Investigations on the Corona Degradation of Polymeric Insulating Samples

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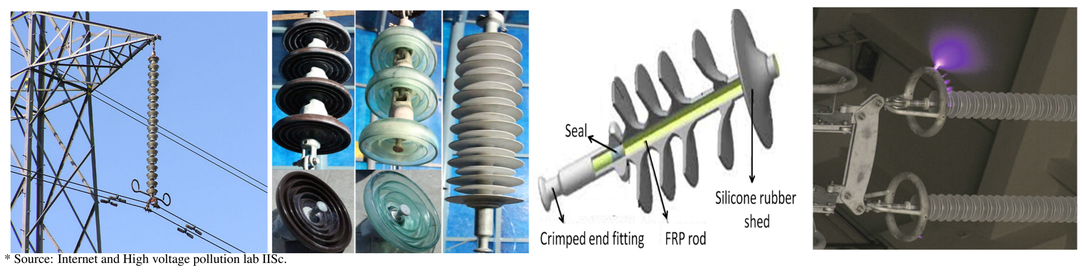
Introduction



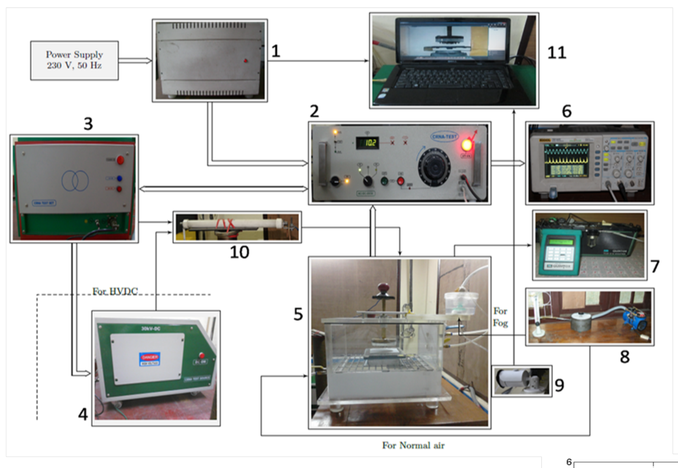
* Source: Internet and High voltage pollution lab IISc.

- Insulators are an integral part of high voltage power transmission system.
- Corona is a localized air breakdown due to intense electric field.
- Occurrence of corona in the high voltage transmission system is unavoidable and it has been identified as one of the degradation inducing factor for polymeric insulators.
- Corona activities are intense under moisture (fog /rain /snow) condition.
- Long-term performance evaluation of polymeric insulators are still under consideration.
- Detection of corona is difficult and presently available techniques are expensive.

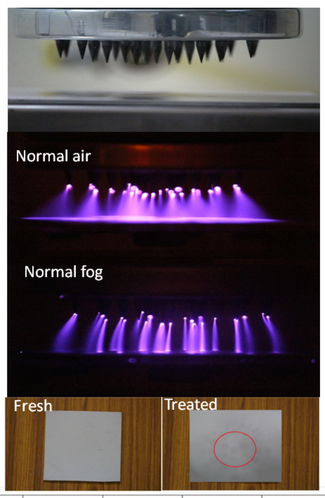
Objectives

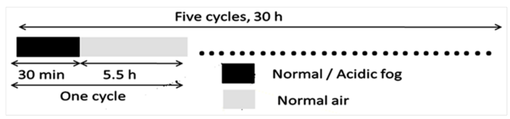
- To develop a methodology to investigate the corona degradation of polymeric insulating samples under different moisture condition.
- An attempt to develop digital image processing for better analysis and interpretation of corona discharge and degradation.

