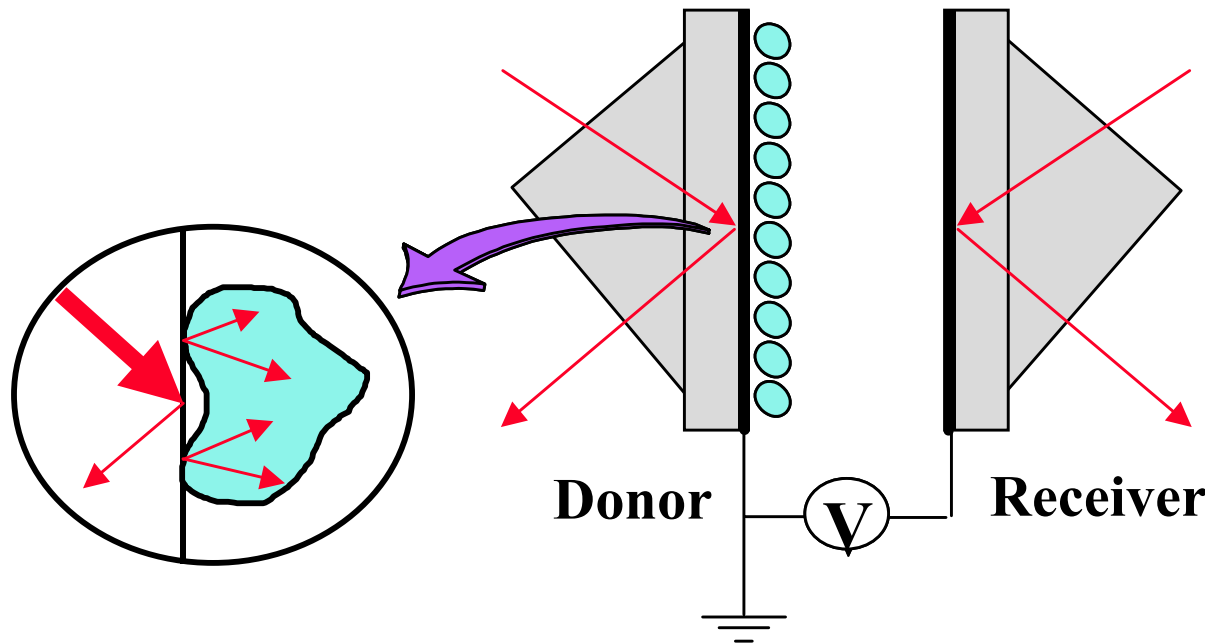


H. Mizes, "Adhesion of Small Particle", Electro. Soc. Amer.
Univ. of Rochester, 6/23/95



Electric Field Detachment

Measure Many Particle Adhesion



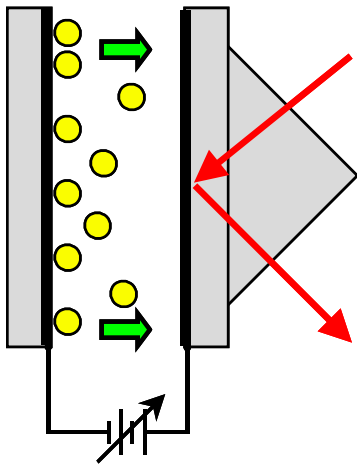
**transparent
conductive
