Charge Roller Testing: Fundamentals and Practice

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Charge Roller Testing: Part I - Fundamentals

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Introduction (1)

- The charge roller is a critical component in modern electrophotographic (EP) printers. Its function is to provide sufficient charge onto the OPC. If it does not function properly, print quality problems such as non-uniformity in density, background and ghosting will result.
- The purpose of this report is to introduce an advanced technology for charge roller testing and diagnostics. The technology is a novel, patented technology developed by QEA called "Electrostatic Charge Decay (ECD)."

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Introduction (2)

- The ECD technology is implemented in a commercially available measurement system, the DRA-2000L. "DRA" stands for dielectric relaxation analysis. It is the most advanced test system today for evaluation of semi-insulating EP components such as the charge roller, mag roller sleeve, development roller, transfer roller, transfer belt and print media.
- The ECD technology overcomes the limitations in the conventional Ohmic resistance measurement method for characterizing charge rollers. The DRA design simulates the physics in the charging process correctly and consequently, the measurement is a very good predictor of charge roller performance.

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Introduction (3)

- Earlier versions of DRA-2000L include the CRT-2000L and MRT-2000L designed specially for testing charge rollers and mag roller sleeves respectively. While the principle behind the three models are identical, the DRA has more advanced functions than both the CRT and MRT, and it is more adaptable to testing the full range* of semi-insulating EP devices.
- Specifically, the DRA includes an equivalent resistance reporting function that was not implemented in the earlier CRT and MRT models. Equivalent resistance is a useful figure of merit for semi-insulating EP devices.

* Proper adapters, add-on fixtures & appropriate software required.

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Introduction (4)

- For an EP device such as a charge roller to function properly, the semi-insulators used must be engineered to provide specific electrical properties.
- The electrical conduction or charge transport mechanism in semi-insulators is very complex. Therefore, its characterization requires a more sophisticated approach than the conventional ohmic resistance measurement method.
- The conventional method uses a static, contact and spot measurement, whereas the ECD method uses dynamic, non-contact measurements that enable large area scanning.

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Introduction (5)

- In this report, the principle of the ECD technology and its implementation in the DRA system for charge roller testing will be reviewed.
- The application of this technology is demonstrated in a case study using a set of charge rollers intended for a modern desktop laser printer*.
- In this case study, both the OEM* and a collection of aftermarket rollers are used to illustrate how the DRA system can be used in materials R&D, production process development, quality control, problem diagnostics, and assessing the reusability of recycled components.

* Hewlett Packard Laserjet HP4000

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Report Contents

- Review on charge roller design, charging mechanism and functional requirements
- Description of the ECD technology and the principle of the DRA system
- ECD measurement parameters and correlation with charge roller performance
- A case study on Laserjet HP4000 charge rollers; 24 samples, which include OEM (new and old) and aftermarket specimens were used.
- Correlating electrical properties and print quality
- Discussion & summary

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Charge Roller Design and Charging Mechanism

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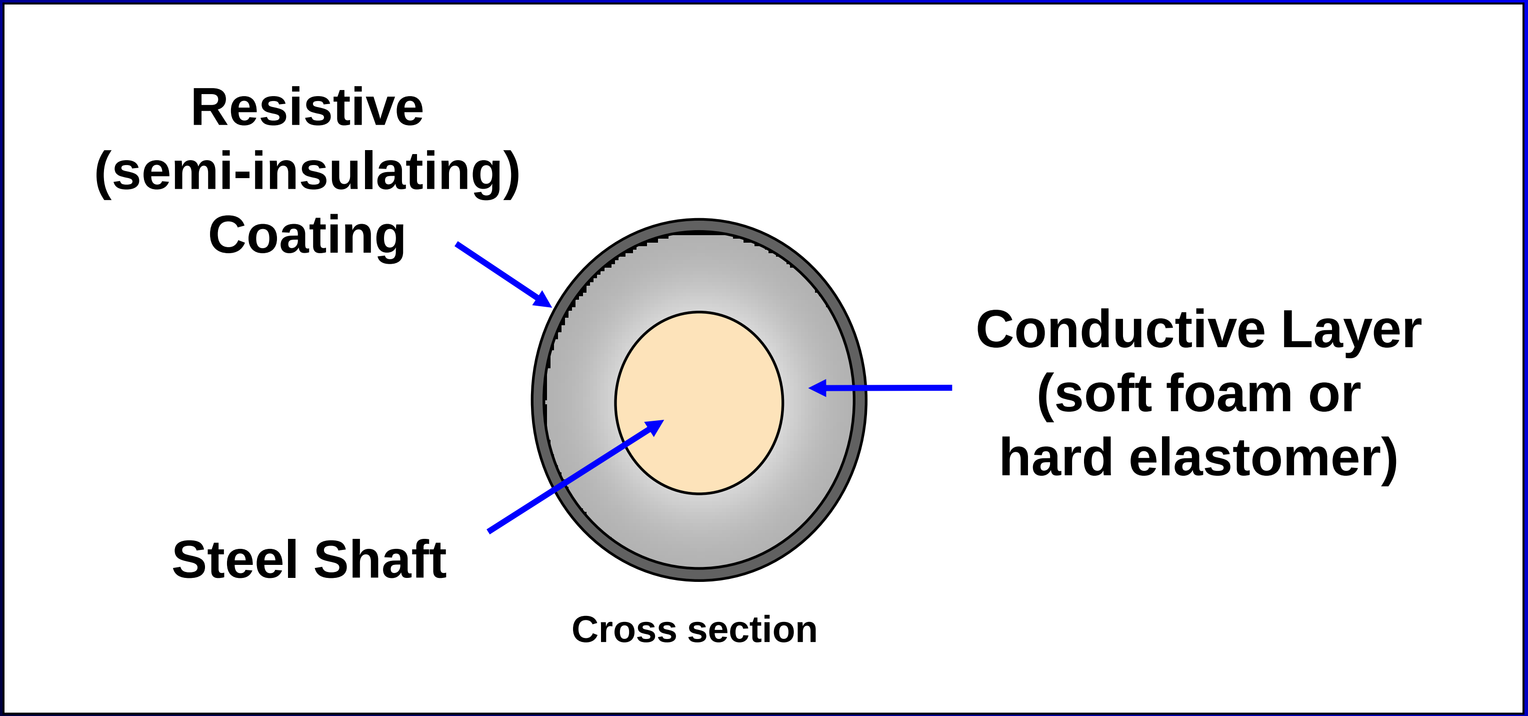
A Representative Charge Roller Design

- The middle layer in a charge roller has a relatively short time constant and hence it behaves as if it is electrically conductive.
- The resistive (semi-insulating) coating, typically 100-200μm in thickness, is for protecting the OPC from damage by arcing.



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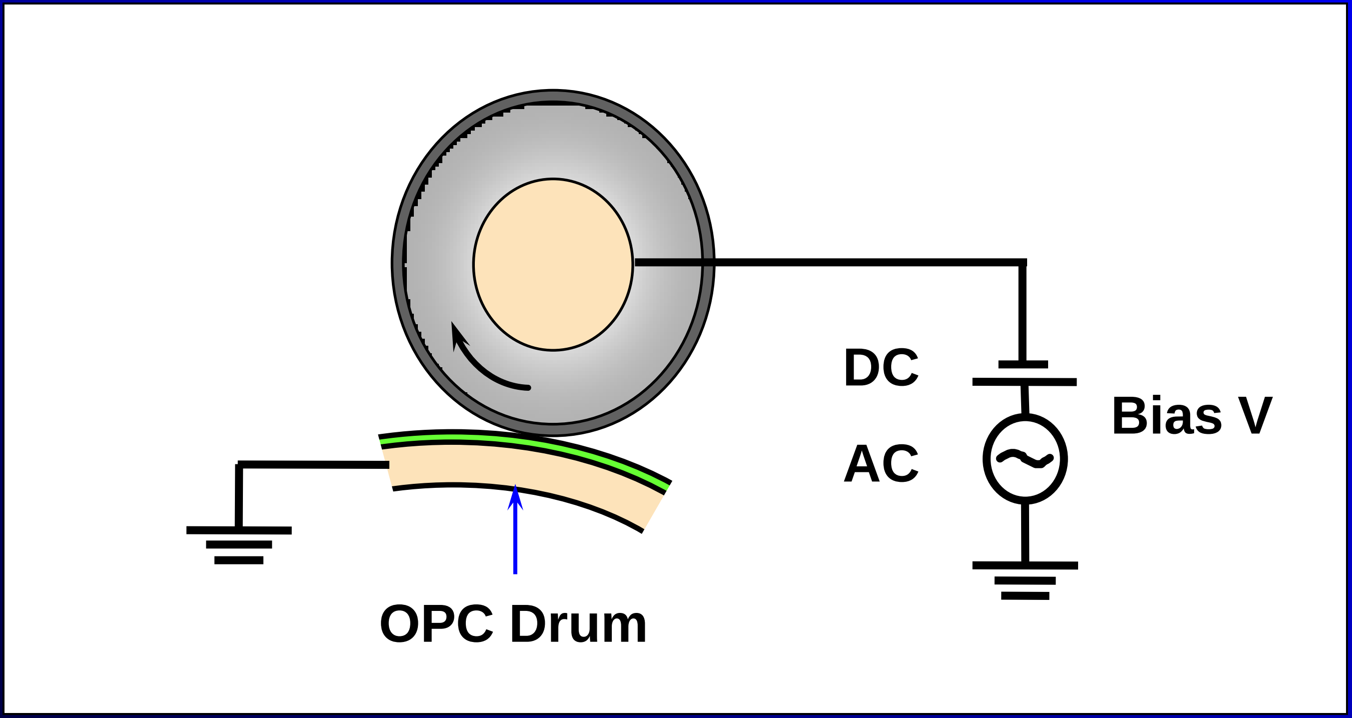
A Typical Charge Roller Charging System

- The bias voltage is either DC only or DC with AC superimposed.
- The HP Laserjet family uses the DC & AC configuration, whereas a few other brands use a DC only design. The operational difference between the two configurations will be examined next.



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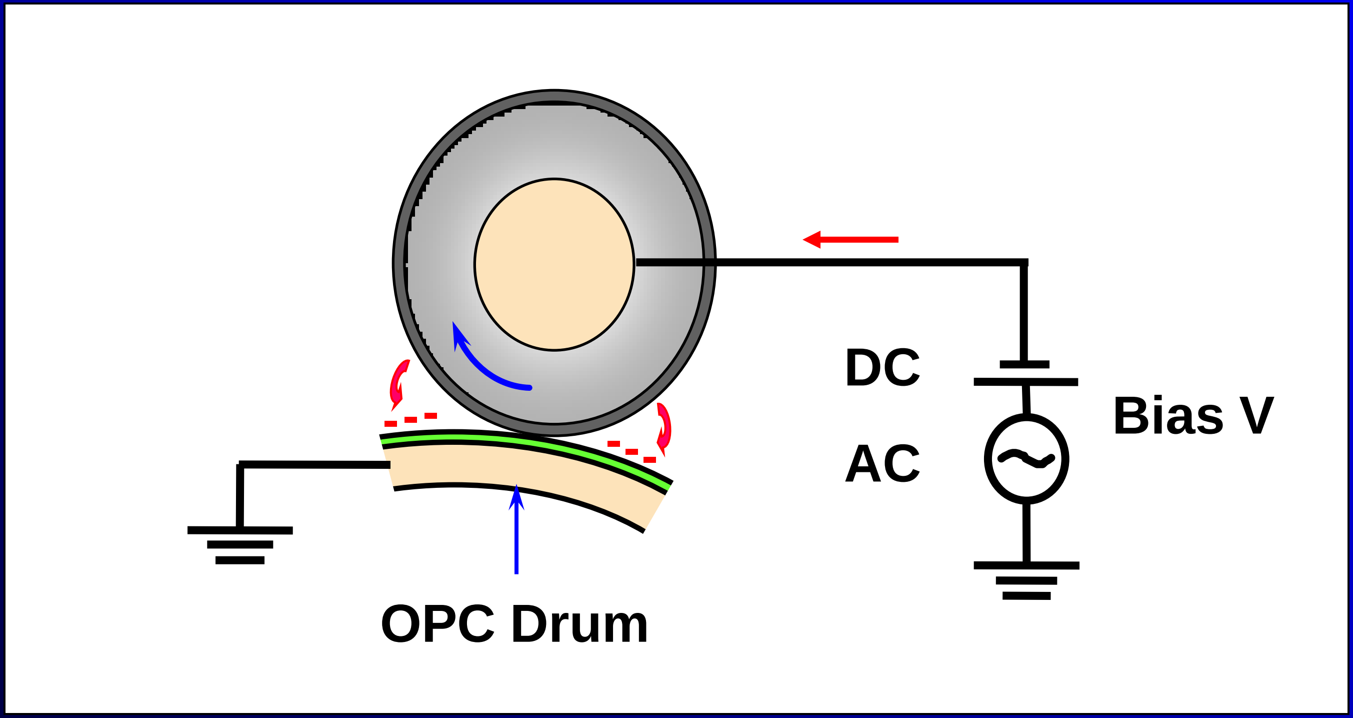
Mechanism of Charge Roller Charging (1)

- The bias voltage creates a non-uniform high electric field at the air gaps between the charge roller and the OPC.
- If the field strength in the airgap is high enough, corona occurs, and ions are generated and driven onto the OPC.



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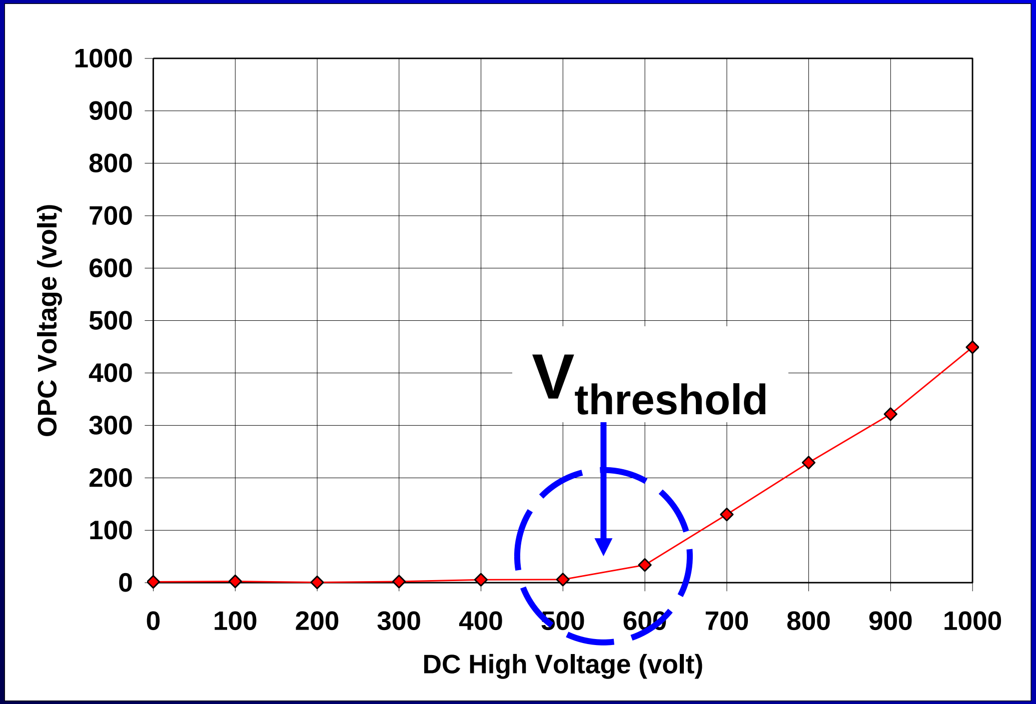
Mechanism of Charge Roller Charging (2)

- A strong evidence for this corona charging mechanism is that a threshold voltage on the order of 500-600V is required to initiate the charging process. This is a consequence of the Paschen breakdown condition for corona discharge in air, i.e., a minimum bias voltage is required before any charge starts to build onto the OPC.



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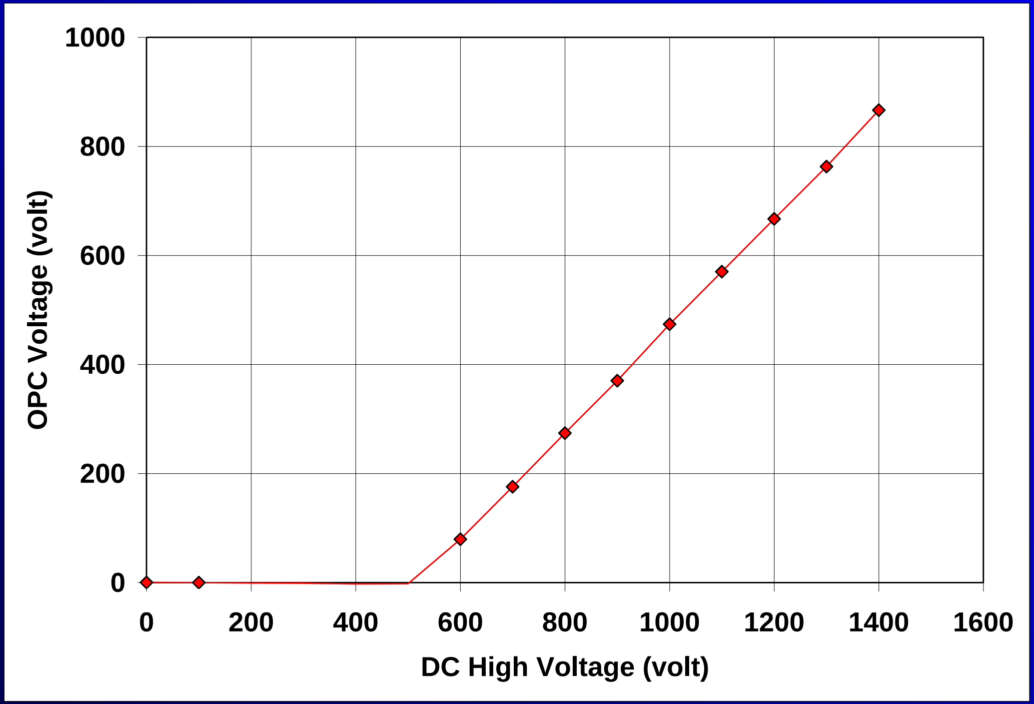
Operational Characteristics – DC Only (1)

- If only a DC bias is applied (i.e., AC=0), a minimum voltage of about 500-600V is required to initiate the charging. Once the DC bias increases above the $V_{threshold}$, charge begins to build up on the OPC, and the OPC voltage increases linearly with the incremental DC voltage.



