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On Counter-Charges in Development Rollers for Electrophotography

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Counter-Charges in Development Rollers for Electrophotography

- **Latent images developed by moving Charged Toners**
  - Extensively studied.
- **Counter-charges : Little attention**
  - Reside in carrier beads (2-component development),
  or development rollers (<u>S</u>ingle-<u>C</u>omponent <u>D</u>ev.)
- **Objectives:**
  - **Quantitative analyses of roles of counter-charges in Toner-charging and Toner-deposition in SCD**
  - **Requirements for ideal roller coating materials, and characterization method for SCD rollers**

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Single-Component Development (SCD)

1. Development Rolls:

Conductive elastomer core

Semi-insulator Coating

2. Toner Charging at Metering Blade (MB):

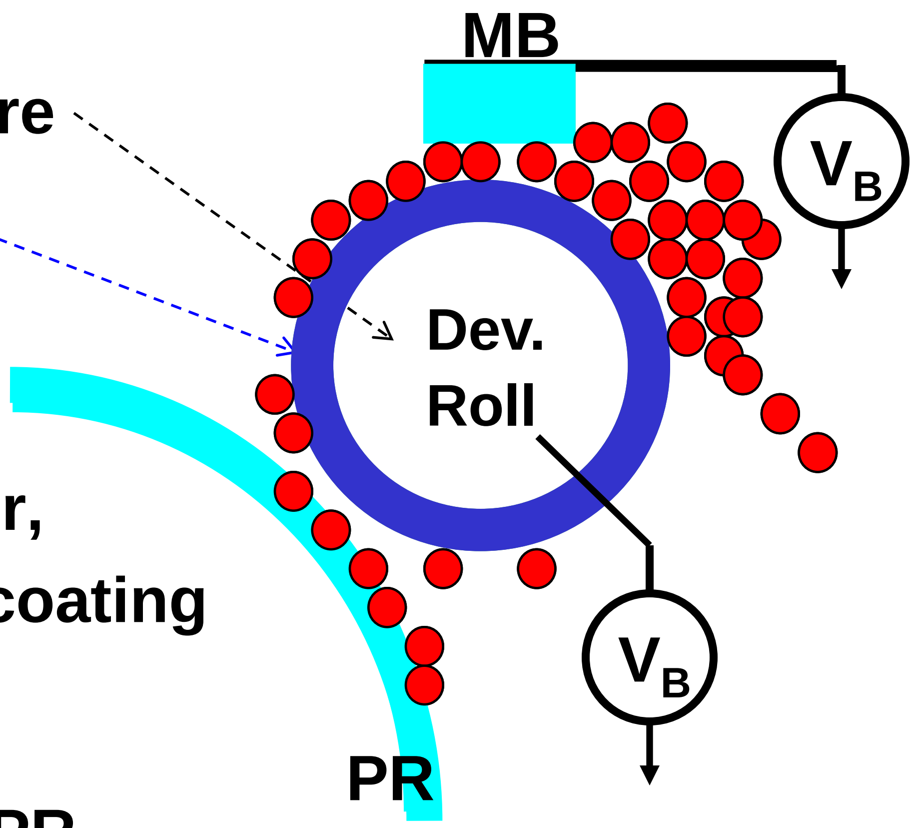
Charges supplied to toner,

Counter-charges to Roll coating

3. Toner deposition:

Charged toners move to PR,

Counter charges impede toner motion, must be removed (neutralized) to improve deposition efficiency



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Single-component Development