Experimentation

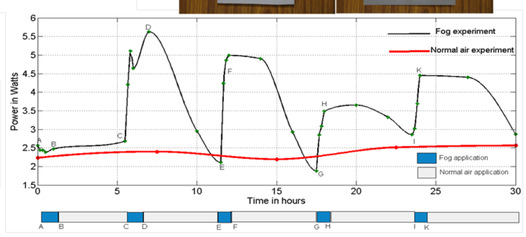


Proposed methodology





Fog cycle

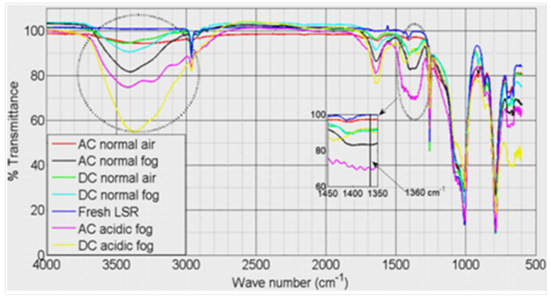


Corona power variation

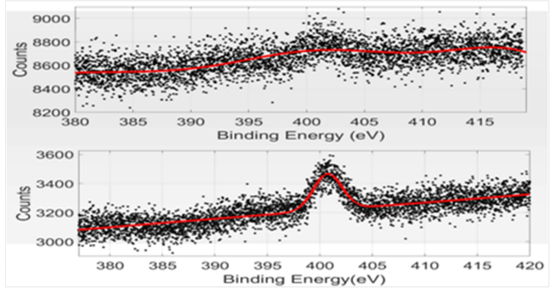
1- Isolation transformer, 2- Control panel, 3- 25 kV_{rms} HVAC source, 4- 30 kV HVDC source, 5- Corona chamber, 6 - Digital storage oscilloscope, 7 - Gas analyzer, 8- flow controlled pump, 9 - Camera, 10 - Resistor 180 kΩ, 11- Discharge monitoring system

- Cyclic application of fog to simulate moisture.
- Experiments conducted - Normal air, Normal fog and Acidic fog.
- Samples used - High Temperature Vulcanized (HTV) silicone rubber, Liquid Silicone Rubber (LSR).

Study of Material Degradation

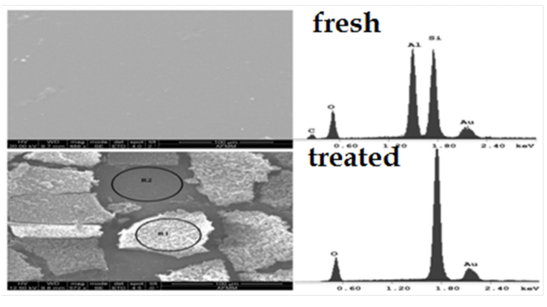


Fourier transform infrared spectroscopy (FTIR)

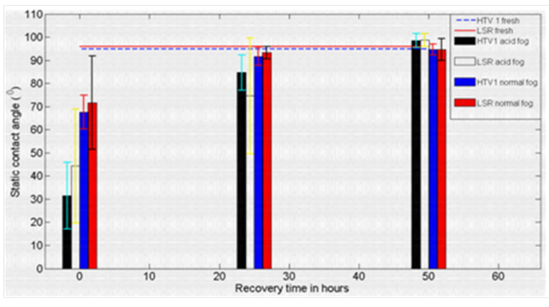


X-ray photoelectron spectroscopy (XPS)

FTIR and XPS analysis → detection of nitric acid on the sample surface



Scanning electron microscopy (SEM)



Contact angle measurement

SEM and contact angle measurement → Loss of Alumina trihydrate (ATH) fillers and hydrophobicity

Digital Image Processing for Corona Analysis

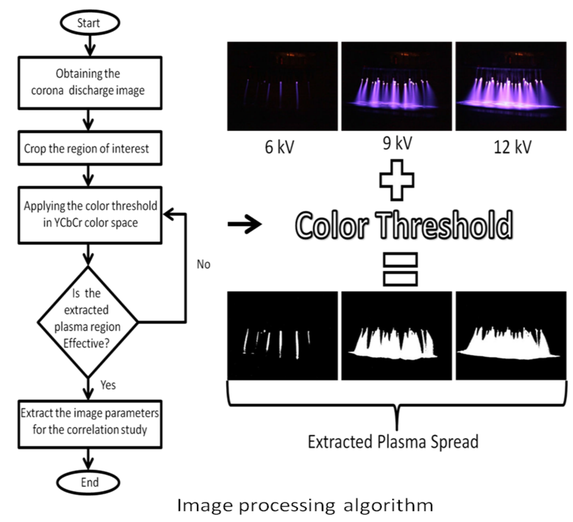
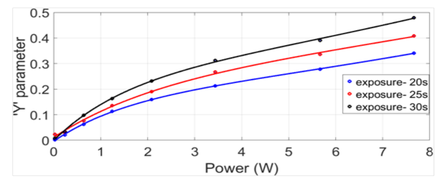