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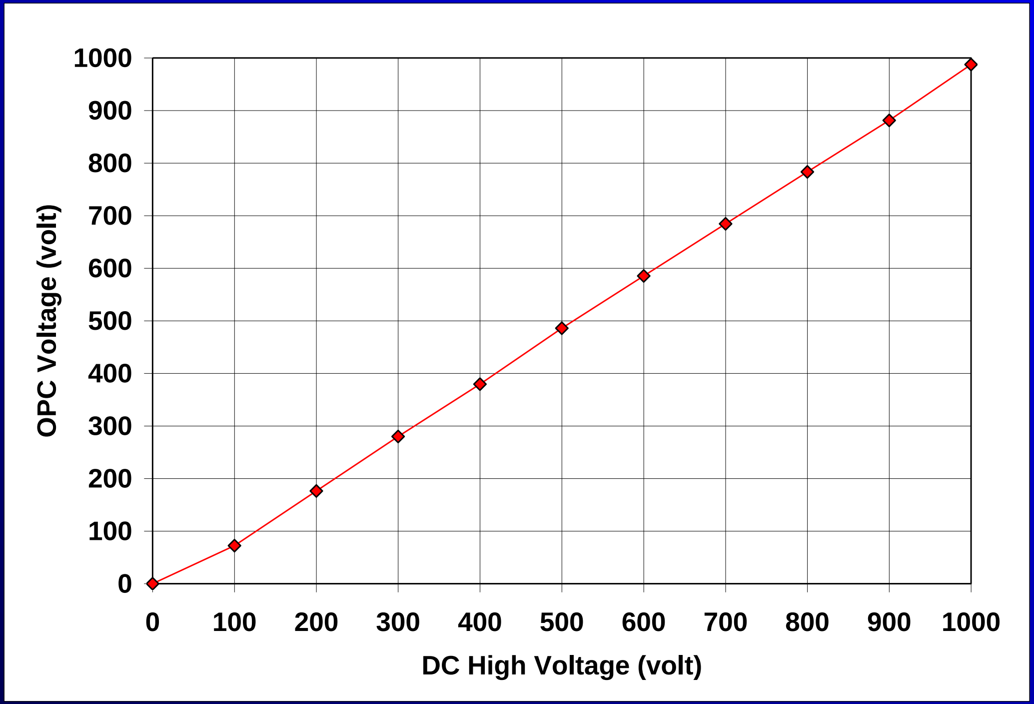
Operational Characteristics – DC+AC (2)

- If the AC bias voltage is approximately $1600V_{pp}$ or above, the OPC voltage is linearly dependent on the DC bias (one-to-one) with no DC threshold required as shown below.
- In other words, if the charging system and its components including the charge roller are functioning properly, $V_{opc} \cong V_{dc}$ for $V_{ac} \geq 1600\ V_{pp}$.



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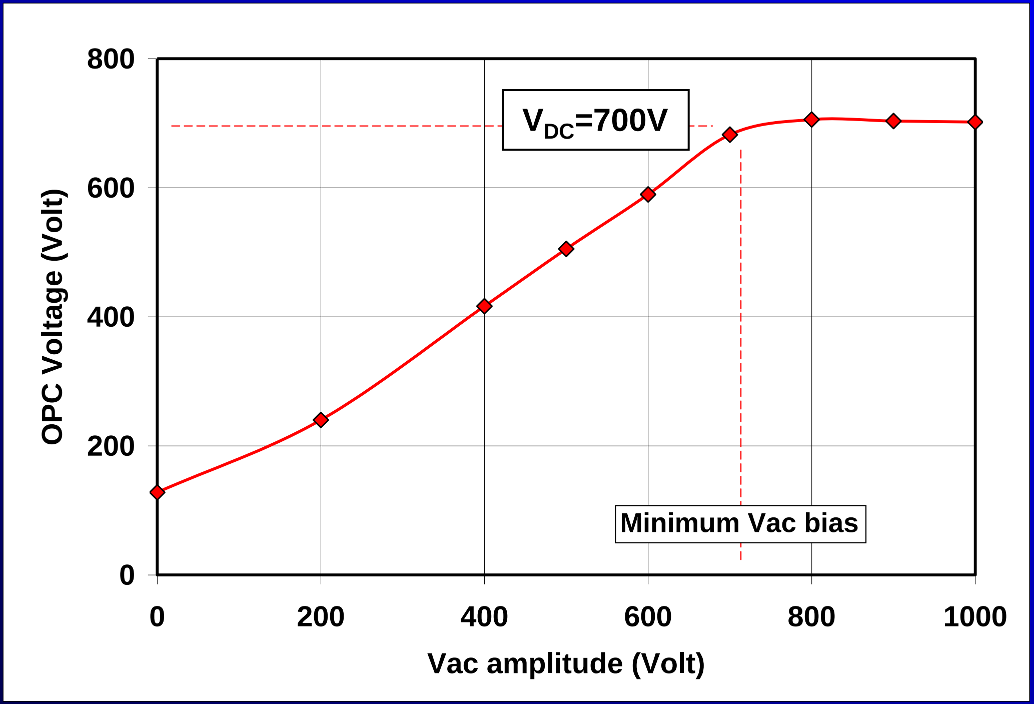
Operational Characteristics – DC+AC (3)

- The graph below further illustrates the DC+AC effect on V_{opc}.
- As V_{ac} sweeps from zero to above $1600V_{pp}$ (or $800V_{amplitude}$), the V_{opc} approaches a peak values controlled by the DC bias.
- The quality of a charge roller will affect the efficiency of the charging process, the charge level on the OPC, and the final OPC voltage.



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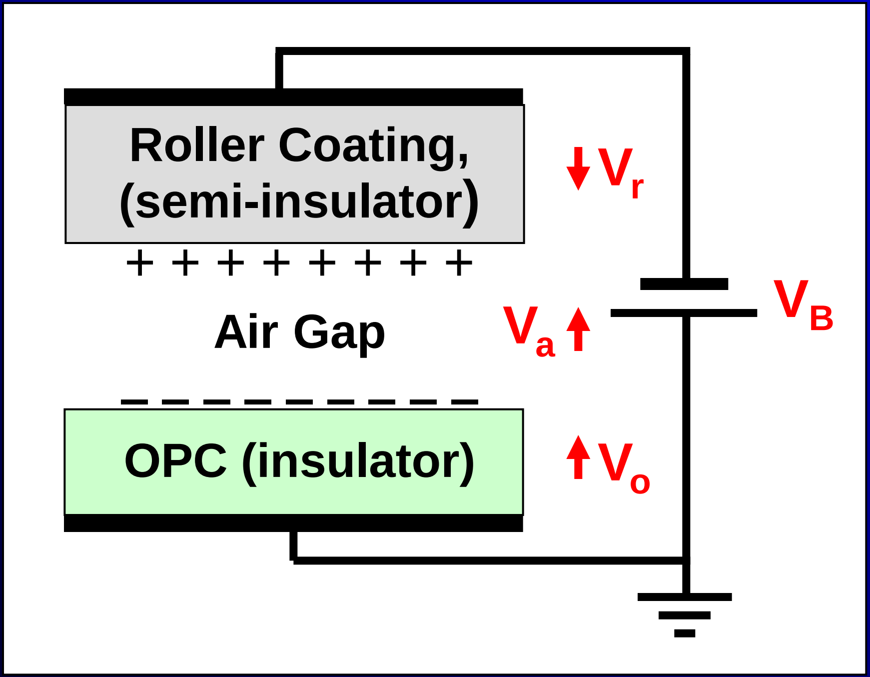
Requirement for Efficient Charging

- Consider the following conceptual model of the electrical circuit in the charging system. In this model, V_r is the voltage across the roller coating.
- As charging progresses, in order for V_o on the OPC to increase, V_r must stay sufficiently low to ensure that V_a remains greater than $V_{threshold}$.



- $V_B = V_r + V_a + V_o$
- For charging, i.e., for V_o to increase:
  1. $V_a \geq V_{threshold}$
  2. V_r must be as low as possible or at the least decrease as charging progresses
  3. The decrease in V_r is called dielectric relaxation
- Fast dielectric relaxation in the charge roller material is the key to efficient (and correct) charging.

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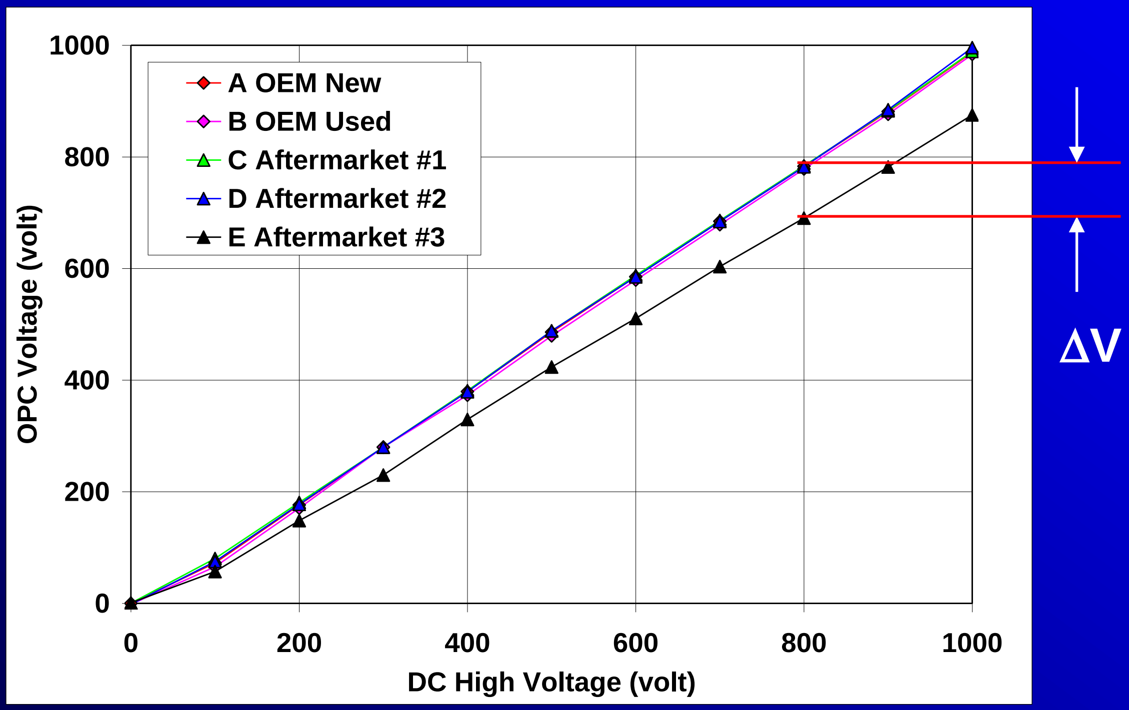
Impact of Charge Roller Quality on V_{opc}

- In this example, the V_{opc} generated from 5 different charge rollers was measured*. As shown, rollers A, B, C and D all charge the OPC quite similarly, but roller E produces a significantly lower V_{opc} (by ~100V).
- As demonstrated later, roller E has a significantly lower dielectric relaxation.



* V_{opc} measured in QEA's PDT-2000LA Advanced Drum Test System.

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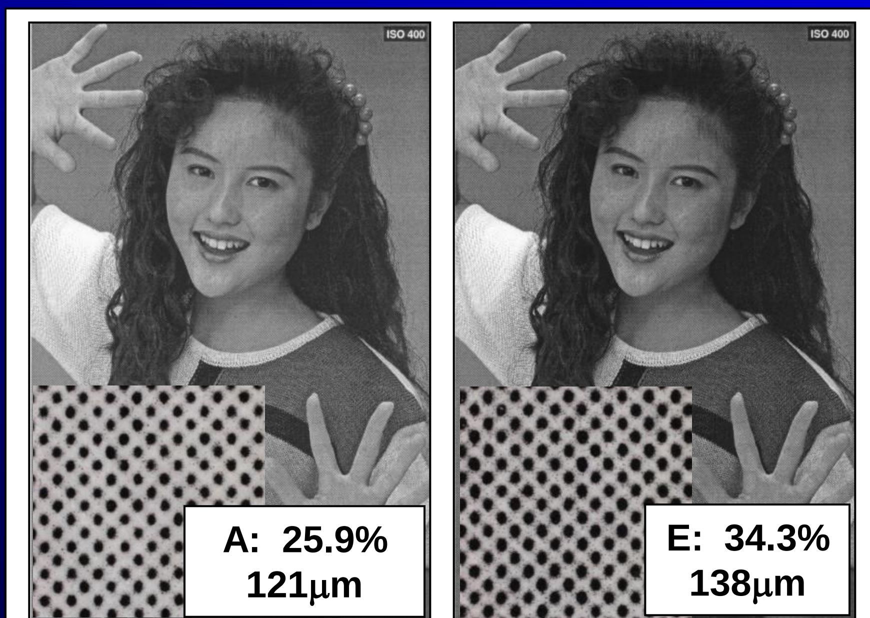
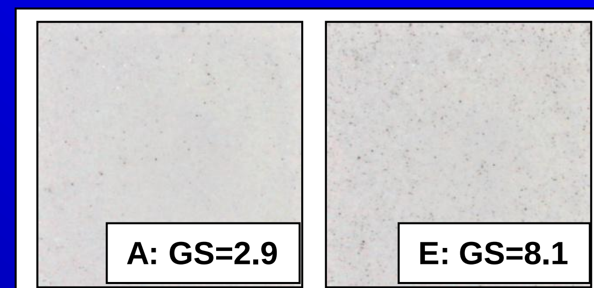
Effect of V_{opc} on Print Quality

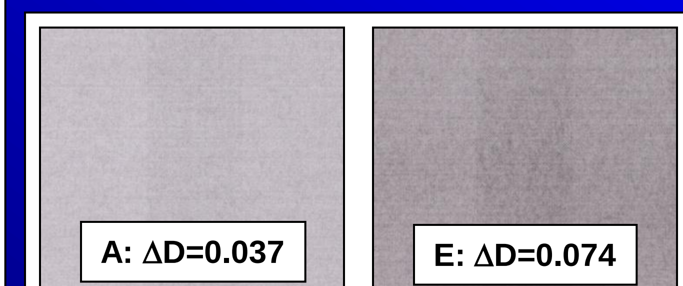
- The significantly lower OPC charge voltage in Sample E affects a number of print quality attributes including dot gain, tone reproduction, background and ghosting.
- The following is an example to illustrate this observation.



Tone reproduction & dot gain



Background



Ghosting

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Test Methods for Semi-insulating Charge Rollers

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Semi-Insulators – What Are They

Semi-Insulators

- Large-area electronics, electrophotography
- Amorphous, molecular, organic, composite, polymers, colloids
- Organic photoreceptors, resistive coatings on rollers and belts, paper, liquid developers

Semi-Conductors

- Microelectronics
- Covalent, inorganic, single crystals
- Silicon, Germanium,
  CdS, CdSe, (II-VI)
  GaAs (III-V)

Common: Low electrical conductivity (σ)

$$\sigma = \text{charge mobility } (\mu) \times \text{charge density } (q)$$

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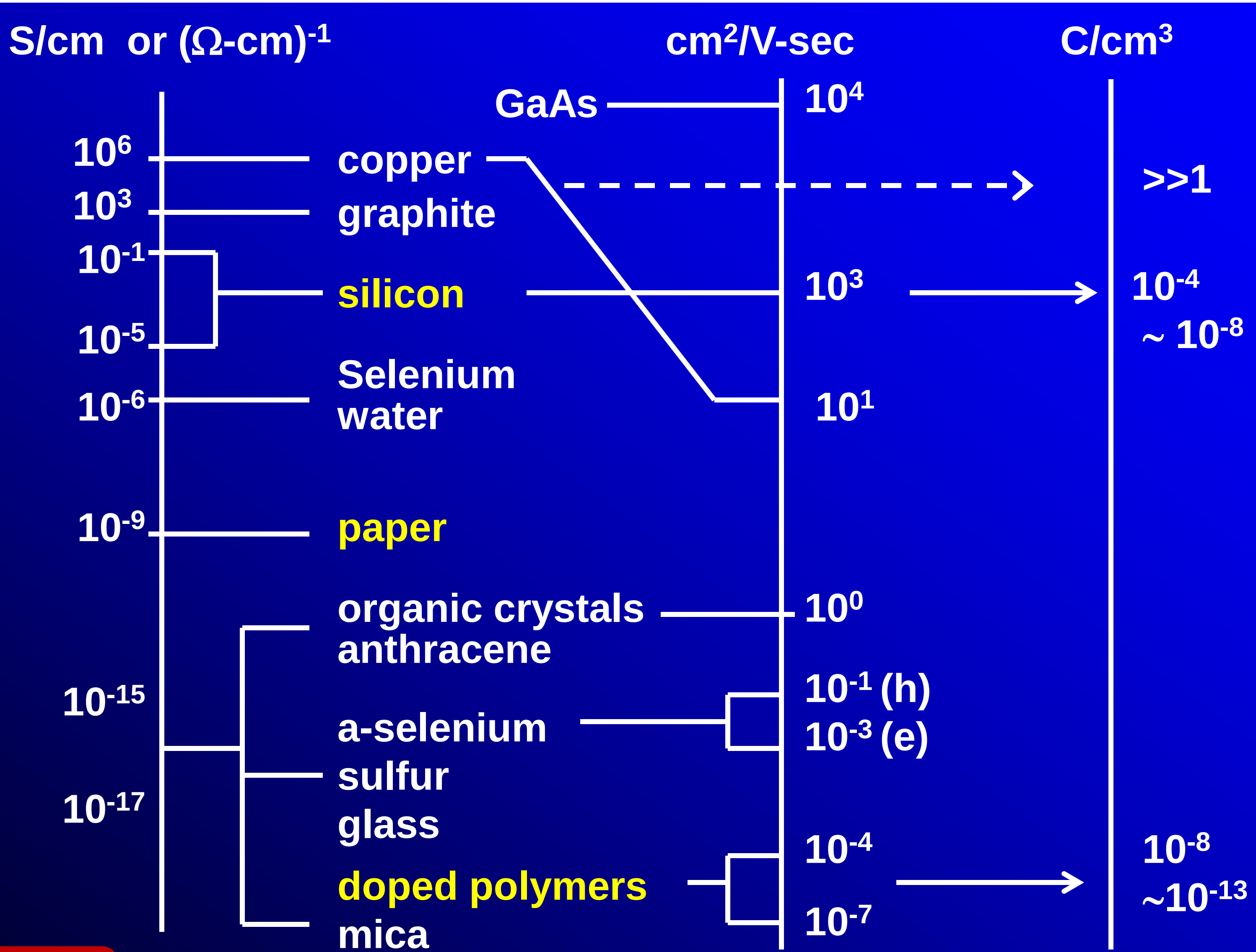
Conductivity(σ) = Mobility (μ) x Charge Density (q)



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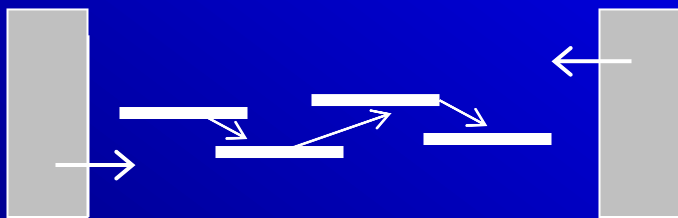
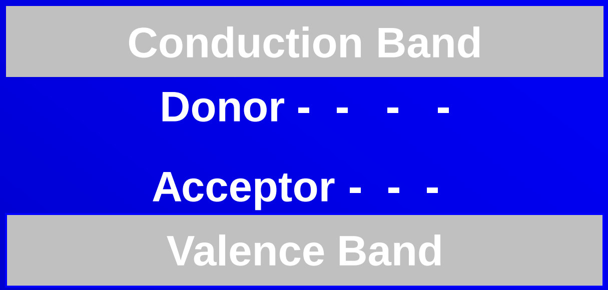
Semi-Insulators vs. Semi-Conductors





- Low mobility (≤ 10^{-5}), due to hopping transport among localized states
- Low charge density, varies with dopant conc. (%), and injection from electrodes

- High mobility (10^{3}), due to band transport in extended states
- Low charge density, very sensitive to dopant concentration (ppm)

- Low conductivity: σ = mobility (μ) x density (q)
- Separate roles of mobility and density in charge transport phenomena

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Charge Transport in Semi-insulators

- Low conductivity due to both low charge density and low charge mobility.
- Charge injection at the electrodes (interfaces) is a key element in the charge transport process.
- Charge mobility and charge injection are both field dependent.
- Mobility, density, and injection each play separate roles in the charge transport process and hence each controls the performance of a semi-insulating EP device separately.
- Such complexity renders the conventional resistivity measurement technique ineffective in characterizing this class of materials.