- Induction at charging, and

  Neutralization at deposition of Counter Charges

- Charge injection and transport

  in Semi-insulator Coating layer

- Charge-Transport Model

  Non-Ohmic nature

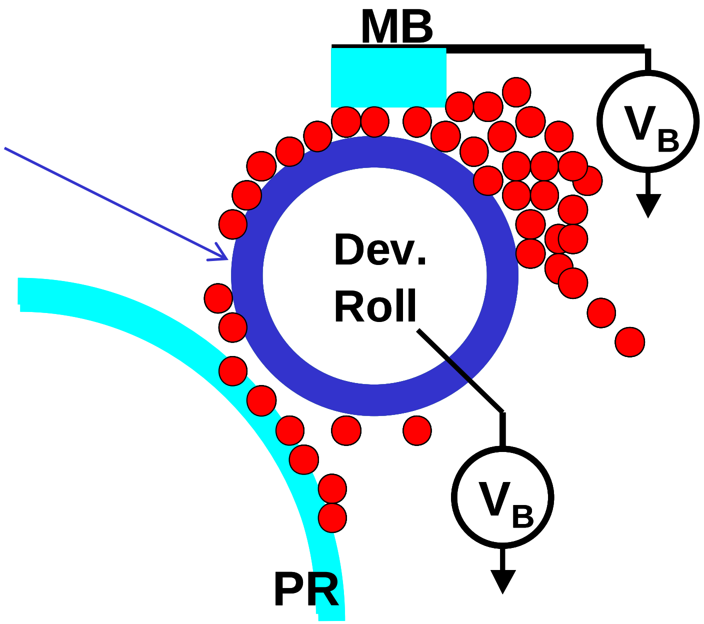
- Applied and reported :

  Roller charging of PR (NIP21)

  Electrostatic toner transfer (NIP16, 20, ICIS'06)

  Liquid development (J. App. Phy. 80, 6796)

  Counter-charges in SCD (This talk)



Charge Transport Model

- **Semi-insulators characterized by 3 parameters**

  1. Densities of mobile charges, $q_p(y, t)$, $q_n(y, t)$,

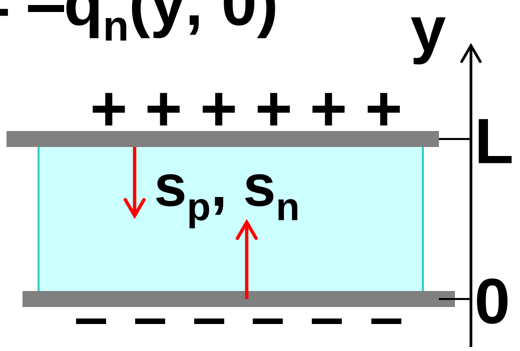
  Initial (intrinsic) value: $q_i = q_p(y, 0) = -q_n(y, 0)$

  2. Charge mobility: $\mu(E)$ - field dependent

  3. Charge injection strength s

  Injection currents from boundary at y

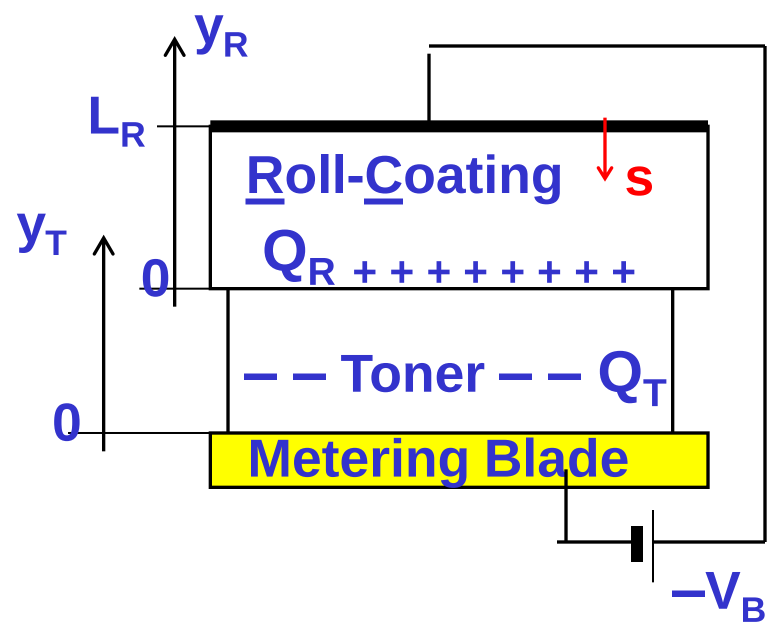
  $J_i = sE(y)$, E(y) = field at y (= 0 or L)