Image processing algorithm

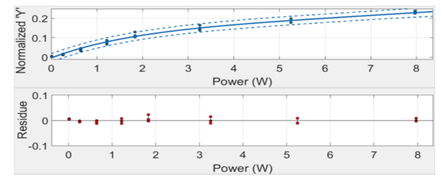
$$2^{EV} = \frac{k^2}{t} \qquad L = L_{ref} \times 2^{(EV-EVref)} \times \frac{ISO_{ref}}{ISO}$$

EV – exposure value, k – camera aperture, t – Exposure time,
ISO – Camera sensor gain

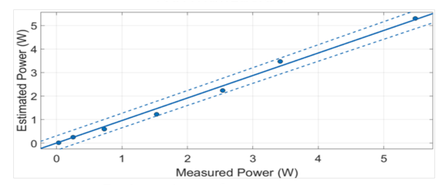
$$Y = 0.2126729\times R + 0.7151522 \times G + 0.0721750\times B$$



Variation of Y parameter with the corona power



Normalization

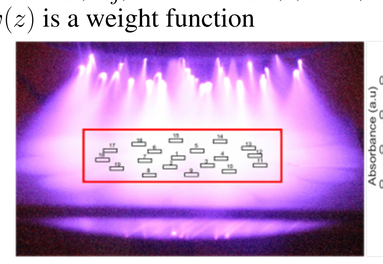


Estimation of corona power

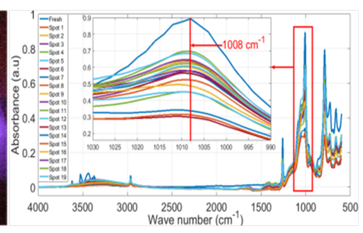
High Dynamic Range (HDR) Imaging

$$\phi = \sum_{i=1}^{N}\sum_{j=1}^{P}\{w(Z_{ij})[g(Z_{ij}) - lnE_i - ln\triangle t_j]\}^2 + \lambda \sum_{z=Z_{min}+1}^{Z_{max}-1}[w(z)g''(z)]^2$$

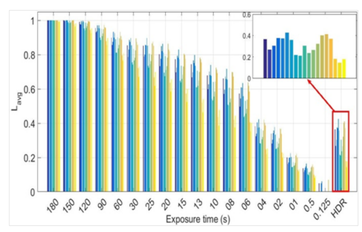
where, $g(Z_{ij}) = lnf^{-1}$, $g''(z) = g(z-1) - 2g(z) + g(z+1)$, λ is a scalar quantity (smoothness term)
$w(z)$ is a weight function



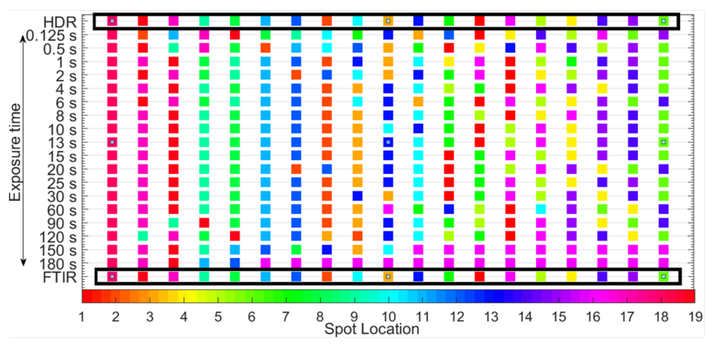
Sample with corona exposed spots



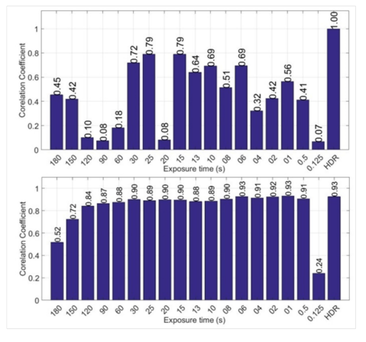
FTIR spectrum



Luminance component variation



Degradation pattern



Correlation coefficients

Summary

- Methodology is proposed to study the moisture aided degradation of polymeric insulating samples.
- Findings:
  - Fog treatment ⇒ More material degradation.
  - Detection of nitric acid ⇒ Brittle fracture in the long-run.
  - Loss of Aluminum trihydrate (ATH) fillers ⇒ Reduction in tracking resistance.
  - Loss and recovery of hydrophobicity ⇒ Reduction in pollution performance.
- The corona power estimated from 'Y' parameter provides a good correlation with the measured values.
- HDR imaging provides true correlation with the material degradation whereas the conventional images resulted in pseudo-correlation.
- Attempt has been made to apply the digital image processing to better analyze and interpret the corona discharges.