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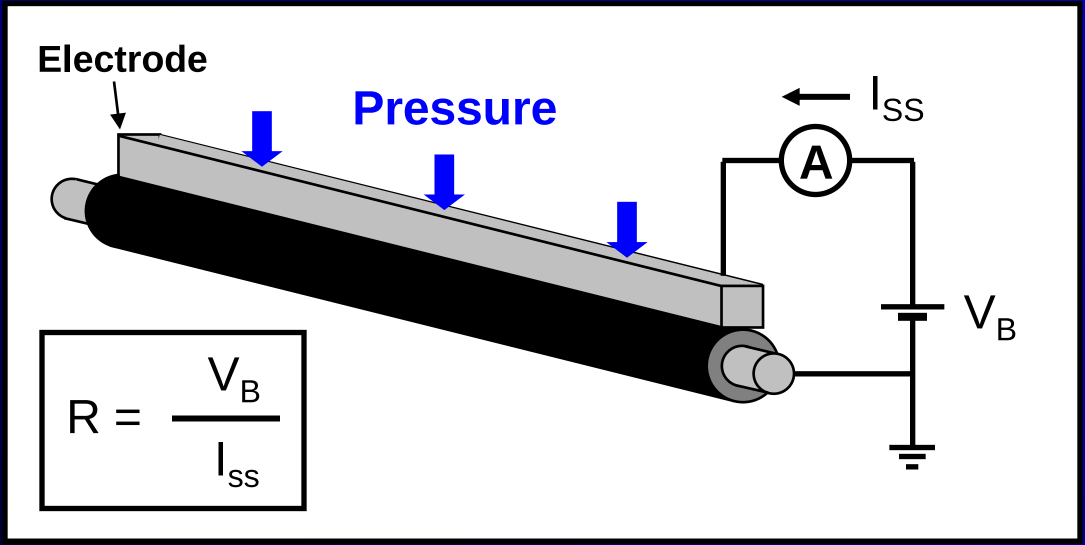
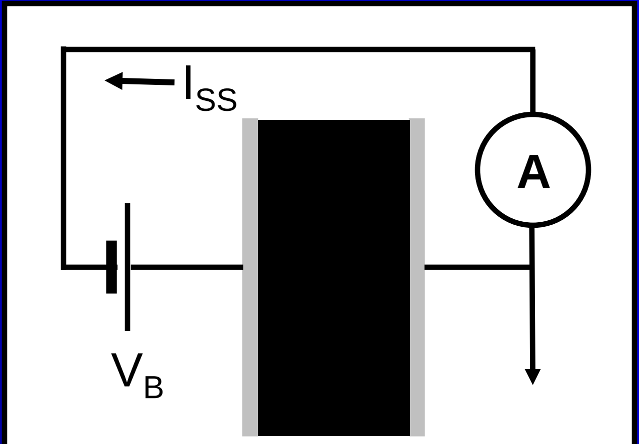
Conventional Resistance Measurement

- In the conventional method of measuring the roller "resistance", a DC bias voltage, typically 500V, is applied between an electrode in contact with the charge roller and the roller shaft. The current flow through the roller I_{SS} is measured, typically at "steady state".
- The roller resistance is the ratio of the applied V_B to the measured I_{SS}.
- As shown in the model, this is a contact, "close-circuit" method.





A "Close-circuit" Method

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Conventional Method – Limitations (1)

- From the steady state current, the conventional method provides only a measure of the injection (or interfacial) characteristics at the interface between the electrode and the charge roller. The "resistivity" so obtained in fact says very little about the true volume resistivity of the device under test. Further, no transient (dynamic) information is captured in the conventional method.
- The measurement results are affected by the applied pressure between the electrode and the charge roller. This is often a source of poor reproducibility in the measurements.
- The contact nature of the method makes the method impractical for scanning a large areas.

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Conventional Method – Limitations (2)

- The conventional method assumes Ohmic conduction in the material-under-test. The relaxation (after an applied voltage is removed) of an Ohmic material should follow an exponential decay with a single time constant. Contrarily, a practical semi-insulator seldom exhibits such relaxation characteristic.
- In summary, the conventional Ohmic resistance measurement method is neither consistent with the physics of semi-insulators nor a practical method to provide consistent, reliable and predictive results for charge roller performance.

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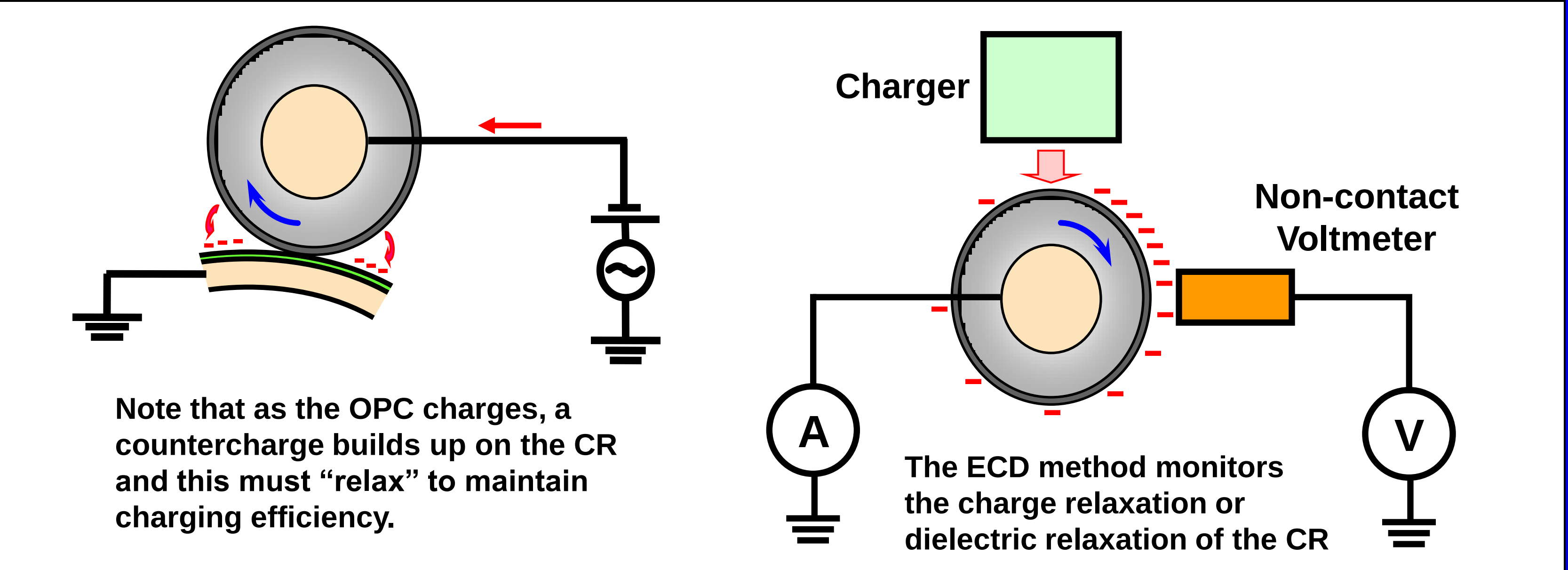
The Electrostatic Charge Decay (ECD) Method

- The ECD method is a much better alternative to the conventional method for characterizing semi-insulating charge rollers.
- It physically simulates the charging process and offers a very practical solution to characterizing charge rollers and predicting their performance.



A Charge Roller Charging System

The ECD Method

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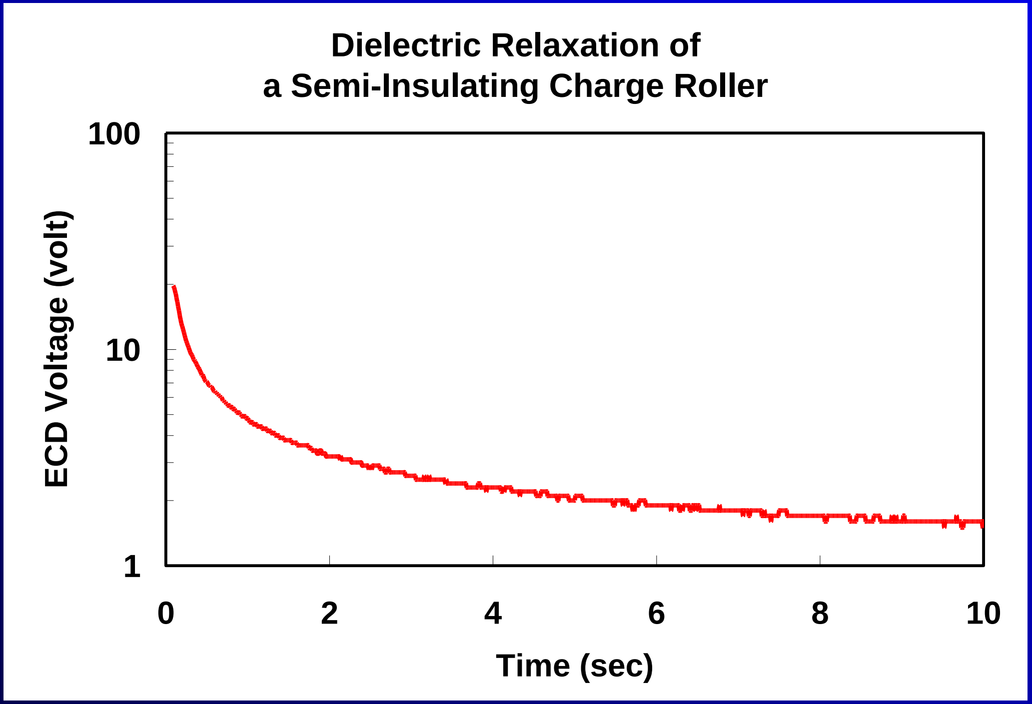
Dielectric Relaxation in Semi-Insulators & ECD Measurement (1)

- The basic ECD technique involves monitoring the ECD voltage-time curve, which is a measure of the dielectric relaxation characteristics of the semi-insulator under test.
- This curve encompasses most of the critical information on the basic phenomena in the charge transport process in a semi-insulator.



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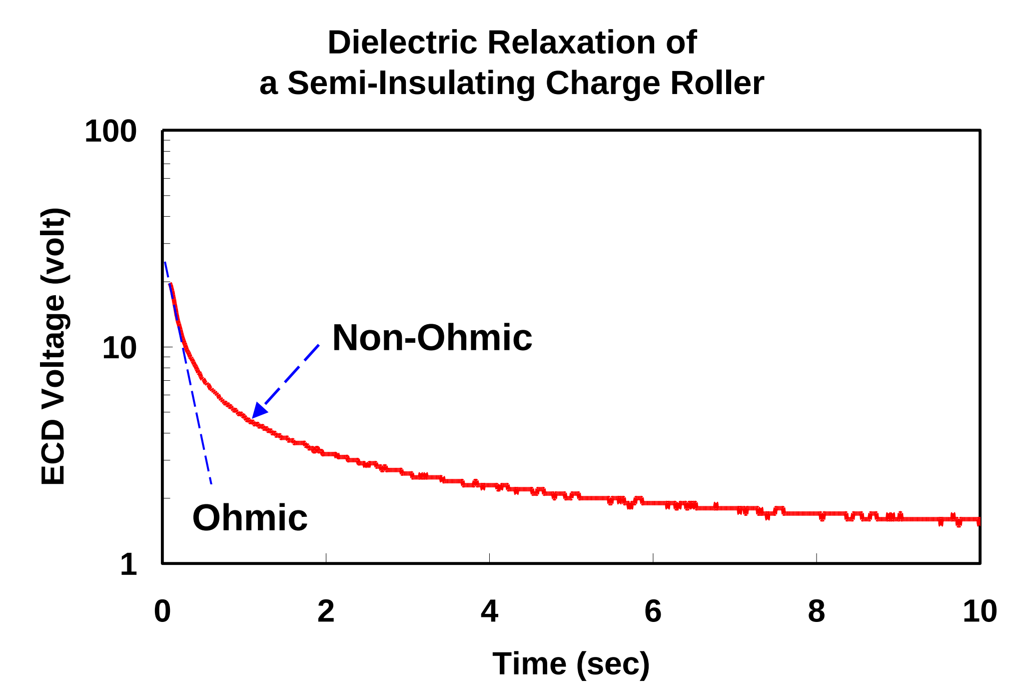
Dielectric Relaxation in Semi-Insulators & ECD Measurement (2)

- In an Ohmic material, such a dielectric relaxation should follow an exponential curve, $V(t)=V_o e^{-1/\tau}$ and a semi-log plot should therefore be linear.
- In the voltage-time curve for a semi-insulator, a semi-log plot is typically non-linear, indicating that such material is non-Ohmic in nature.



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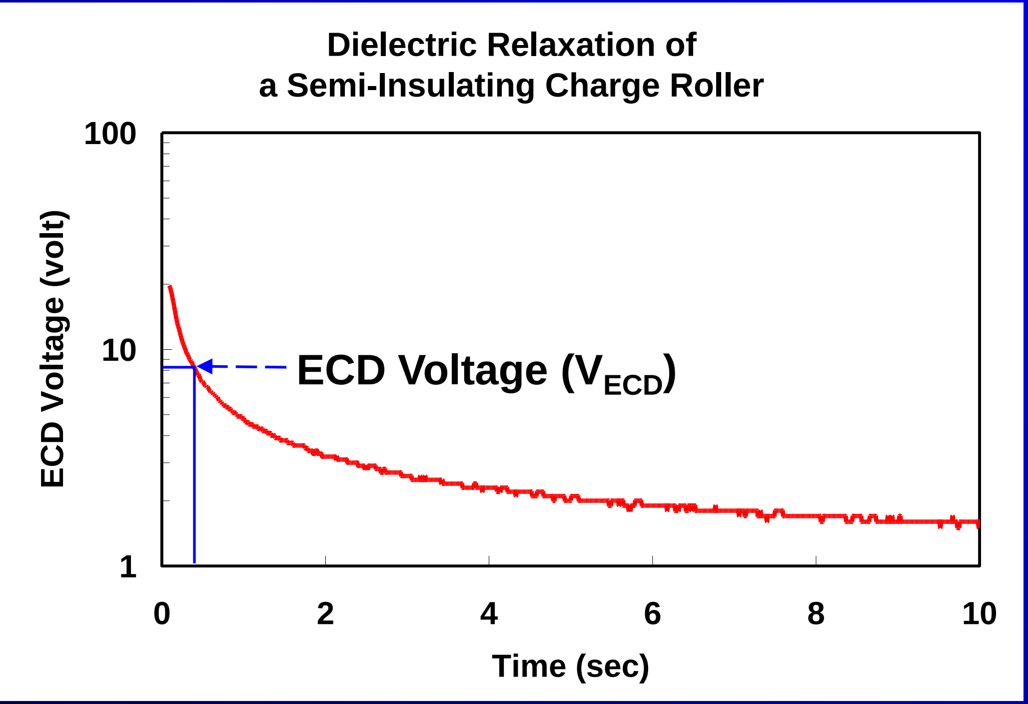
Dielectric Relaxation in Semi-Insulators & ECD Measurement (3)

- In practice, a good metric for charge roller performance is an "ECD voltage" read at a time relevant to the printing process and speed.
- Typically, for predicting charge roller performance, the critical time is within the first second in the relaxation curve.



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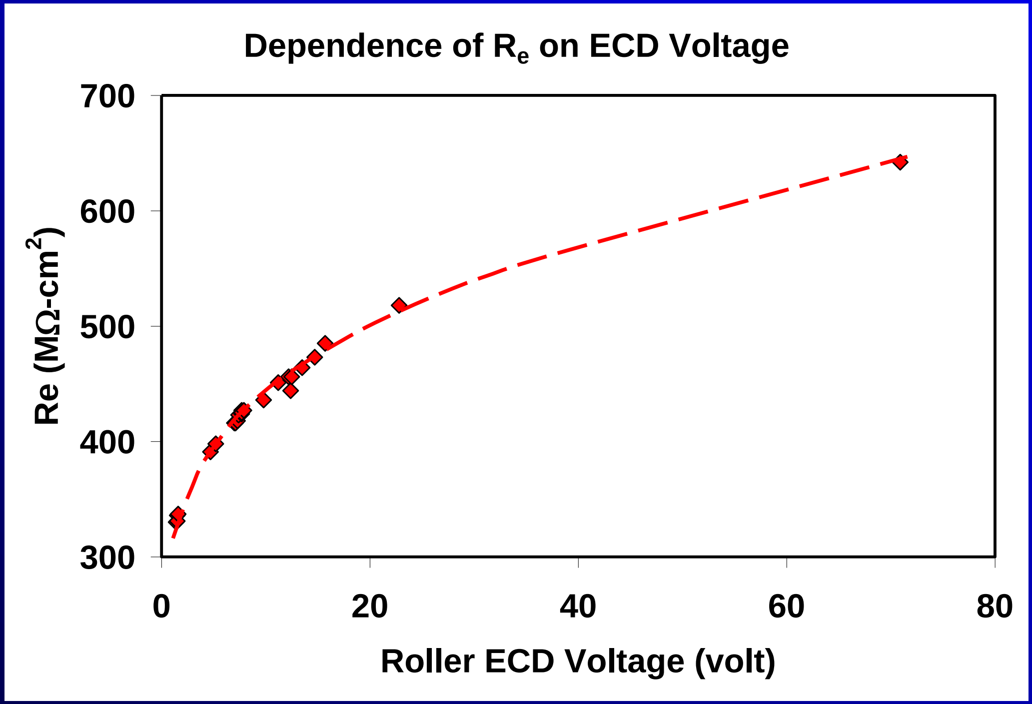
Equivalent Resistance R_e (1)

- In QEA's DRA-2000L implementation of the ECD method, the current flow through the charge roller is also measured.
- Using the voltage and current information, an additional performance metric for a charge roller called the "Equivalent Resistance, R_e" can be derived.



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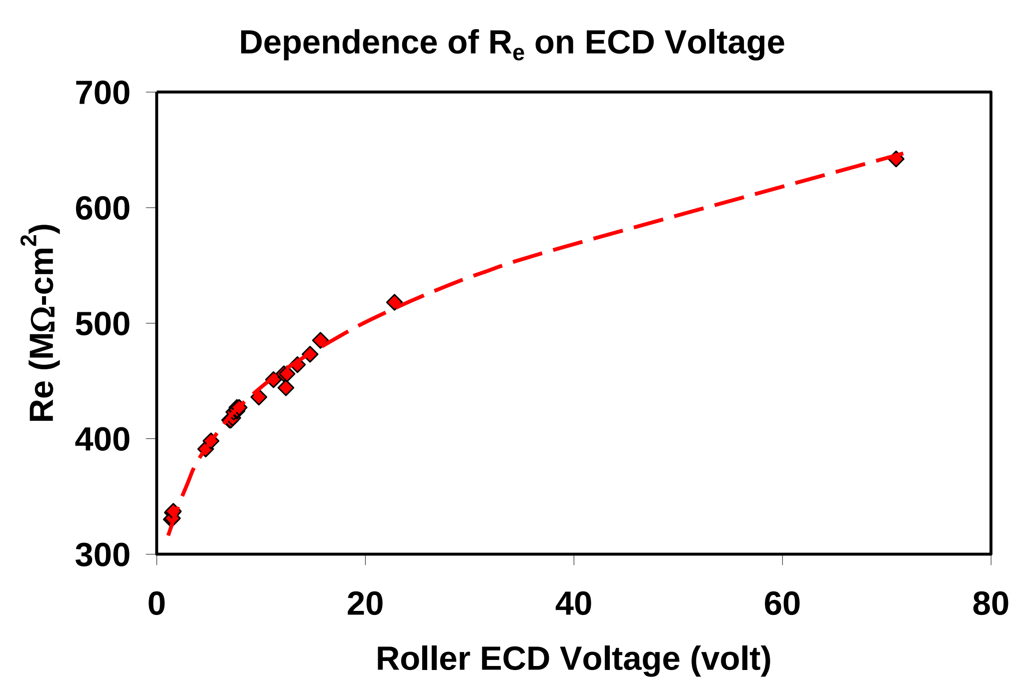
Equivalent Resistance R_e (2)

- R_e is a complex function of the measured voltage and current.
- R_e relates to the measured voltage V_{ECD} non-linearly as shown below.
- In the DRA system, R_e is estimated based on a theoretical model.