- **Continuity eq. $\partial q(y, t)/\partial t = -\partial(\mu q E)/\partial y$**
- **Poisson's eq. $\partial E(y, t)/\partial y = (q_p + q_n)/\varepsilon$**
- **Results for SCD charging and deposition**

Toner Charging in SCD (1)

	Toner	Coating
Thickness:	L_T	L_R
Permittivity:	ε_T	ε_R



- Bias voltage V_B
- Toner charge density:

$$Q_T(t) = [V_B - Q_R(t)D_R - U_R(t)]/(D_T/2 + D_R) \qquad (D = L/\varepsilon = 1/C)$$

- $Q_R(t)$ = Interface charge density
- $U_R(t) = \int_0^{LR} dy \int_0^{y'} (q_P + q_N)dy'/\varepsilon_R$

} Counter-charges

- Transport equations, calculate $Q_R(t)$, $U_R(t) \rightarrow Q_T(t)$

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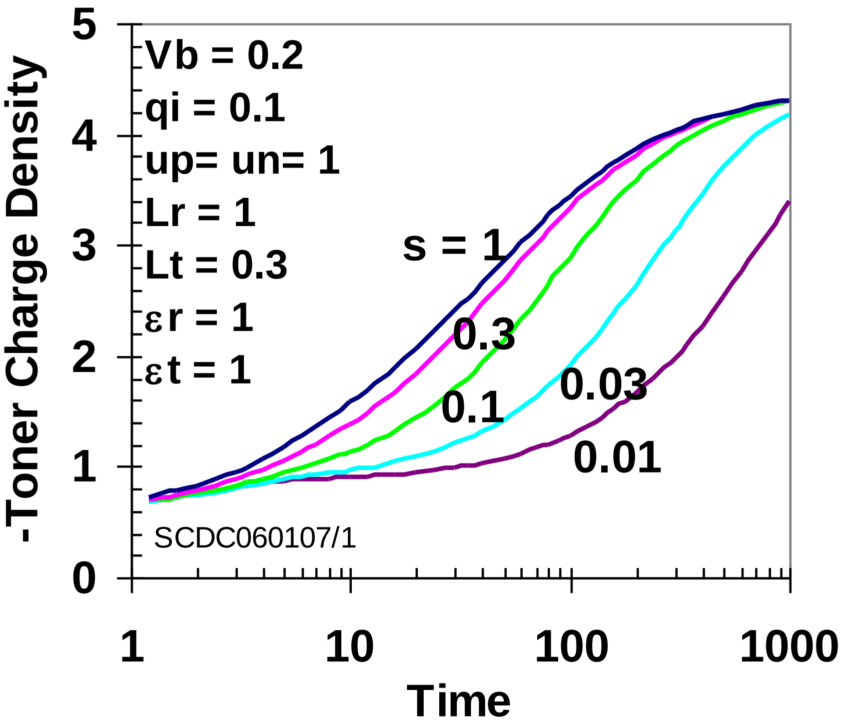
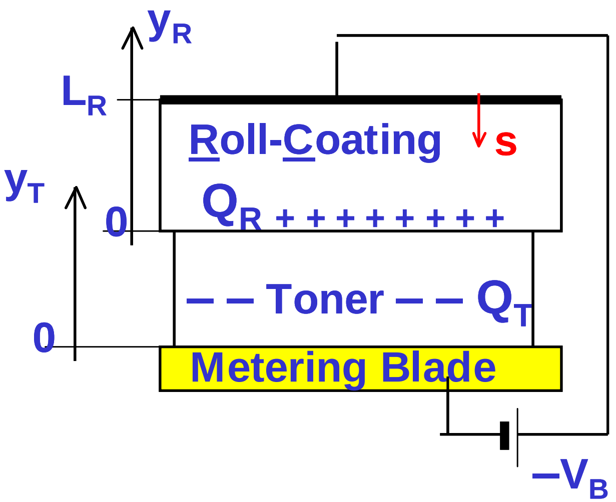
Toner Charging in SCD (2)

- **Growth of toner charge $Q_T(t)$ with time**





Units:

$t_o = L_R^2/\mu_o V_B \approx 10$ msec

$s_o = \mu_o q_o = \varepsilon_o / t_o \approx 3\text{x}10^{-11}$ S/cm

$q_o = \varepsilon_o V_B / L_R^2 \approx 3\text{x}10^{-6}$ C/cm^3

- **Dependence on Injection Strength s very significant at $t \approx 100t_o$**

- **High speed printing -- short charging time: high s important**

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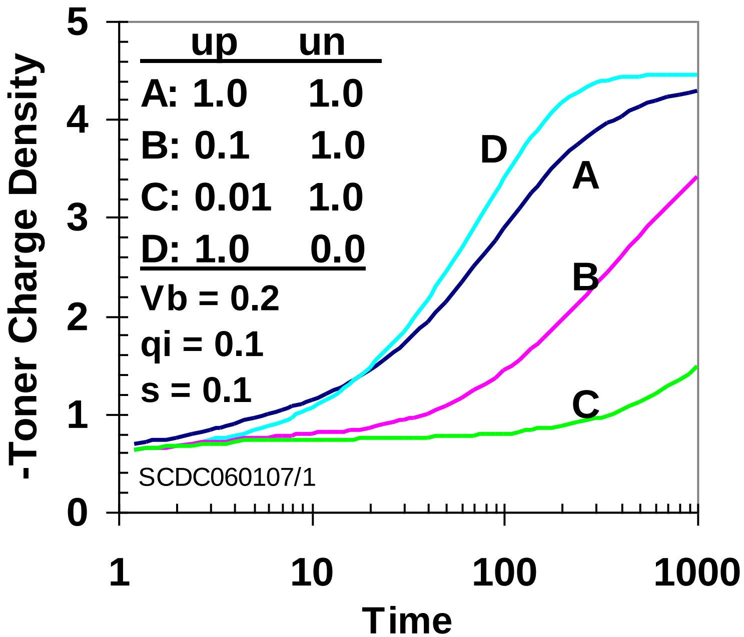
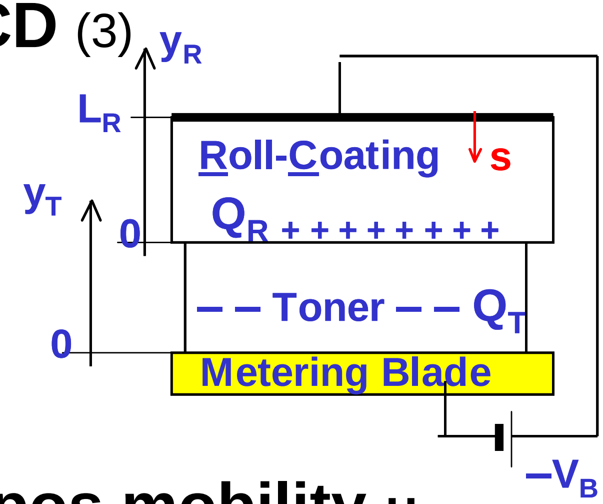
Toner Charging in SCD (3)

- **Dependence on mobility μ_p, μ_n**



in RC



For $Q_T < 0$

- **Smaller pos mobility μ_p has significant effect (A, B, C)**
- **Insensitive to neg μ_n (A, D)**
- **Build-up of counter-charge mostly from injection of pos charge from V_B, not from depletion of neg charge in coating layer**