electrodes**

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

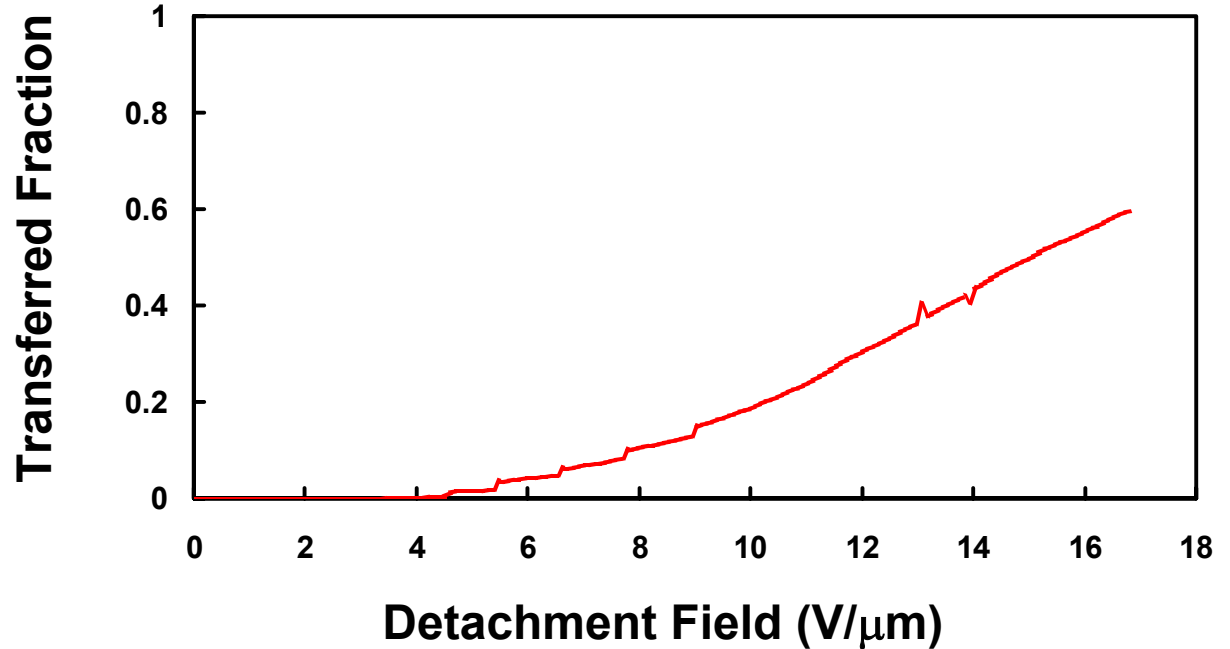


Electrical Field Detachment of Charged Toner

Detachment Cell

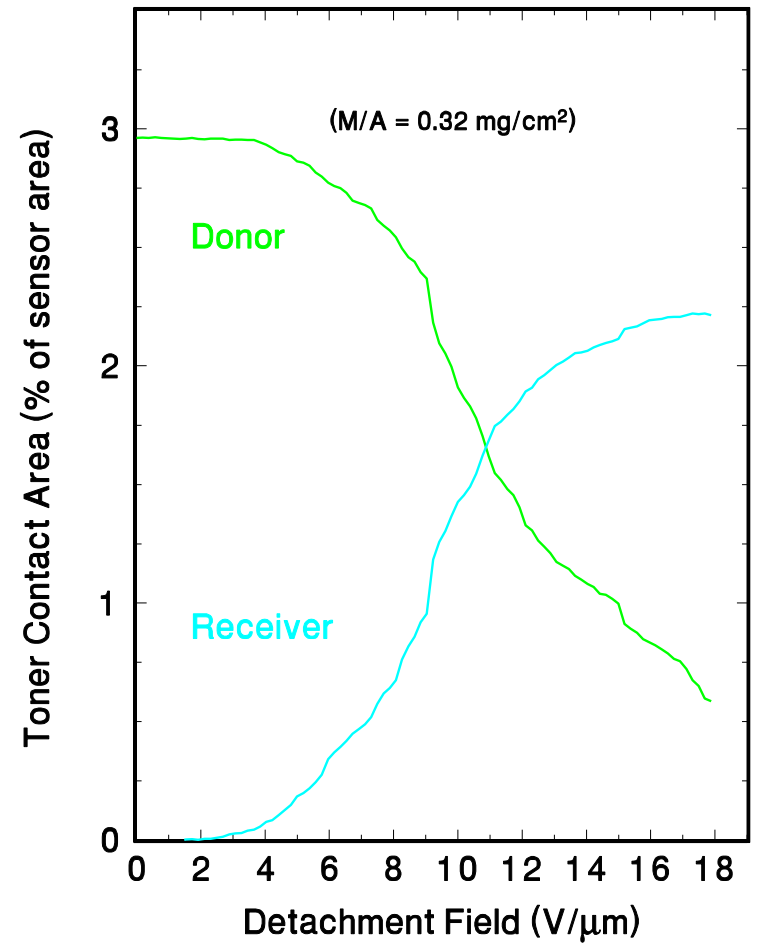
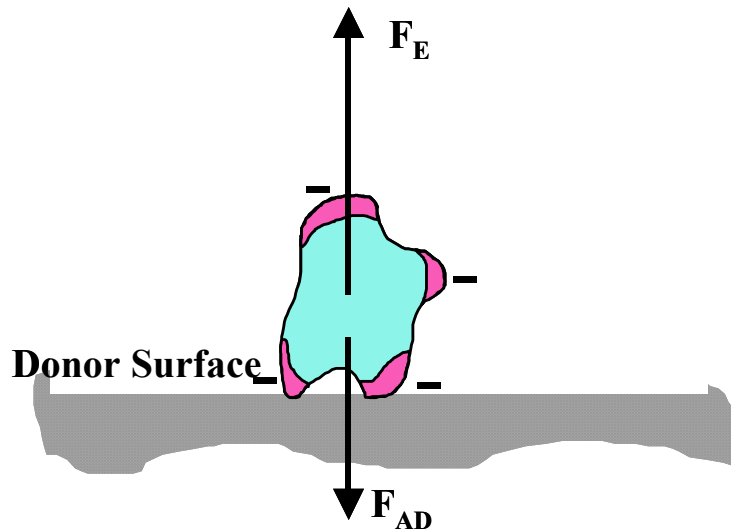