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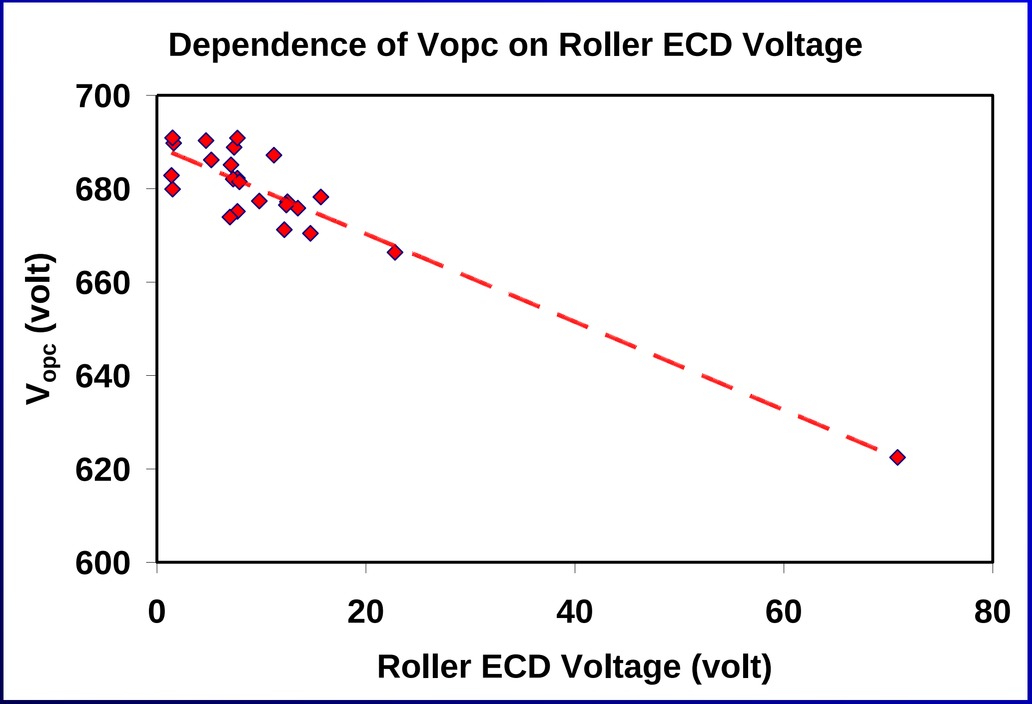
Correlating V_{ECD}, R_e and V_{opc} (1)

- The following result demonstrates that the ECD voltage V_{ECD} measured in the DRA-2000L correlates directly with the charge level on the OPC (V_{opc}).
- V_{opc} can be measured in a test system such as QEA's PDT-2000LA, which is instrumented with a charge roller charging sub-system.



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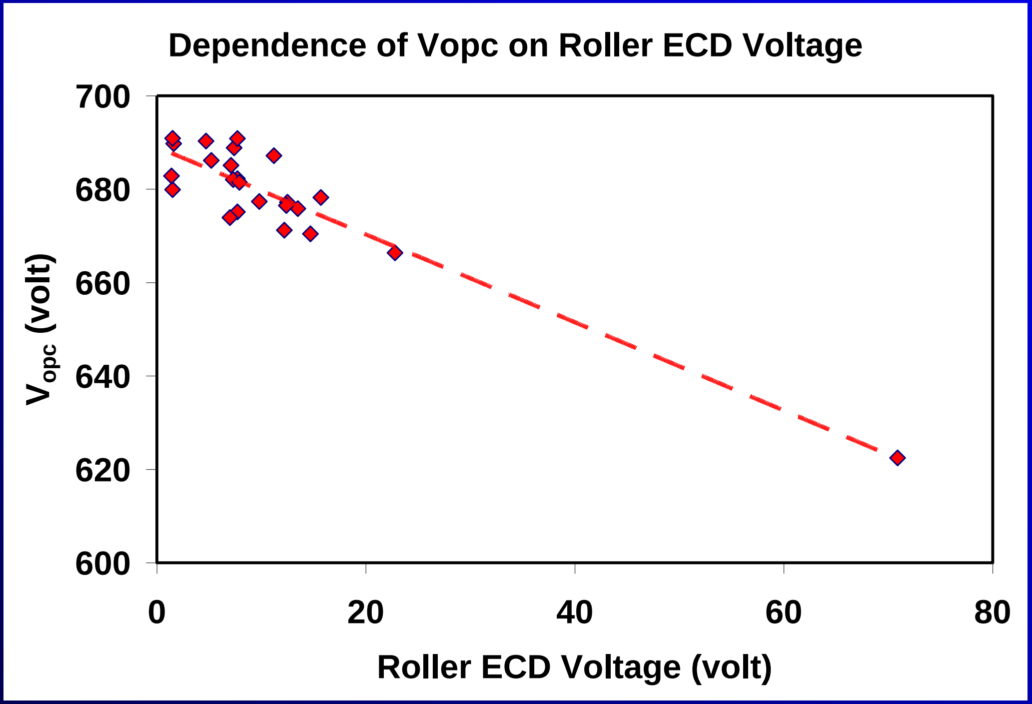
Correlating V_{ECD}, R_e and V_{opc} (2)

- **The result shown here demonstrates that the higher the "ECD voltage" measured on a charge roller, the lower is the OPC voltage due to the charge roller's lower dielectric relaxation rate and a decrease in its charging efficiency.**



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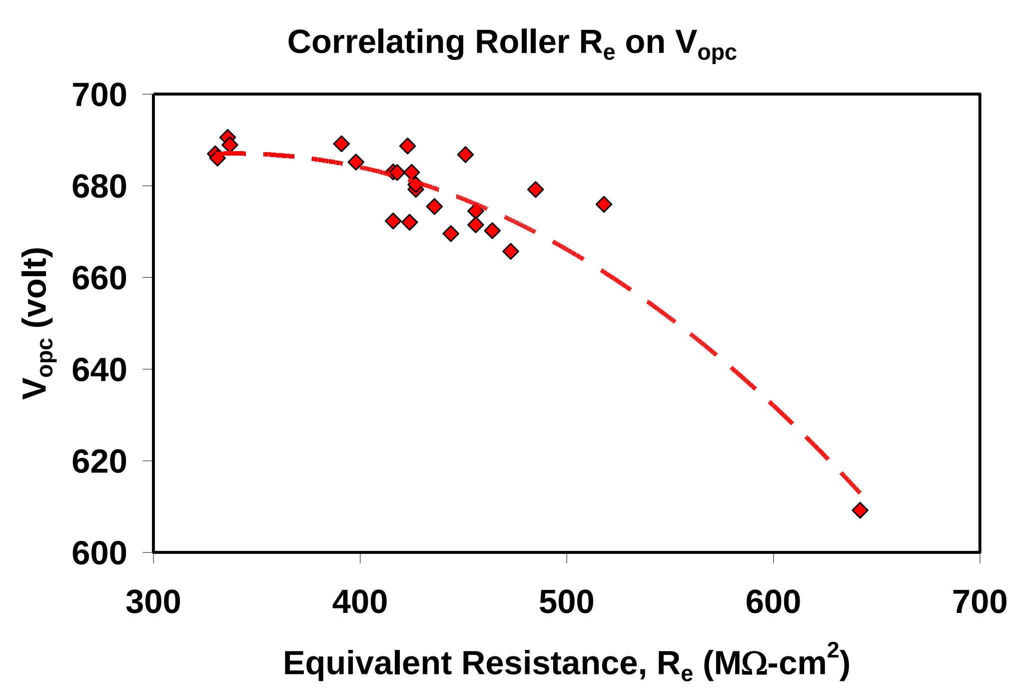
Correlating V_{ECD}, R_e and V_{opc} (3)

- The same set of data is plotted here with V_{opc} vs R_e instead of the roller ECD voltage.
- As shown, the higher the R_e of the charge roller, the lower is the V_{opc}.



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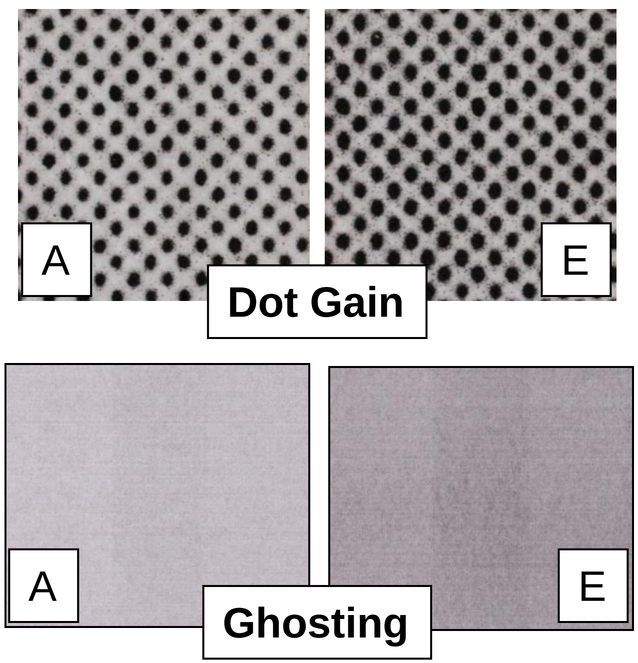
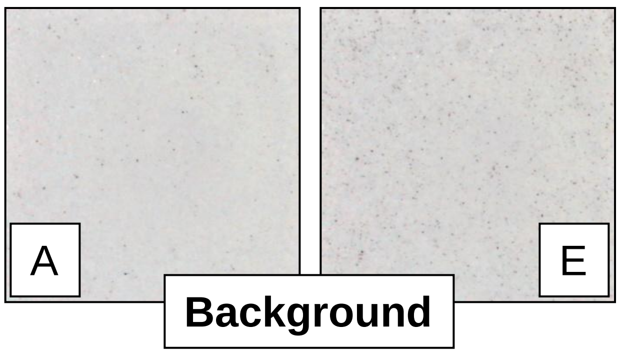
Predicting Charge Roller Performance

- To complete the discussion on predicting charge roller performance, the previous example on dot gain, ghosting and background is reproduced here to demonstrate the correlation between V_{ECD}, R_e and print quality.
- As shown in these images, higher V_{ECD} and R_e correlate with higher dot gain, and more severe background and ghosting.





Sample	V_{ECD} (volt)	R_e (MΩ-cm^2)
A	7.1	416
E	70.9	642

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Charge Roller Testing: Part II – A Case Study

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A Case Study (1)

- To demonstrate the efficacy of the ECD method and the DRA-2000L implementation, a case study is summarized in this report.
- The charge rollers used in this study are a set of 24 charge rollers intended for the HP4000 Laserjet printer.
- The charge rollers studied include both the OEM and a collection of aftermarket rollers.
- The OEM rollers include both new and recycled samples.

qea

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A Case Study (2)

- The study includes:
  - Measuring dielectric relaxation in the charge rollers using the DRA-2000L analysis system
  - Measuring OPC voltage using charge roller charging (by the same set of charge rollers) in the PDT-2000LA OPC Drum Test System
  - Correlating the electrical results with print testing and print quality analysis using the Personal IAS Image Analysis System.

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Measurement Tools (1)

- The DRA-2000L Dielectric Relaxation Analysis System is the primary tool for charge roller characterization.
- The test functions include both scanning (partial or full-body maps) and spot measurements (for V_{ECD}-time and charging current).

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Measurement Tools (2)

- The PDT-2000LA Advanced Photoconducting Drum Test System is used to characterize the charging efficiency of the charge rollers tested in the DRA-2000L. Both corona and charge roller charging are available on this system and the charge roller charging mode was used to measure V_{opc} for both DC and DC+AC charging.

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Measurement Tools (3)

- Each charge roller sample was installed in an OEM toner cartridge. Print testing was performed on a HP4000 printer in good condition.
- Print quality analysis on tone reproduction, dot gain, background and ghosting was performed using the Personal IAS image analysis system.

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Tools (4)

- A suite of test targets was used (i.e. more than one).
- The targets are designed to:
  - Allow correlation between subjective assessment and objective measurements on the same page.
  - Stress different aspects in the charge roller characteristics.
  - Make it easy for interpreting the results.
- An HP4000 printer was used. The relationship between printing settings and PQ was examined.

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Sample ID

- OEM – 4 new rollers (with different design and appearance); identified as Samples 1 to 4.
- OEM – 4 used rollers (with varying degree of usage); identified as Samples 5-12.
- Aftermarket – from at least 6 manufacturers with different designs and material formulations; identified as Samples 13-24.

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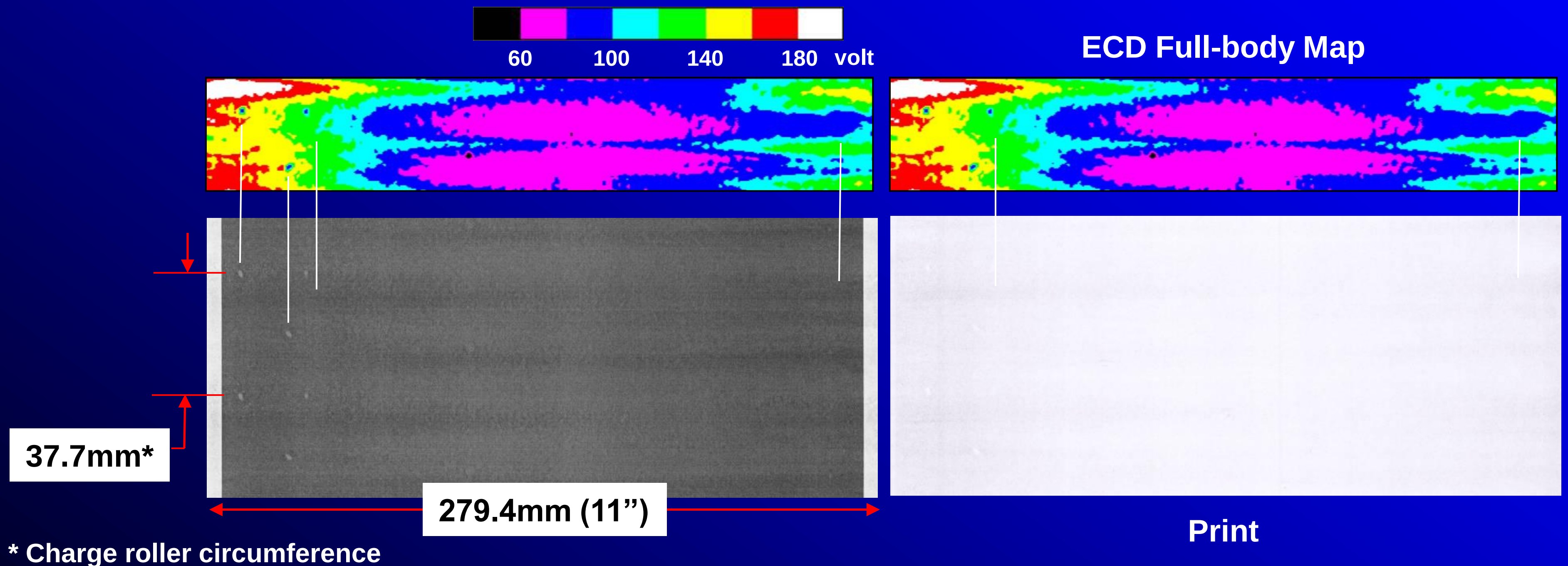
Charge Roller Mapping

- The full-body ECD map shown below for a very poor charge roller clearly demonstrates the correlation between V_{ECD} and print quality.
- The non-uniformity in V_{ECD} can be mapped directly to a print density variation map (on a 40% gray page) and a background map (on a white page). Such results clearly demonstrate the efficacy of the ECD method.



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Correlating ECD Measurements with Print Quality

- In the following slides, the correlation between charge roller dielectric relaxation and three important print quality attributes: optical density (or dot gain and tone reproduction), background and ghosting are examined quantitatively for the set of charge roller samples studied.
- The print tests were performed at two printer density settings – PD = 1 and 5 respectively.

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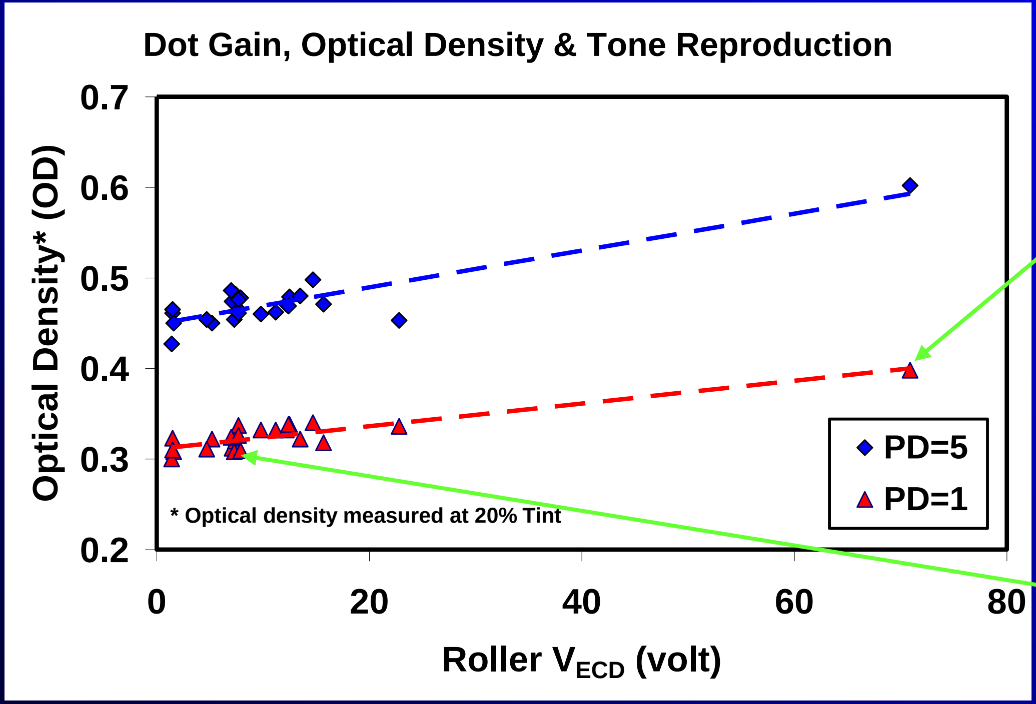
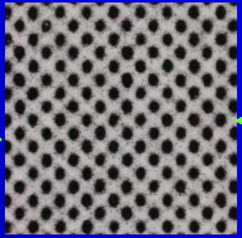
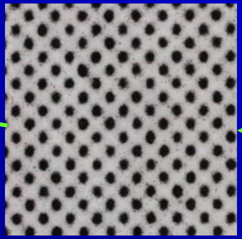
Dot Gain, Optical Density & Tone Reproduction (1)

- Dot gain is found to increase with V_{ECD}, i.e., poor charging leads to higher dot gain and less controlled tone reproduction at both high and low print settings.