Units

Mobility: μ_o $\approx 10^{-5}$ cm²/ Vs

Time: $t_o = L_R^2/\mu_o V_B$ $\approx 10^{-2}$ sec

Chg density: $q_o = \varepsilon_o V_B / L_R^2$ $\approx 3\times10^{-6}$ C/cm³

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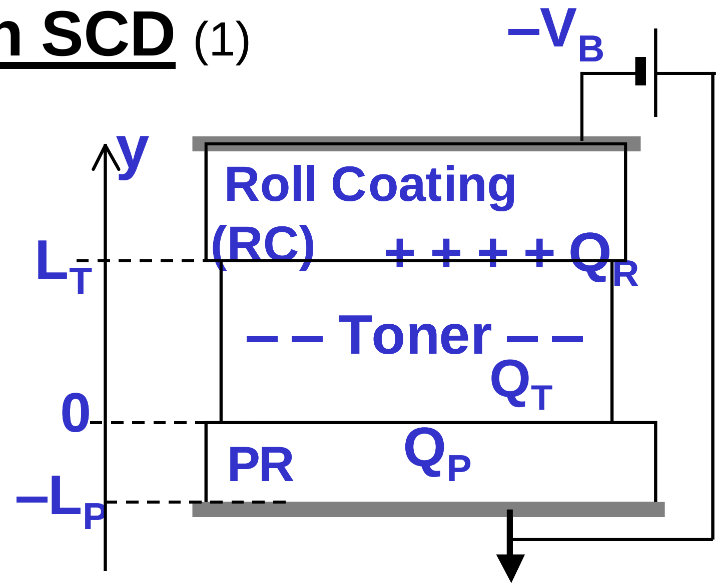
Toner Deposition in SCD (1)



- **Fields and Voltages in layers**
  - **Photoreceptor: E_P, V_P**
  - **Toner-layer: $E_T(y)$, V_T**
  - **Roller coating: $E_R(y)$, V_R**
- **Bias voltage: $-V_B = V_P + V_T + V_R$**
- **Gauss' theorem relates charges Q_P, Q_R, Q_T to E's**
- **Field in toner layer:**

$$E_T(y, t) = E_{T0} + (Q_T/\varepsilon)(y/L_T)$$ (detail in Proc. paper)

$$= \text{func.}[V_B, Q_P, Q_T, Q_R(t), U_R(t), L\text{'s}, \varepsilon\text{'s}]$$

- **Injection & transport of Counter-charges in RC contribute to $Q_R(t)$, $U_R(t)$**

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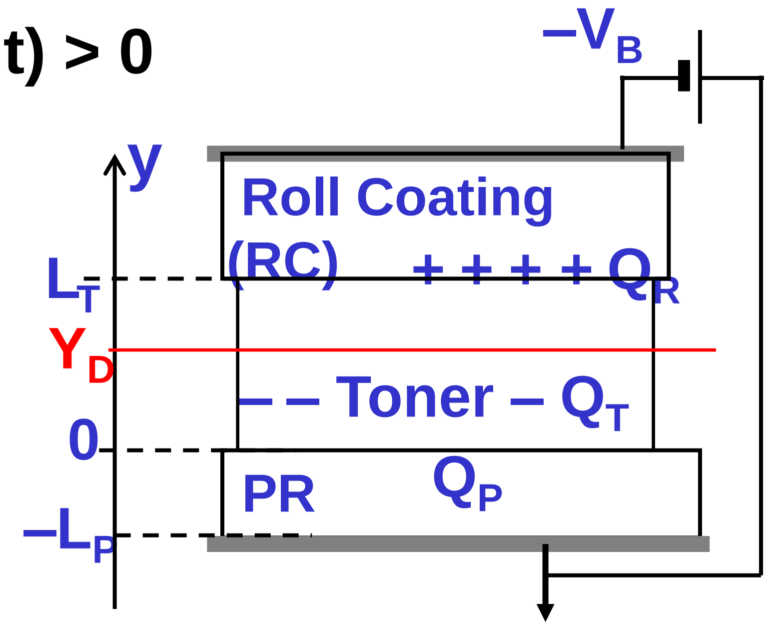
Toner Deposition in SCD (2)