Adhesion of Triboelectrically Charged Toner





Toner Transferred
When $F_E > F_{AD}$



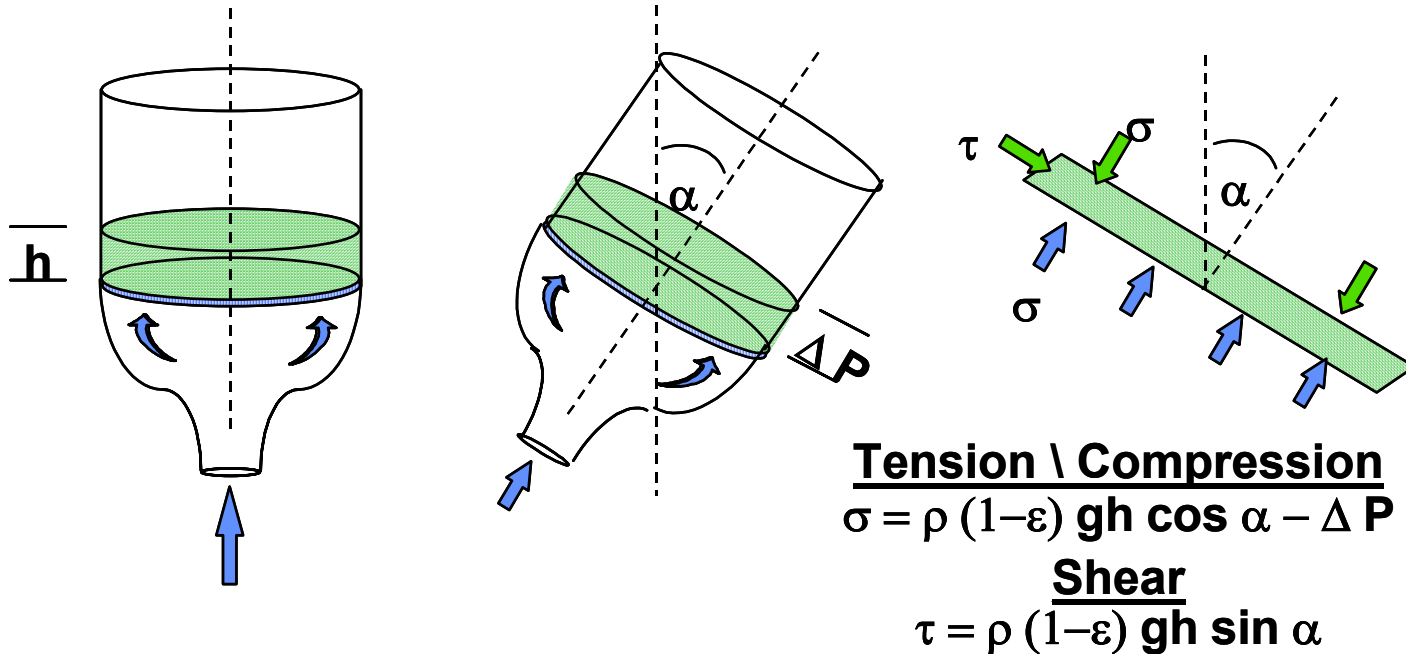
E. Eklund, W. Wayman, L. Brillson, D. Hays, 1994 IS&T Proc.,
10th Int. Cong. on Non-Impact Printing, 142-146