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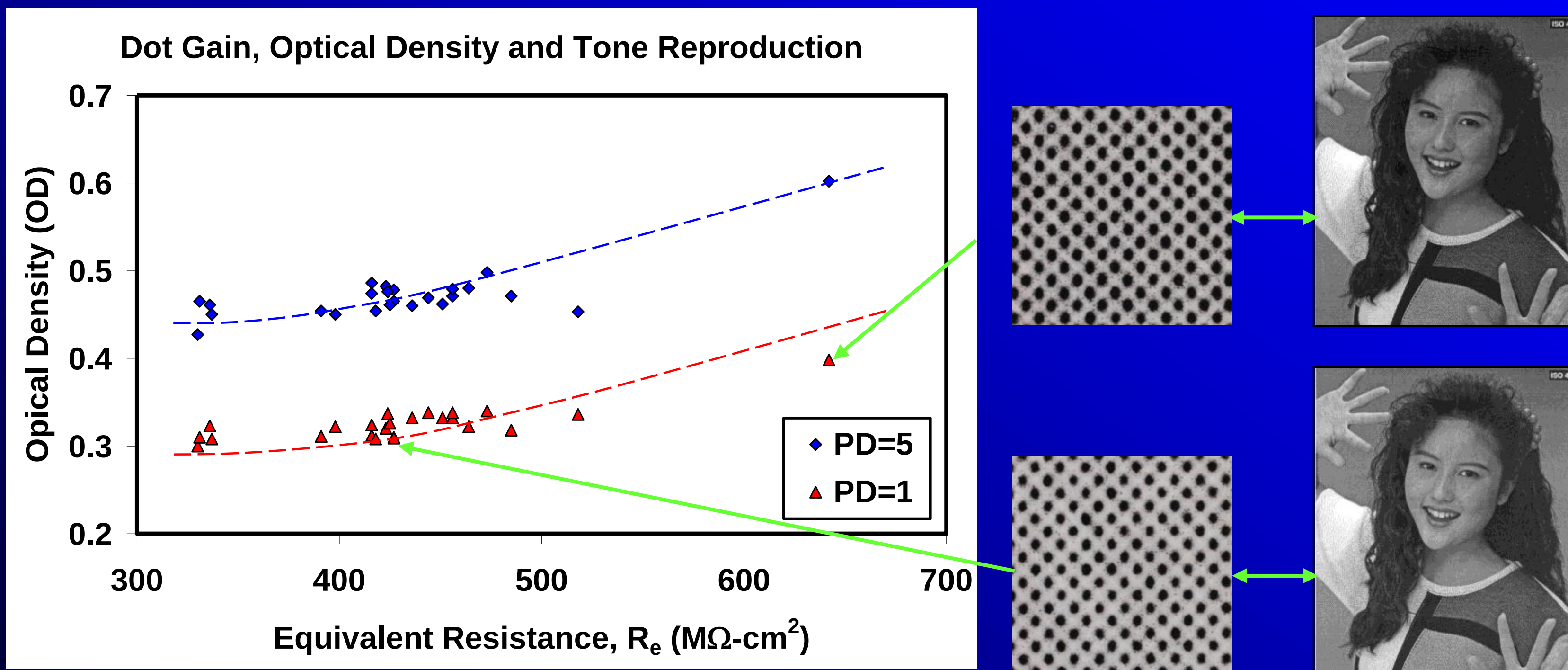
Dot Gain, Optical Density & Tone Reproduction (2)

- The same data is plotted vs the Equivalent Resistance R_e.
- Similar correlation to V_{ECD} can be seen.



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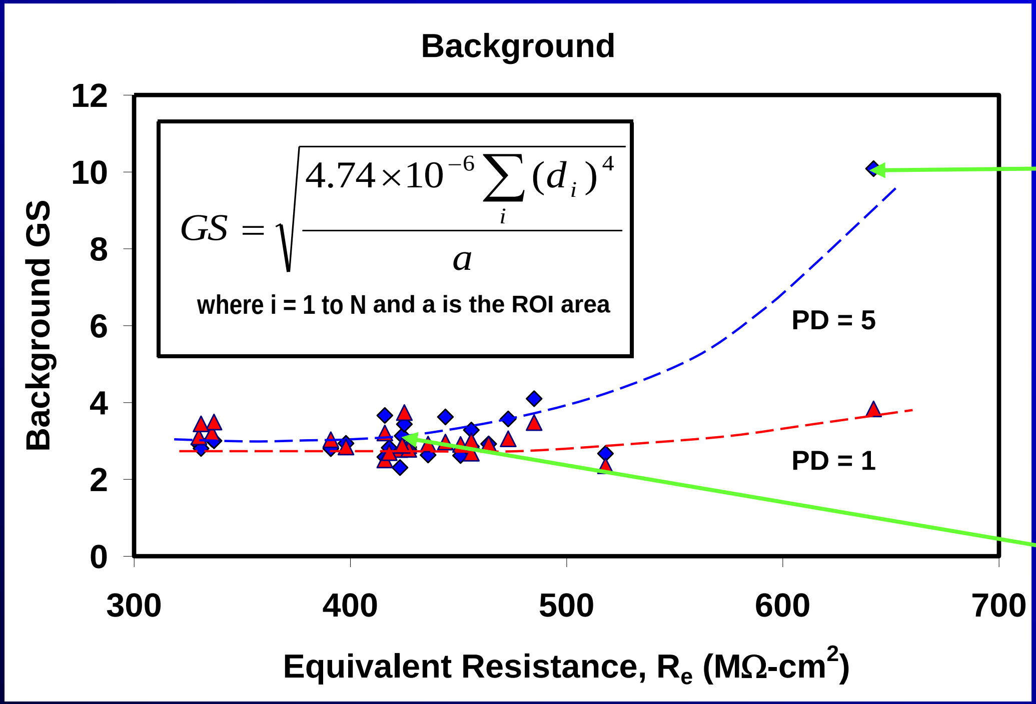
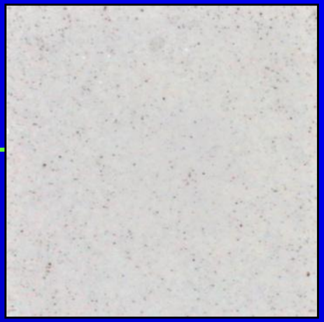
Background

- Background is toner deposited in an unprinted area. If background is high, it gives an undesirable gray appearance.
- Background can be evaluated by the GS method. GS depends on size (d_i) and the number of toner particles (N) measured in the region of interest.



$$GS = \sqrt{\frac{4.74\times10^{-6}\sum_i (d_i)^4}{a}}$$



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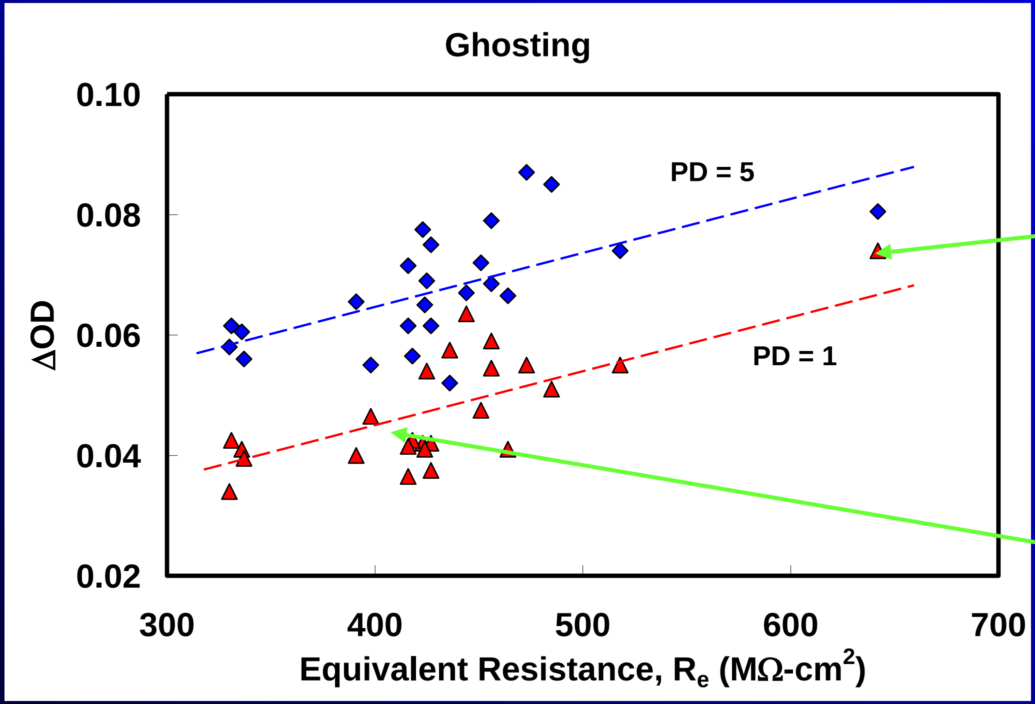
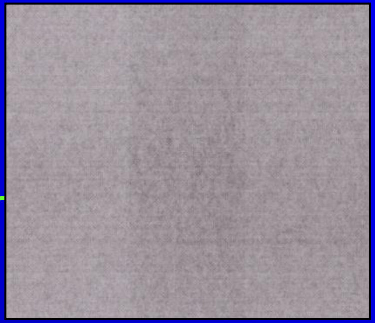
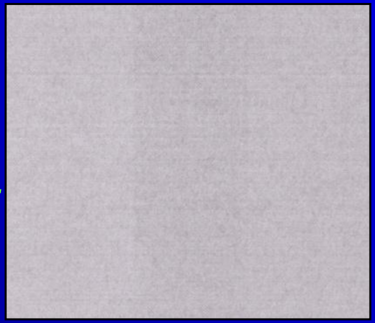
Ghosting

- Ghosting is essentially a memory effect, i.e., an image of an earlier part in a print is repeated either "positively" or "negatively" in the later part in the same or subsequent pages. In this example, positive ghosting is seen.
- Ghosting is measured by the density difference between the "ghost" and its surround. As shown, higher charge roller R_e leads to higher ΔOD.







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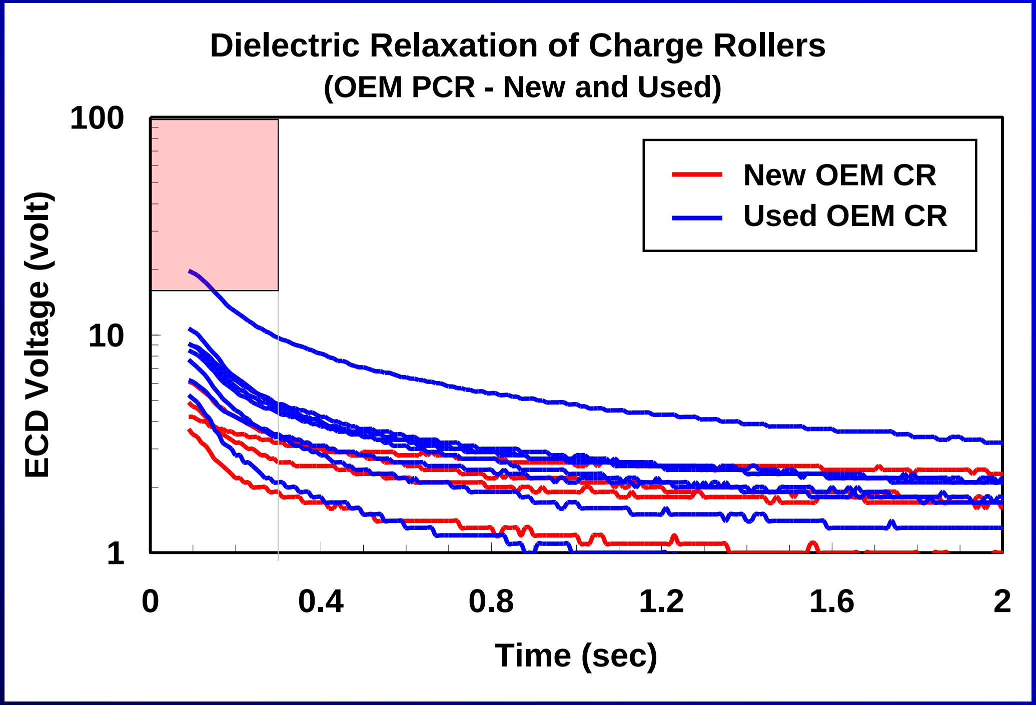
Dielectric Relaxation Analysis (1)

- In the V_{ECD}-time curve below, the results for 4 OEM new and 8 OEM used HP4000 charge roller are shown.
- In this plot, a region at the top left corner is highlighted to indicate where dot gain, background and ghosting problems are likely.



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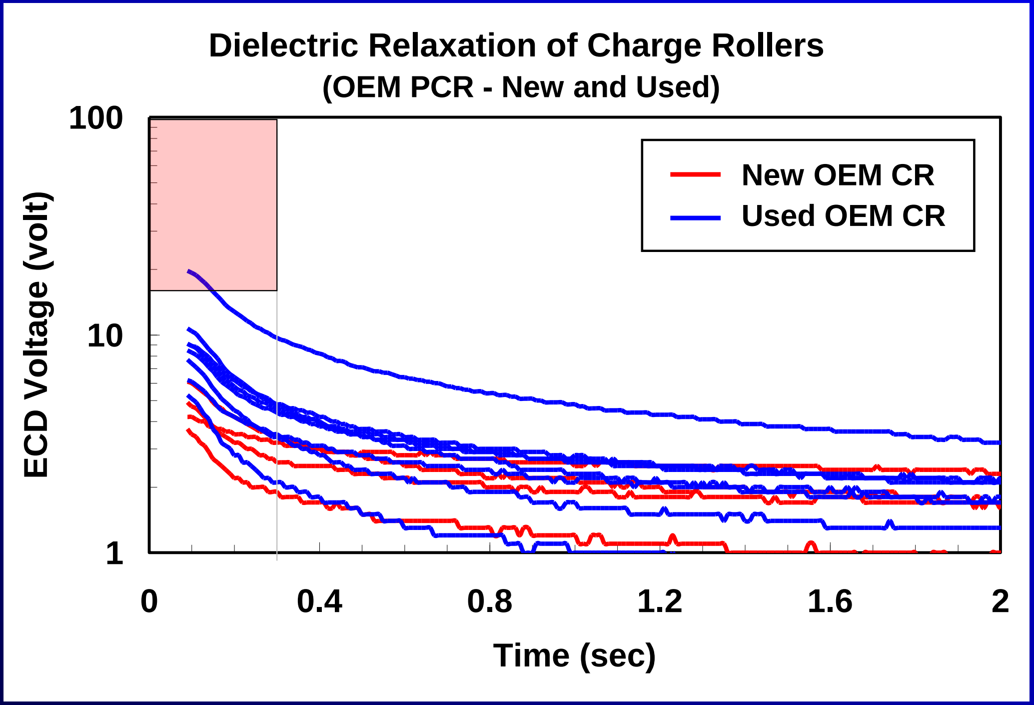
Dielectric Relaxation Analysis (2)

- This region is bounded by time < 0.3 sec and V_{ECD} > 15 volt. The interpretation of this region (or, a failure criterion) is that: if the process speed is such that the cycle time (for one revolution) of the charge roller is less than 0.3 sec, V_{ECD} should be less than 15V for problem-free charging.



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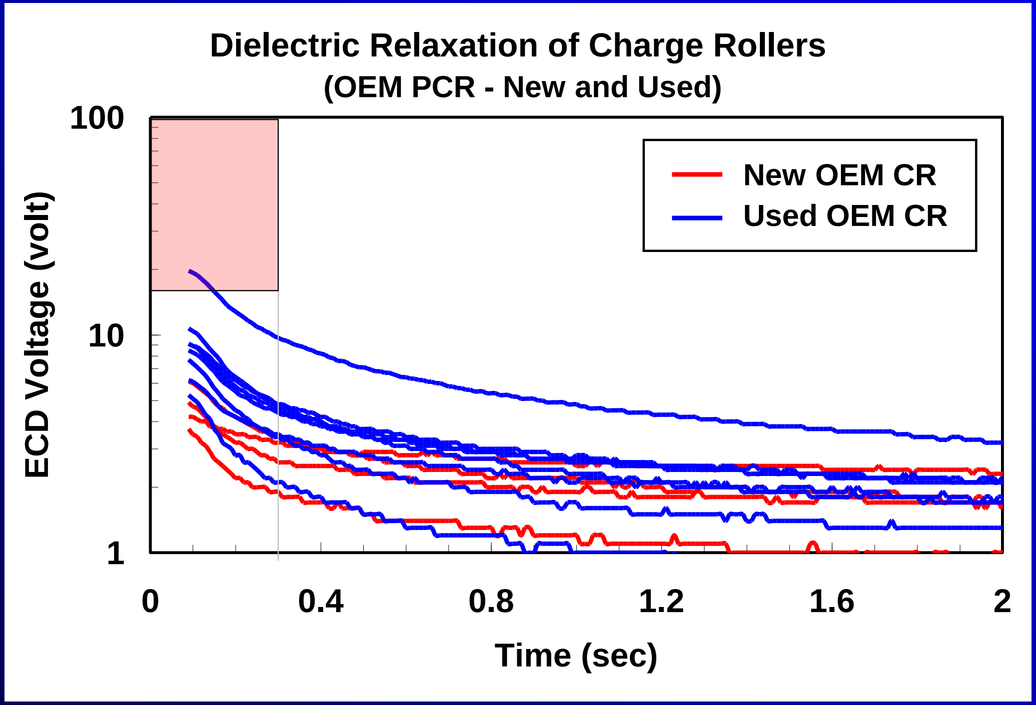
Dielectric Relaxation Analysis (3)

- In this set of data, most relaxation curves do not cross into the critical region except for one particular roller.
- Even for this roller, the crossing of V = 15V happens at around t < 0.2 sec, suggesting that all rollers in this batch will perform acceptably – and experimentally, they do.



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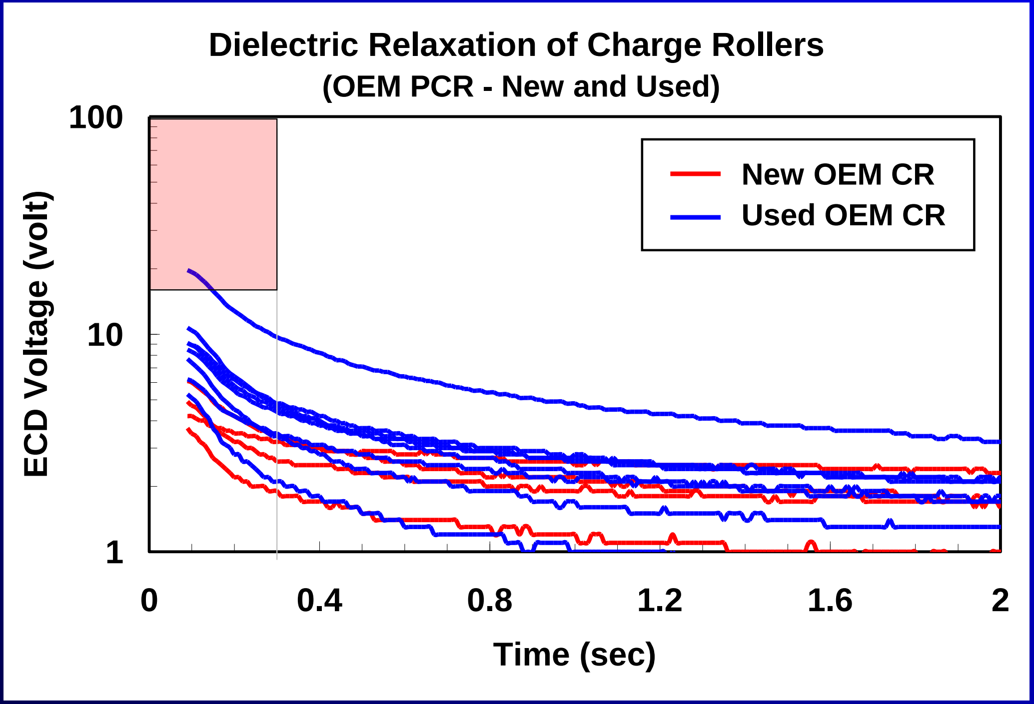
Dielectric Relaxation Analysis (4)

- How was the acceptance (or failure) criterion arrived at?
- The time criterion is estimated from the process speed. For example, if the print speed is 20ppm or ~100mm/sec, than the cycle time for a Ø12mm charge roller is about 0.3sec.
- The voltage criterion is determined empirically by relating PQ and V_{ECD}.