- Negative toner deposition: $E_T(y, t) > 0$
- Demarcation line at $y = Y_D$

  $E_T > 0$ for $y < Y_D$

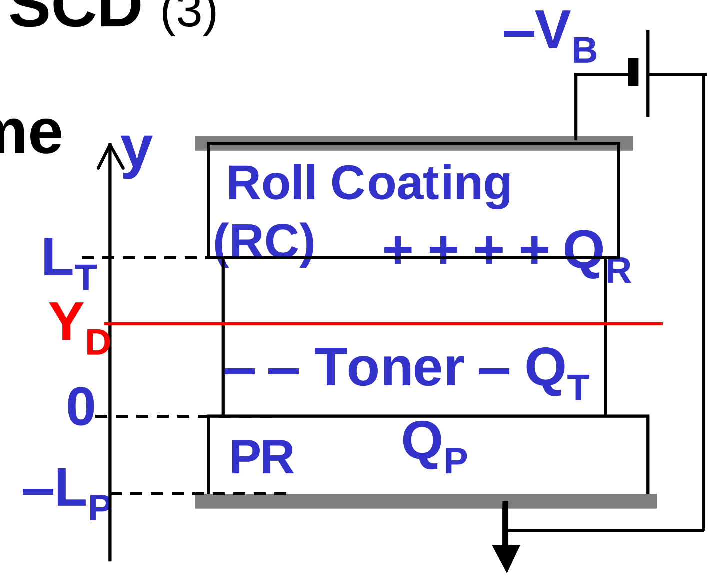
  $E_T < 0$ for $y > Y_D$
- $E_T(Y_D) = E_{T0} + (Q_T/\varepsilon_T)(Y_D/L_T) = 0$
- Deposition efficiency:

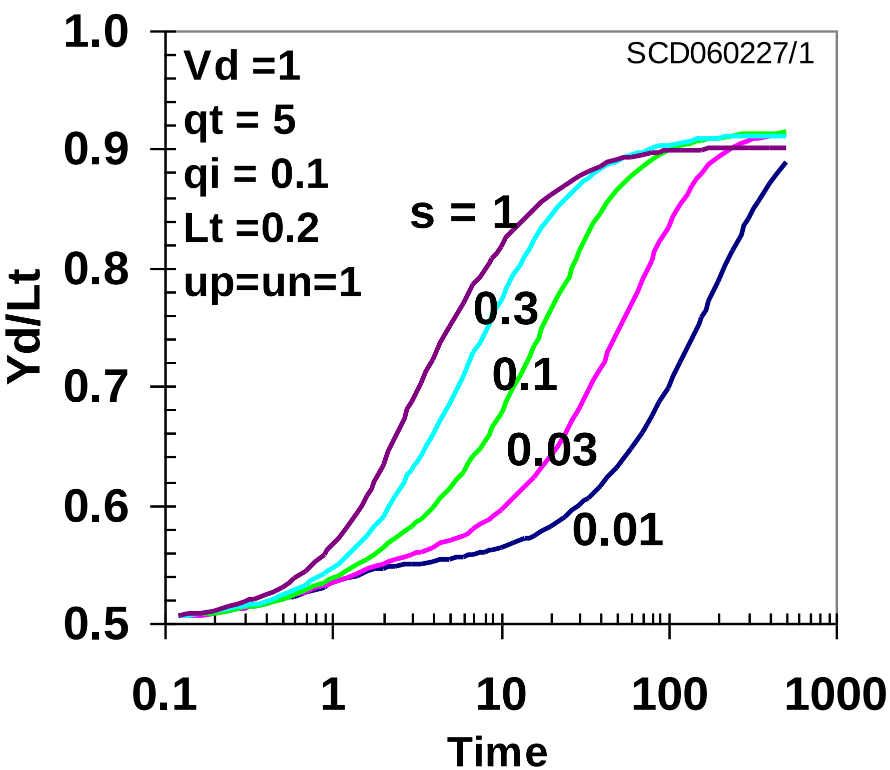
  $Y_D/L_T = -\, \varepsilon_T E_{T0}/Q_T$

  $= \text{func.}[V_B, Q_P, Q_T, Q_R(t), U_R(t), L\text{'s}, \varepsilon\text{'s}]$ (in proc. paper)
- $Q_R(t)$, $U_R(t)$ from Transport Eqs.
- Time evolution of Deposition efficiency Y_D/L_T

Toner Deposition in SCD (3)

- Deposition efficiency Y_D/L_T vs. time
- Dependence on strength s of injection into RC from V_B





- Significant effects due to small s, in time 10 < t <100
- Time unit: $t_o = L_R^2/\mu_o V_B \approx 10$ msec