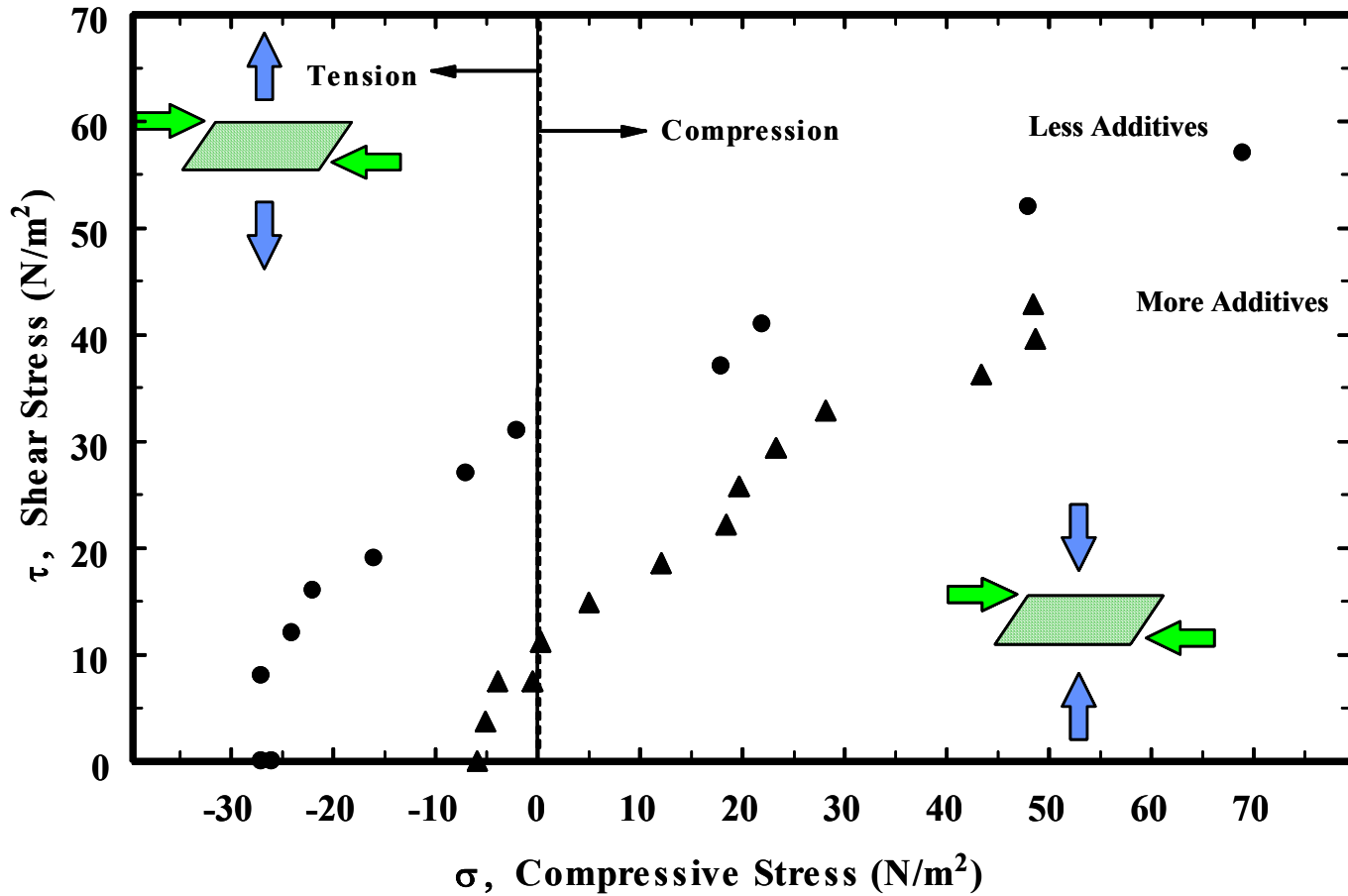
Fluidized Bed

Measure Powder Cohesion

Stresses on the toner bed



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





Q&A