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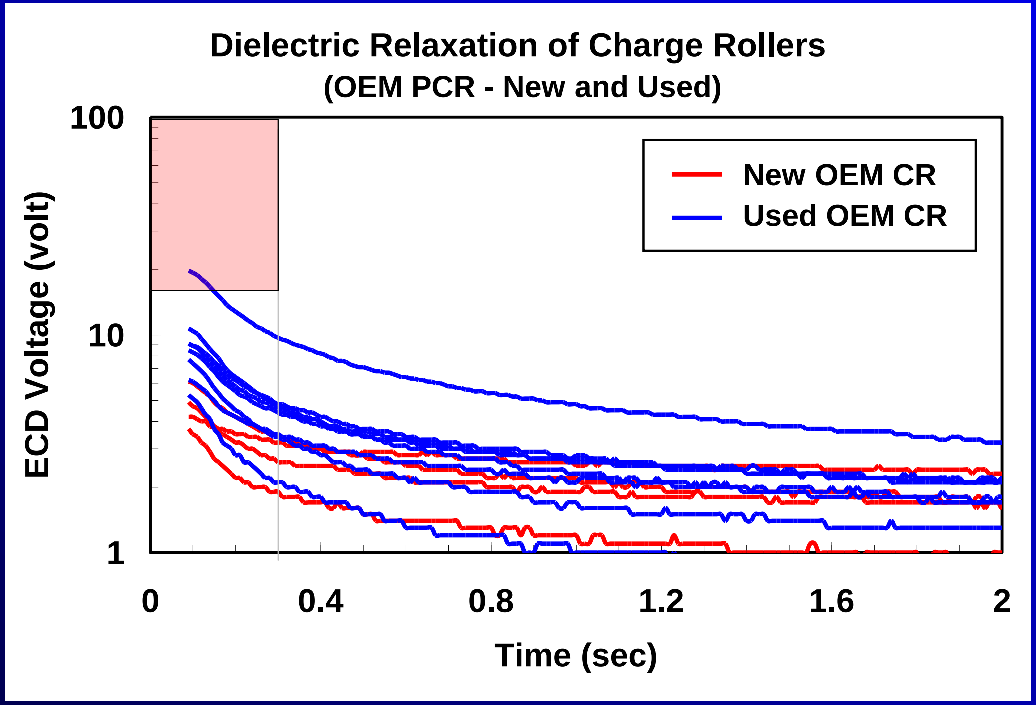
Dielectric Relaxation Analysis (5)

- This example demonstrates an important practical application of the ECD technique and the DRA-2000L test system for charge roller quality control and reusability assessment.
- By monitoring the ECD voltage (or R_e), we now have a quantitative means to make objective quality decisions on charge rollers.



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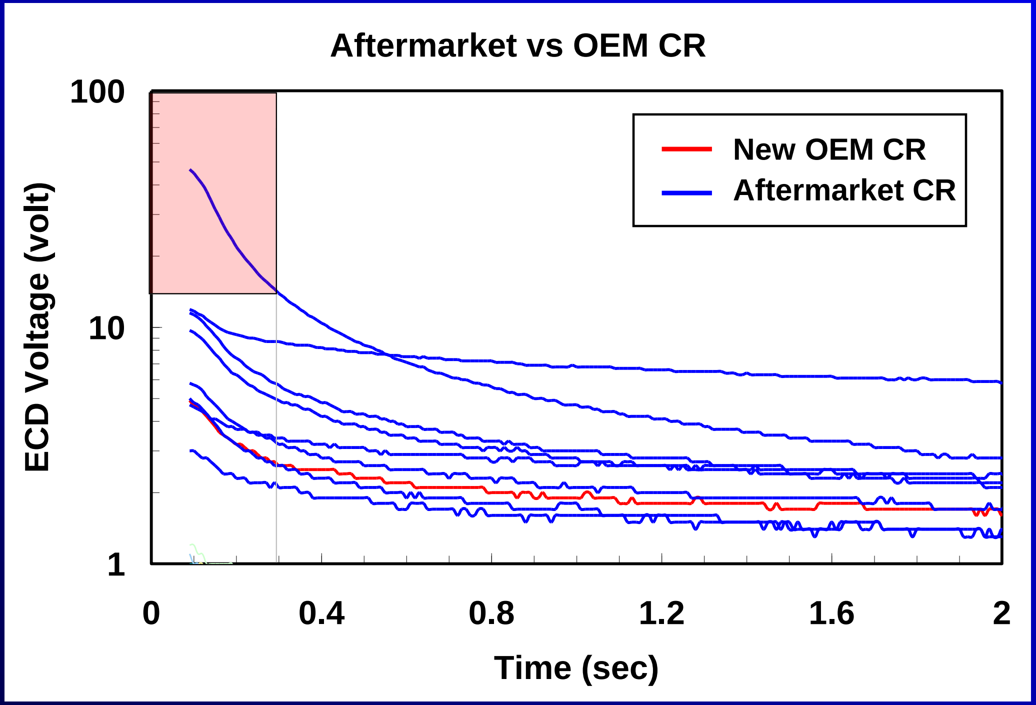
Dielectric Relaxation Analysis (6)

- The relaxation curves for 12 aftermarket rollers from several suppliers are shown below. The data for one OEM roller is shown also as a reference.
- As shown, the aftermarket roller quality is quite diverse, from better than the OEM (lower V_{ECD}) to much worse (higher V_{ECD}).



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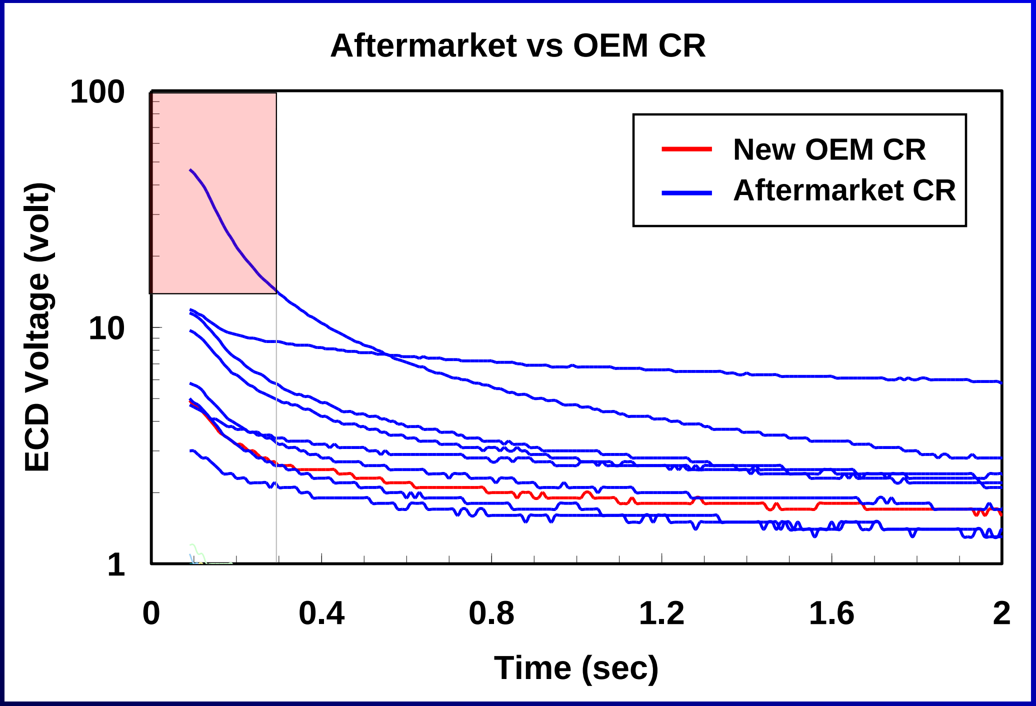
Dielectric Relaxation Analysis (7)

- One aftermarket roller in this batch fails quite clearly.
- Notably, several other rollers, while passing the failure criterion, are relatively close to it. These rollers have a low margin of safety (even if the manufacturing variability is very low) since any slight degradation in use many "push it over the edge".



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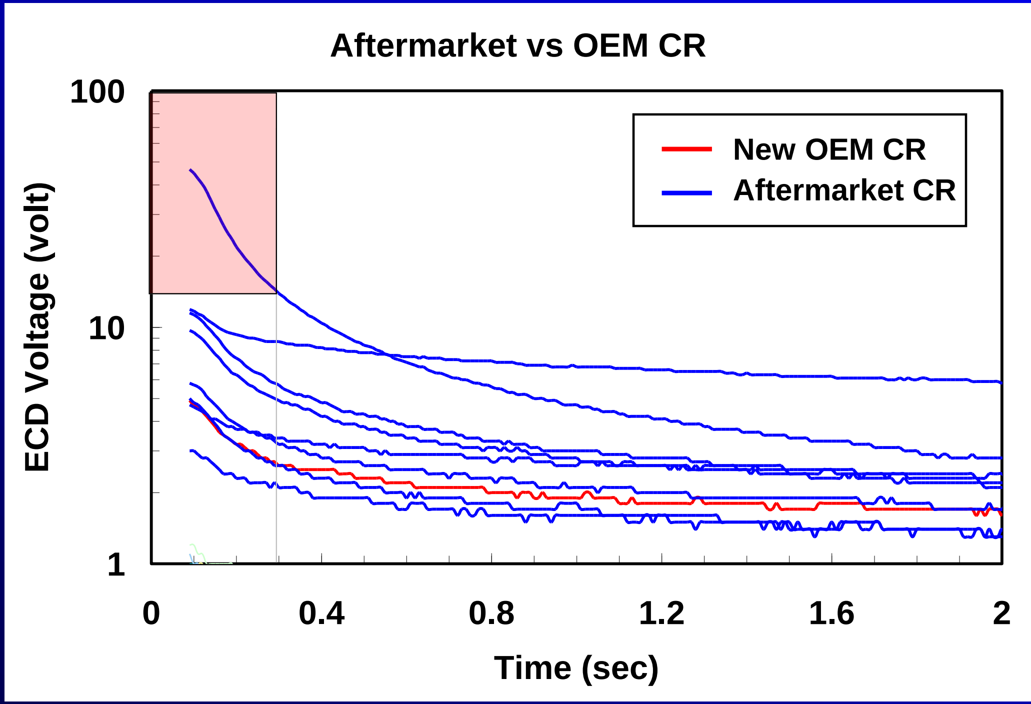
Dielectric Relaxation Analysis (8)

- Rollers with marginal quality would be limited to use in lower speed engines and are therefore less flexible in meeting different engine requirements.
- This further demonstrates how ECD and DRA provides a quantitative tool to make rational quality decisions on charge rollers.



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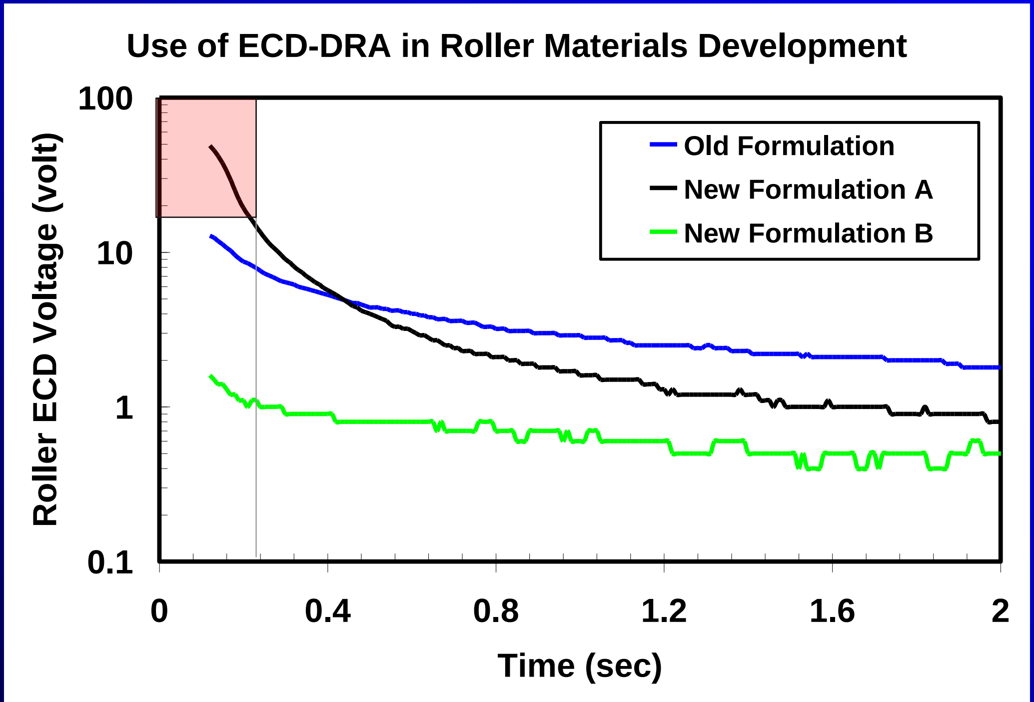
Dielectric Relaxation Analysis (9)

- **Another Example – a supplier decided that existing (old) formulation of the roller coating has marginal performance and started to investigate new methods to control the dielectric relaxation of the coating material. The data below shows significant improvements in new formulation B but much worst performance in formulation A.**



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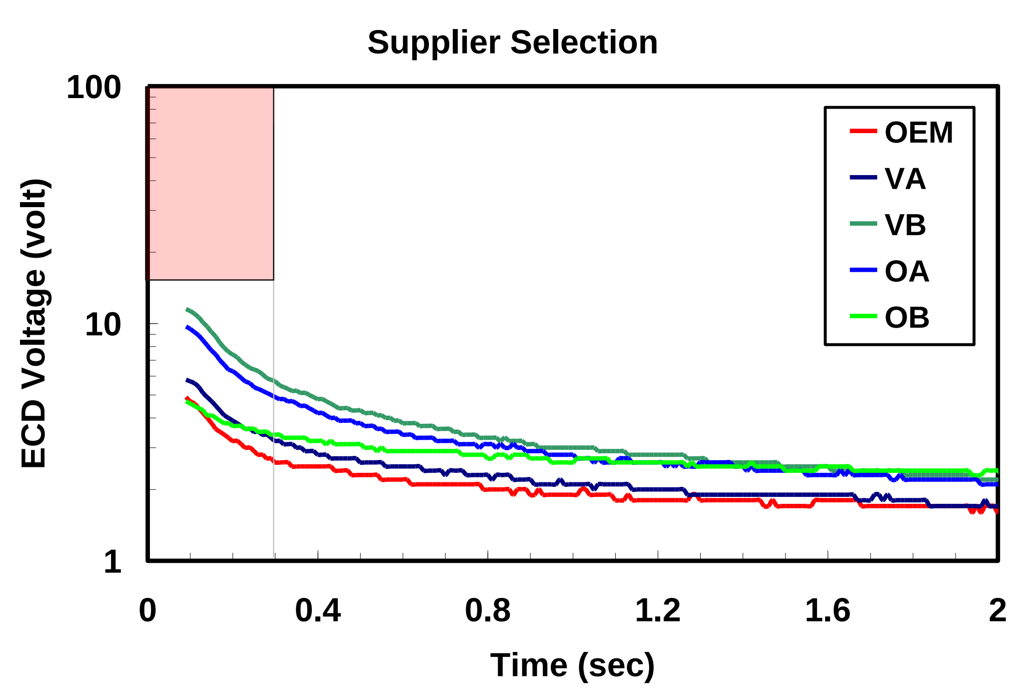
Dielectric Relaxation Analysis (10)

- Another Example – a cartridge manufacturer is evaluating two charge roller suppliers and is finding it very difficult to distinguish the roller samples supplied by print testing since the prints all look acceptable.
- The ECD-DRA measurements suggest each supplier (V & O) happened to have submitted a good and a marginal sample. ECD-DRA provides quantitative information that cannot be obtained from print testing.



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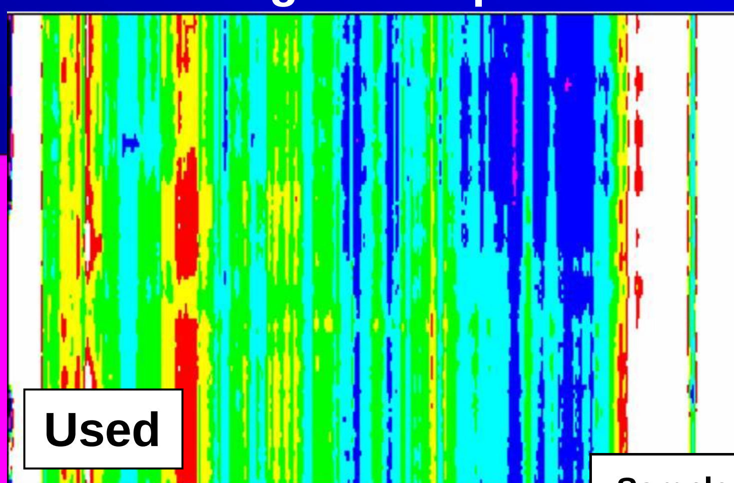
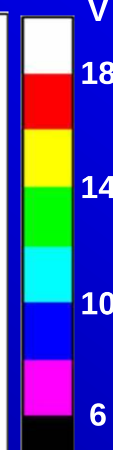
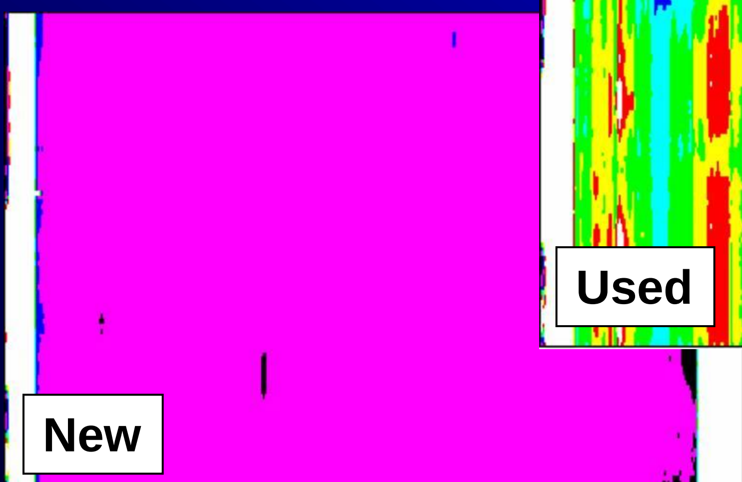
Dielectric Relaxation Analysis (11)

- Another example – a print engine manufacturer is investigating why complaints in print quality for a particular model are on the rise. Engineering study suggested that the charge roller may be the culprit.
- As shown in the ECD maps and the numerical results, the used charge roller has degraded quite significantly in uniformity and V_{ECD} and Re have increased significantly also. This is a good example of applying ECD-DRA to diagnostics of charge roller problems.