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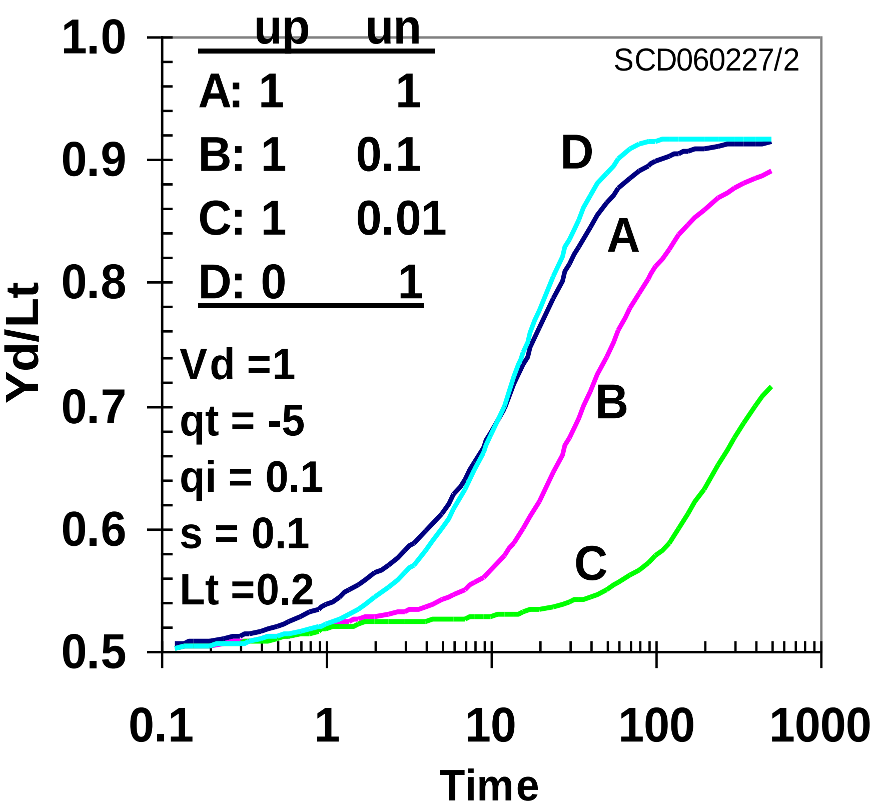
Toner Deposition in SCD (4)

- Charge mobility (μ_P, μ_N) dependence of Y_D/L_T (Q_T< 0)



- Neg. μ_n reduced (A →B →C)
  → Significant decrease
- Pos. μ_p reduced (A →D)
  → No effects
- Neutralize Counter-charge requires negative charge injection and transport
  → opposite to polarity required at charging

For efficient charging & deposition, it requires good injection (s) and transport (μ) for both pos and neg charges in SCD roller-coating

Summary and Conclusions (1)

- **In SCD, Counter Charges in semi-insulator coating**
  Induced at toner Charging, and
  Neutralized at toner Deposition steps
- **Analyses: Charge-Transport model**
- **Good bi-polar charge injection and transport**
  e.g., for negative toners,
  Pos. charge inject. & transport for Charging
  Neg. charge inject. & transport for Deposition
- **Process time >≈ 100 t_o ($t_o = L_R^2/\mu V_B$)**
  High speed printing requires high mobility μ (+ and –)
- **Dev. Roller performance can't be evaluated properly**
  with closed-circuit resistance measurements

Summary and Conclusions (2)

- **Alternative evaluation method:**

  Electrostatic Charge Decay (ECD) technique

  (NIP-11, 15, 16, 17; ICIS'02; JHC-00, 02, 05)