Sample	V_{ECD} (volt)	R_e (MΩ-cm^2)
New	6.8	419
Used	12.7	465

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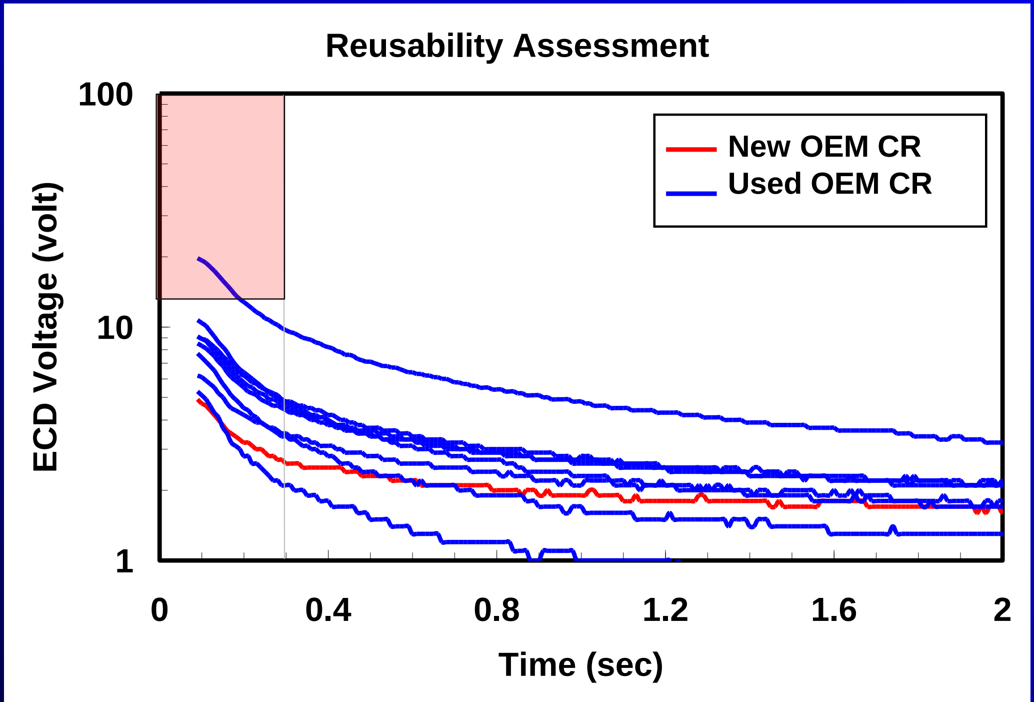
Dielectric Relaxation Analysis (12)

- Another example – similarly a toner cartridge re-manufacturer found it very difficult (or impossible) to screen recycled charge rollers by visual inspection or print testing.
- ECD-DRA measurements "grade" the roller condition quantitatively as shown below and hence provides a reliable means for reusability assessment.



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Summary

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Charge Rollers: Design & Functions (1)

- The charge roller is a critical component in many modern electrophotographic (EP) engines.
- A typical charge roller consists of a metal shaft at the core, a conductive elastomer (foam or solid) in the middle, and a semi-insulating coating on top.
- The charge roller's function is to impart a sufficient level of charge onto the OPC in order to provide and maintain an acceptable level of print quality.
- If the OPC is not charged adequately, the control of tone reproduction will suffer, and print defects such as background and ghosting will be introduced.

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Charge Rollers: Design & Functions (2)

- The semi-insulating coating is essential for preventing arcing damage to the OPC, but it also brings some challenges to roller design and manufacturing.
- If the coating material is not selected properly, it will impede the performance of the charge roller and will result in the print quality problems as described above.
- To engineer the coating material and to ensure consistent quality in charge roller production, a proper measurement tool is essential.
- Unfortunately, the conventional Ohmic resistance technique that many people have adopted is simply ineffective for this purpose.

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Roller Charging Mechanism

- Charging roller charging of an OPC happens at the air gap between the two devices by a “micro” scale corona charging process.
- Such a process requires that the electrical field in the air gap be maintained above a certain level (i.e the Paschen criterion).
- The voltage across the air gap (hence the field in the gap) is controlled by the bias voltage, the voltage developed on the OPC and the voltage across the charge roller. The last quantity, i.e., the voltage across the roller, must “relax” in order to ensure that the air gap voltage remains high while the OPC voltage builds up.

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Charge Roller Testing

- The “relaxation” of any charge build up on the charge roller in its operation is the key to OPC charging efficiency. Evaluating such “dielectric relaxation” is therefore central to the testing of charge rollers.
- Further, the charge roller coating is a semi-insulating material. Such materials cannot be adequately characterized by the conventional Ohmic resistance measurement technique for a variety of reasons as detailed in earlier discussions. A much better alternative is the Electrostatic Charge Decay (ECD) method developed by QEA.
- The ECD method is implemented in a commercially available instrument called the DRA-2000L.

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Features of the DRA-2000L

- The DRA-2000L is a dielectric relaxation analysis system suitable for testing all the critical semi-insulating devices in an EP printer. These include: charge roller, mag roller sleeve, development roller, and transfer media such as transfer roller, transfer belt and paper.
- The DRA measures the ECD voltage, current and also provides a figure of merit called equivalent resistance.
- The DRA is a computerized test system. The measurement is non-contact and full-body maps of a roller can also be obtained to assess the uniformity of the roller coating.

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A Case Study (1)

- A case study was conducted to demonstrate the efficacy of the ECD method and the DRA-2000L test system.
- The samples used include 24 rollers for the HP4000 printer. The set was selected to include new OEM, used OEM, and aftermarket rollers from several sources.
- The case study demonstrated the principle of the ECD method and the application of the DRA system to roller development, production QC, recycled component assessment, and also problem-solving.

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A Case Study (2)

- In the case study, the DRA-2000L was first used to characterize the dielectric relaxation of the charge rollers. Charge relaxation curves (V_{ECD} vs time) and maps of the rollers were obtained.
- The performance predicted by the DRA measurements (i.e., is a roller good or bad) was verified by measuring the charging effectiveness of each roller in QEA's PDT-2000LA OPC drum test system. In this system, the voltage developed on the OPC for each roller is obtained under both DC+AC and DC only conditions.
- The results from DRA-2000L and PDT-2000LA correlate very well.

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A Case Study (3)

- The last step in the case study is to perform print testing using a toner cartridge installed with the charge rollers tested. The quality of the test prints were evaluated in terms of dot gain (tone reproduction), background and ghosting using QEA's Personal IAS image analysis system.
- Generally, low relaxation rollers result in high dot gain (poor tone reproduction control), and high background and ghosting.
- The correlation between measurements from DRA-2000L, PDT-2000LA and Personal IAS strongly support the efficacy of the DRA-2000L.

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A Case Study (4)

- In this report, several specific examples of successful applications of the DRA-2000L have been described:
  – Formulation of coating materials
  – Selection of roller vendors
  – Diagnosis of print engine problem
  – Assessing reusability of recycled charge rollers
- Additional test reports are also included in the Appendices for further illustrations on DRA-2000L applications.

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Concluding Remarks

- The Electrostatic Charge Decay (ECD) method and its implementation in the DRA-2000L Dielectric Relaxation Analysis System offers a novel and practical approach to charge roller testing.
- The ECD method is based on a fundamental understanding of the roller charging mechanism, and the design of the DRA-2000L simulates the environment and the conditions of the charging process.
- The DRA-2000L is the best tool available for charge roller testing today.

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Appendix

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Appendix C: An Example on Using the DRA-2000L for Charge Roller Failure Analysis

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March, 2006

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Objective

- In this study, the DRA-2000L is used in an investigation on why an aftermarket charge roller that has been successfully used for quite some time "suddenly" is failing the customer's acceptance test.
- "Normal" (good) and "NG" (bad) rollers are used to reveal the differences, if any.
- New coating formulations are also tested to look for improvements.

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Test Samples (1)

- The charge rollers studied in this example are originally intended for the HP LJ1020, 1200, or similar printers (~15 ppm). Recently, the end-user (a toner cartridge remanufacturer) is exploring the use of the same roller in the higher speed HP LJ1300 and 1320 (20 and 22 ppm respectively). The test samples are selected to help in understanding why some rollers are failing recently.
- To help the analysis, OEM rollers for LJ1200, LJ1320 and LJ4000 are also tested to provide some reference data.

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Test Samples (2)

- 3 OEM rollers are also included in the study as a reference:
  - A: HP1200 OEM (New)
  - B: HP1320 OEM (New)
  - C: HP4000 OEM (New)
- There are a total of 5 aftermarket rollers (including commercial and experimental samples):
  - D: HP1200 “Normal”
  - E: HP1200 “NG”
  - F: HP1200 IC LR
  - G: HP1200 IC HR
  - H: HP4000 “Normal”

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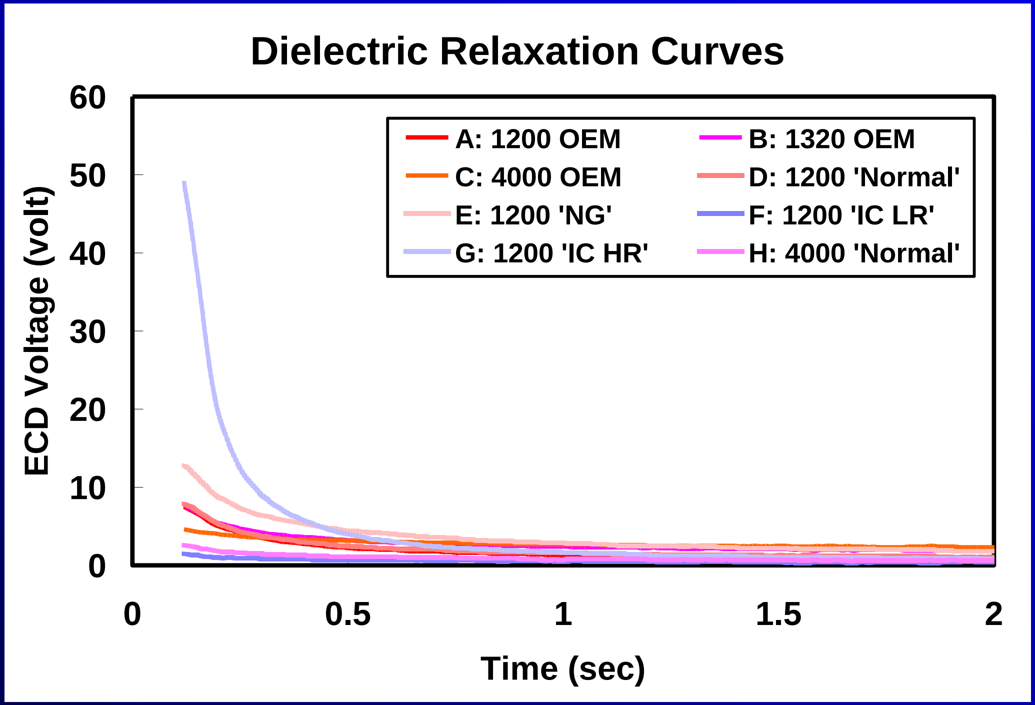
Dielectric Relaxation (V_{ECD} and R_e)
Linear Scale

- The relaxation curves of all rollers show quite a range in dielectric relaxation behaviors. The next slide in a semi-log scale will highlight this further. Sample G is the lowest and E the second lowest in dielectric relaxation. Both samples are known to have print quality problems.



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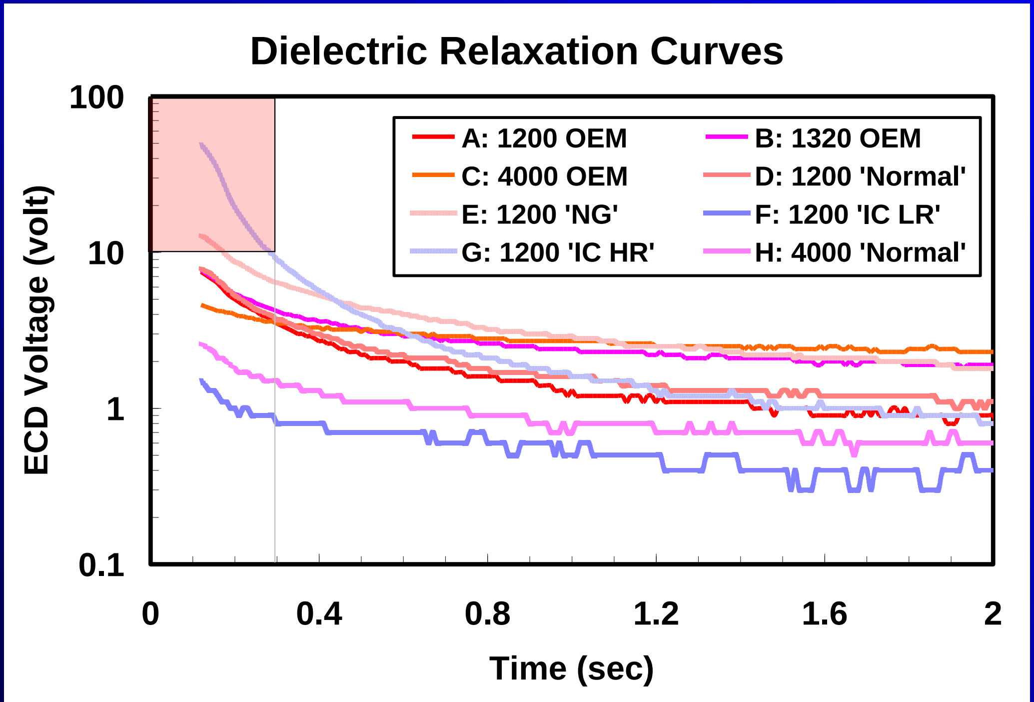
Dielectric Relaxation (V_{ECD} and R_e)
Semi-log Scale

- These semi-log plots at short time give a clearer view on the differences between the various rollers.
- Sample G, 1200 ‘IC HR’ is definitely in the critical zone that is expected to have print quality problems.
- Sample E, 1200 ‘NG’ is marginal and may have localized problems.



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V_{ECD} and R_e (Mean & Standard Deviation) Obtained from Uniformity Mapping (1)

- Samples G and E have high V_{ECD} and R_e – high potential for print quality problems.
- Sample D, labeled as 1200 'Normal" is in fact quite marginal in its relaxation characteristics since V_{ECD} is high, and more importantly, the uniformity is relatively poor (with high stdev value).

	V_{ECD} (volt)		R_e ($M\Omega$–cm^2)	
Sample	Mean	Stdev	Mean	Stdev
C: 4000 OEM	6.5	0.4	410.1	3.7
H: 4000 'Normal'	4.1	1.2	382.5	14.3
D: 1200 'Normal'	9.3	1.7	438.9	14.7
E: 1200 'NG'	11.5	3.5	454.1	23.6
F: 1200 'IC LR'	1.6	0.1	335.2	4.6
G: 1200 'IC HR'	41.9	13.8	599.8	55.5

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V_{ECD} and R_e (Mean & Standard Deviation) Obtained from Uniformity Mapping (2)

- Sample F (1200 'IC LR') has very low V_{ECD} and R_e. In addition to high uniformity, therefore it is likely to be a very good roller.
- Generally, the standard deviation in both V_{ECD} and R_e are high compare with those of the OEM. In other words, these aftermarket rollers are quite non-uniform and may lead to print quality problems immediately or eventually under unfavorable print conditions such as an increase in print speed.

	V_{ECD} (volt)		R_e (MΩ–cm^2)	
Sample	Mean	Stdev	Mean	Stdev
C: 4000 OEM	6.5	0.4	410.1	3.7
H: 4000 'Normal'	4.1	1.2	382.5	14.3
D: 1200 'Normal'	9.3	1.7	438.9	14.7
E: 1200 'NG'	11.5	3.5	454.1	23.6
F: 1200 'IC LR'	1.6	0.1	335.2	4.6
G: 1200 'IC HR'	41.9	13.8	599.8	55.5

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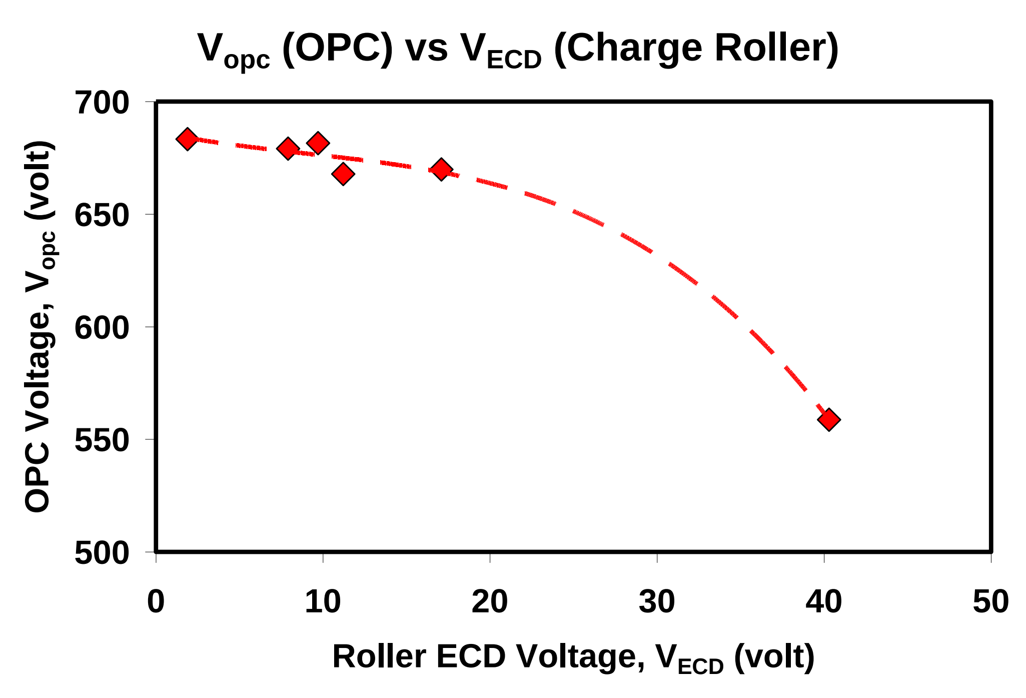
Effect of Roller Dielectric Relaxation on OPC Charging Efficiency (1)

- Dielectric relaxation in charge rollers directly impacts OPC charging efficiency as shown in a graph of Vopc vs V_{ECD}
- The OPC voltage is measured in an OPC drum test system (PDT-2000LA).



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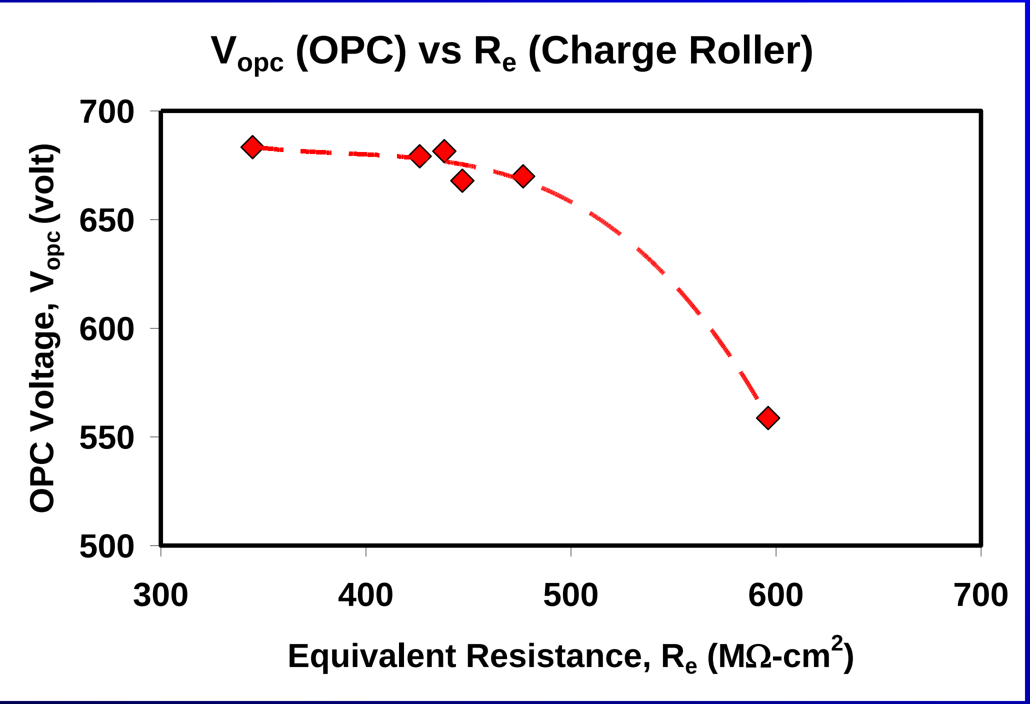
Effect of Roller Dielectric Relaxation on OPC Charging Efficiency (2)

- A similar correlation can be seen between roller R_e and V_{opc}.
- The higher is the R_e, the lower the V_{opc}.



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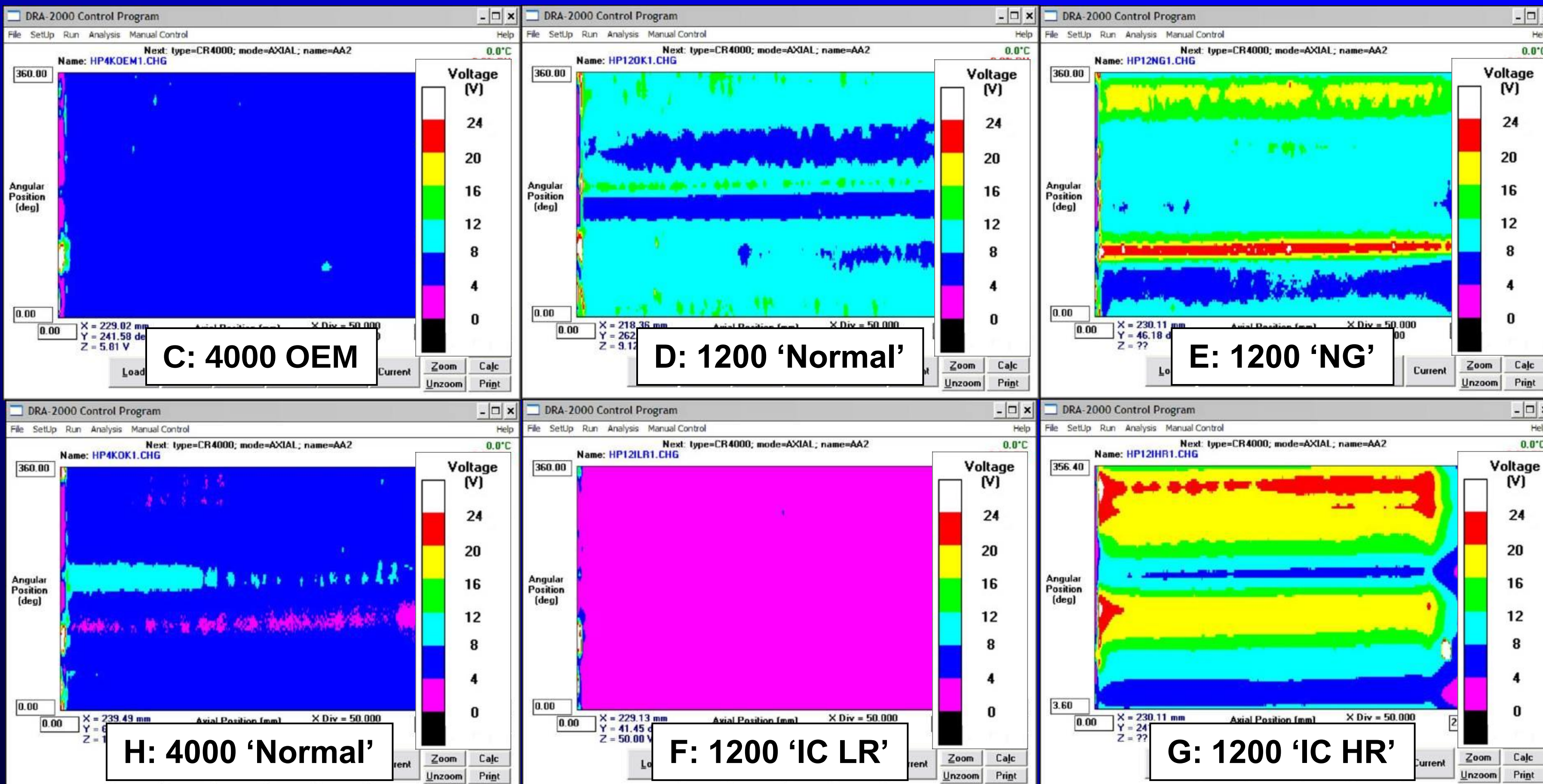
Dielectric Relaxation (V_{ECD}) Maps



- Note that other than Sample F, all other aftermarket samples have noticeable non-uniformity circumferentially (top-to-bottom).

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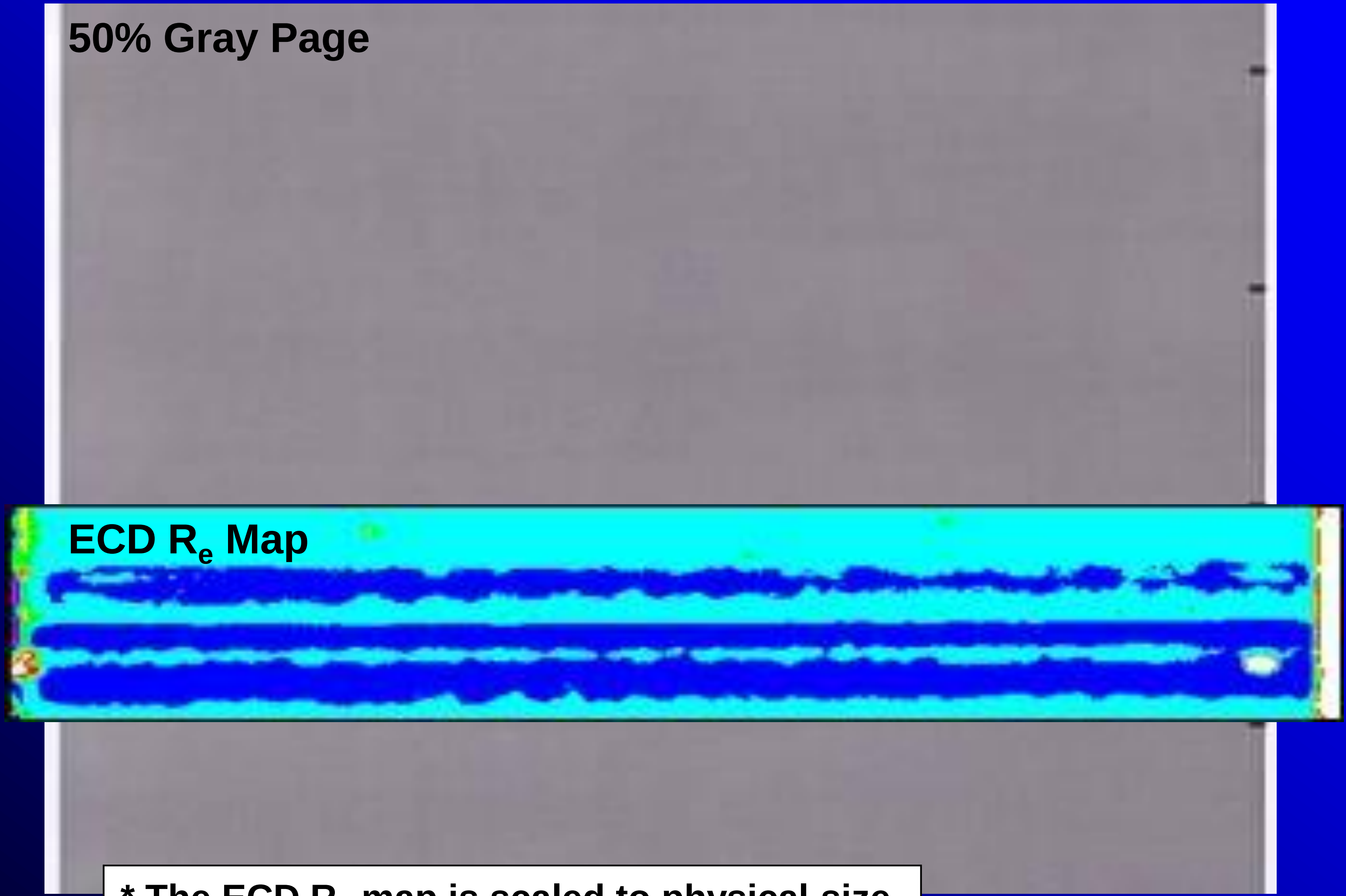
Sample D: 1200 ‘Normal’



* The ECD R_e map is scaled to physical size.

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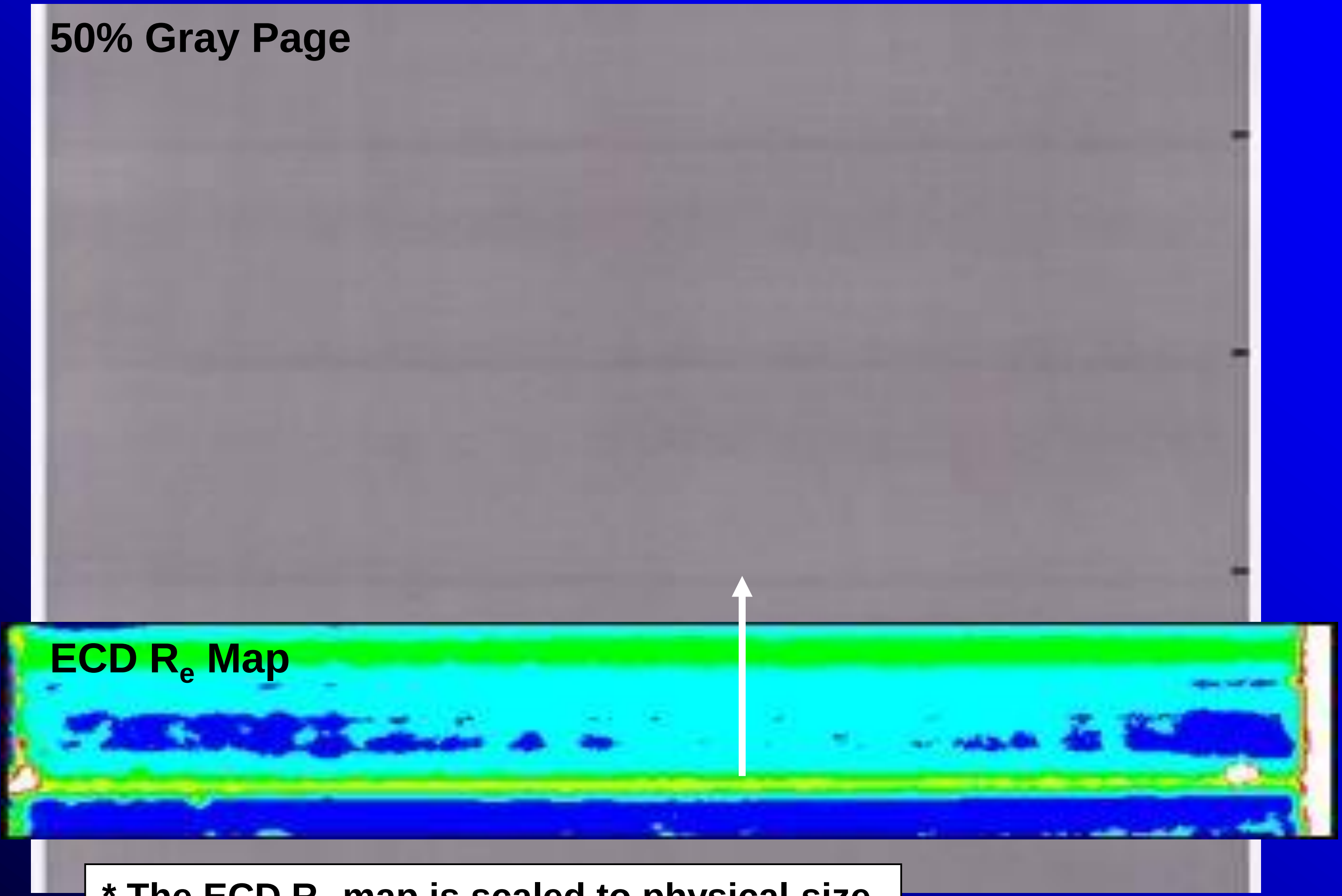
Sample E: 1200 'NG'



* The ECD R_e map is scaled to physical size.

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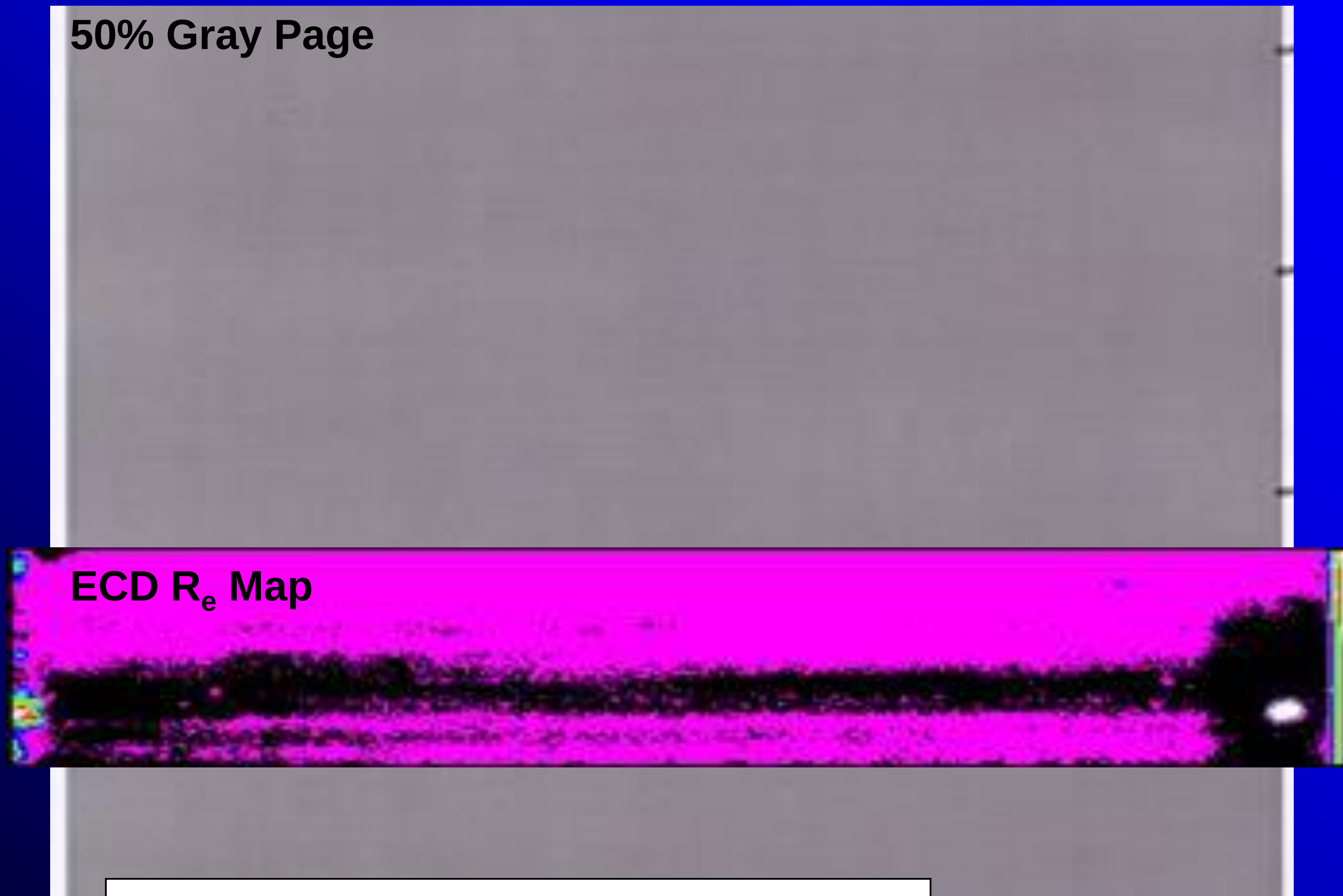
Sample F: 1200 'IC LR'



* The ECD R_e map is scaled to physical size.

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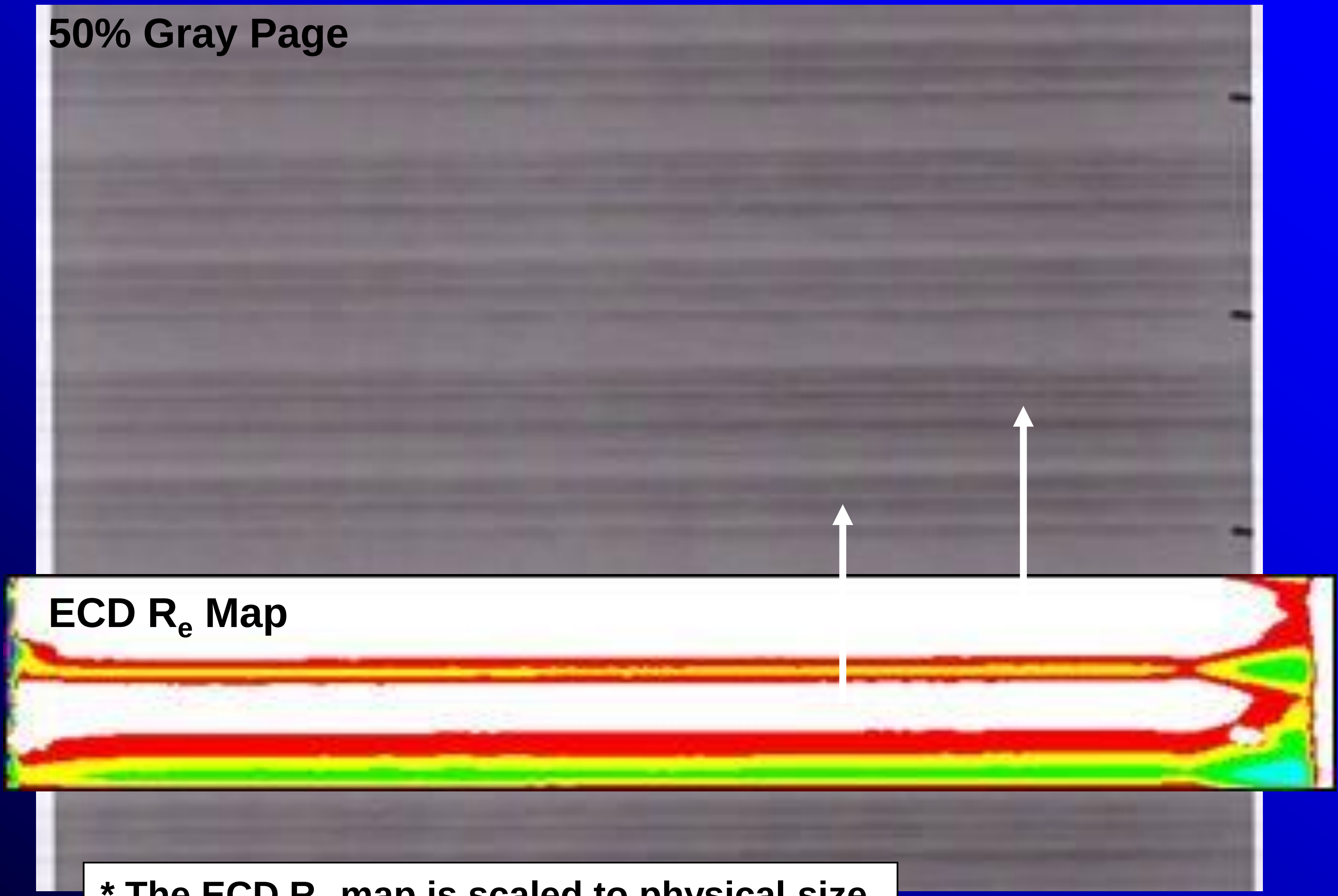
Sample G: 1200 'IC HR'



* The ECD R_e map is scaled to physical size.

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Summary Remarks

- This example demonstrates the effectiveness of the DRA system in solving charge roller materials or process problems.
- Using V_{ECD} (and/or R_e) measurements, the roller conditions can be assessed quantitatively to reveal hidden problems that could not be seen by conventional resistance measurement techniques.
- Using DRA-2000L's unique mapping function, roller coating uniformity can be detected. The correlation between print results (e.g. in the 50% gray page) and the roller ECD (R_e) map is an extremely powerful feature for failure analysis and process improvements.

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