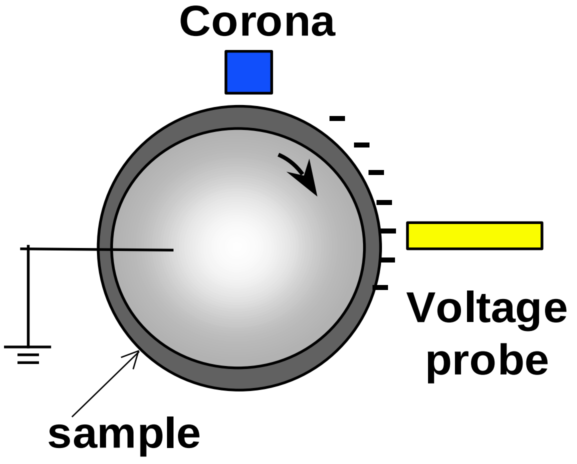
- **Open-circuit voltage decay**

  - simulating actual process in Electrophotography

- **Field applied by Corona charging**

  - Scan and map large area,

  efficient, non-destructive



- **Applied to transfer belts, paper,**

  charge rolls, dev- rolls, PR

- **Consistently predict device performance**

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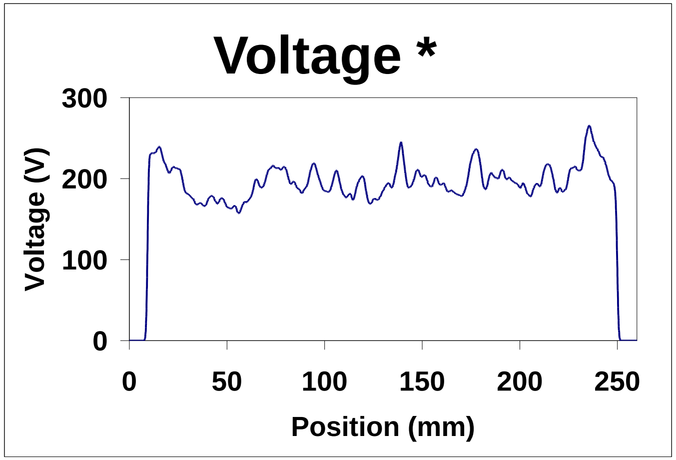
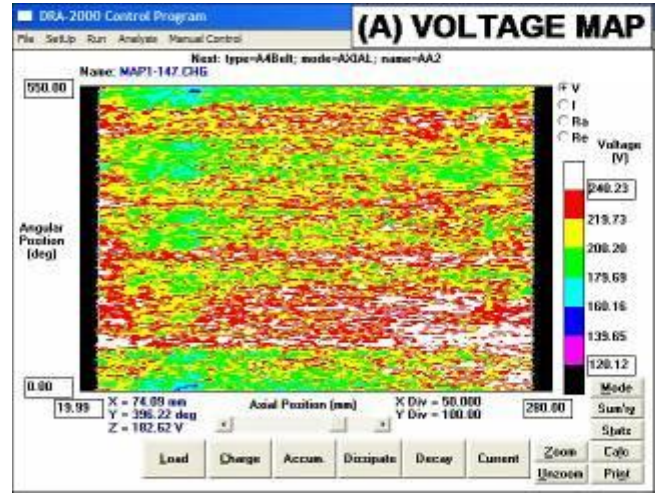
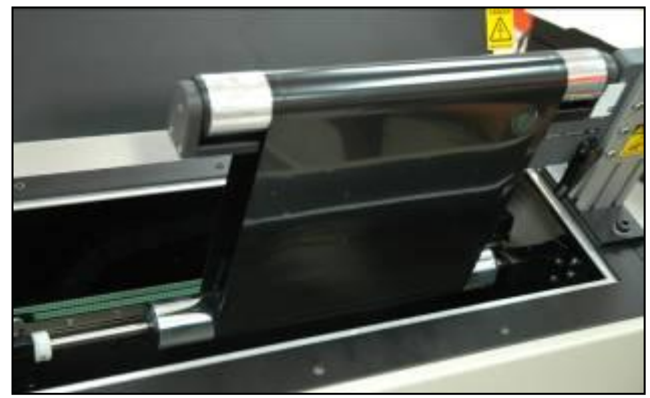
ECD Data for Intermediate Transfer Belt







Rolls and Belts Testing Fixture

Exhibit Booth #210

NIP-22 Denver, September. 2006

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