Publications (forming part of the research work)

1. Subba Reddy B., and Shakthi Prasad D., "Effect of Coldfog on the Corona Induced Degradation of Silicone Rubber Samples," *IEEE Trans. on Dielectric and Electrical Insulation,* Vol. 22, Issue 3, pp. 1711-1718, June 2015.
2. Subba Reddy B., and Shakthi Prasad D., "Corona degradation of the polymer insulator samples under different fog condition," *IEEE Trans. on Dielectric and Electrical Insulation,* Vol. 23, No. 1, pp. 359-367, February-2016.
3. Shakthi Prasad D., and B. Subba Reddy, "Impact of Mist and Acidic Fog on Polymer Insulator Samples Exposed to Corona Discharges," *IEEE Trans. Dielectric and Electrical Insulation,* Vol.23, No. 3, pp. 1546-1554, June 2016.
4. Shakthi Prasad D., and B. Subba Reddy, "Digital Image Processing Techniques for Estimating Power Released from the Corona Discharges," *IEEE Trans. on Dielectric and Electrical Insulation ,* Vol. 24, No. 1, pp. 75 - 82, Jan 2017.
5. Shakthi Prasad D., and B. Subba Reddy, "Study of Corona Degradation of Polymeric Insulating Samples Using High Dynamic Range Imaging Technique," *IEEE Trans. on Dielectric and Electrical Insulation* Vol. 24, No. 2, pp. 1169-1177, April 2017.
6. Shakthi Prasad D., and B. Subba Reddy, "Study on Corona Activity using Image Processing Approach," *IEEE Trans. on Industry Application,* (accepted for publication).

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Shakthi Prasad D.

Research supervisor

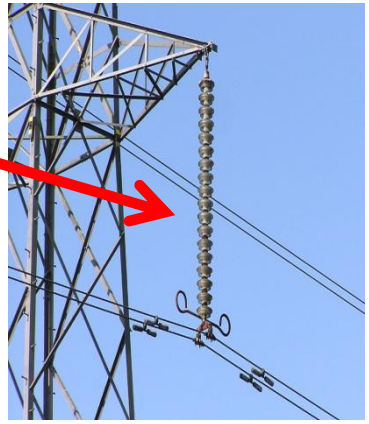
Dr. Subba Reddy B.

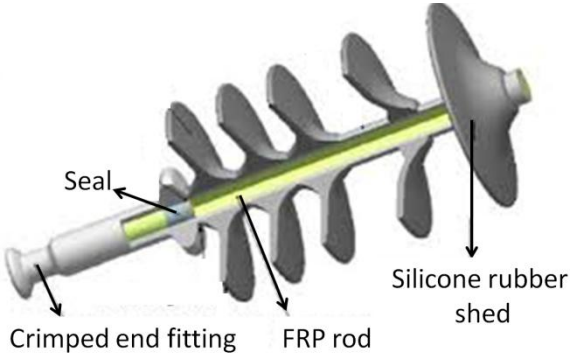
Department of Electrical Engineering

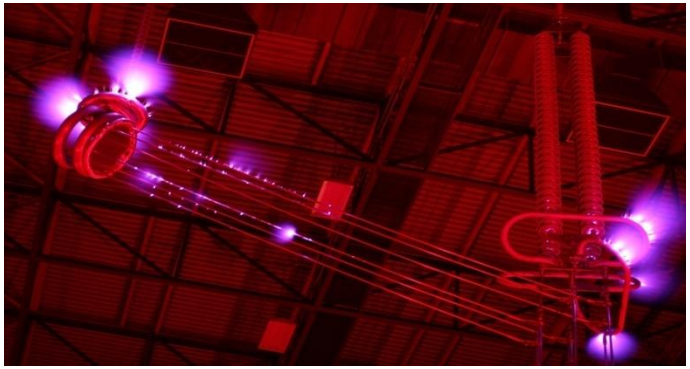
EECS Research Students Symposium - 2017

Indian Institute of Science, Bangalore

Introduction

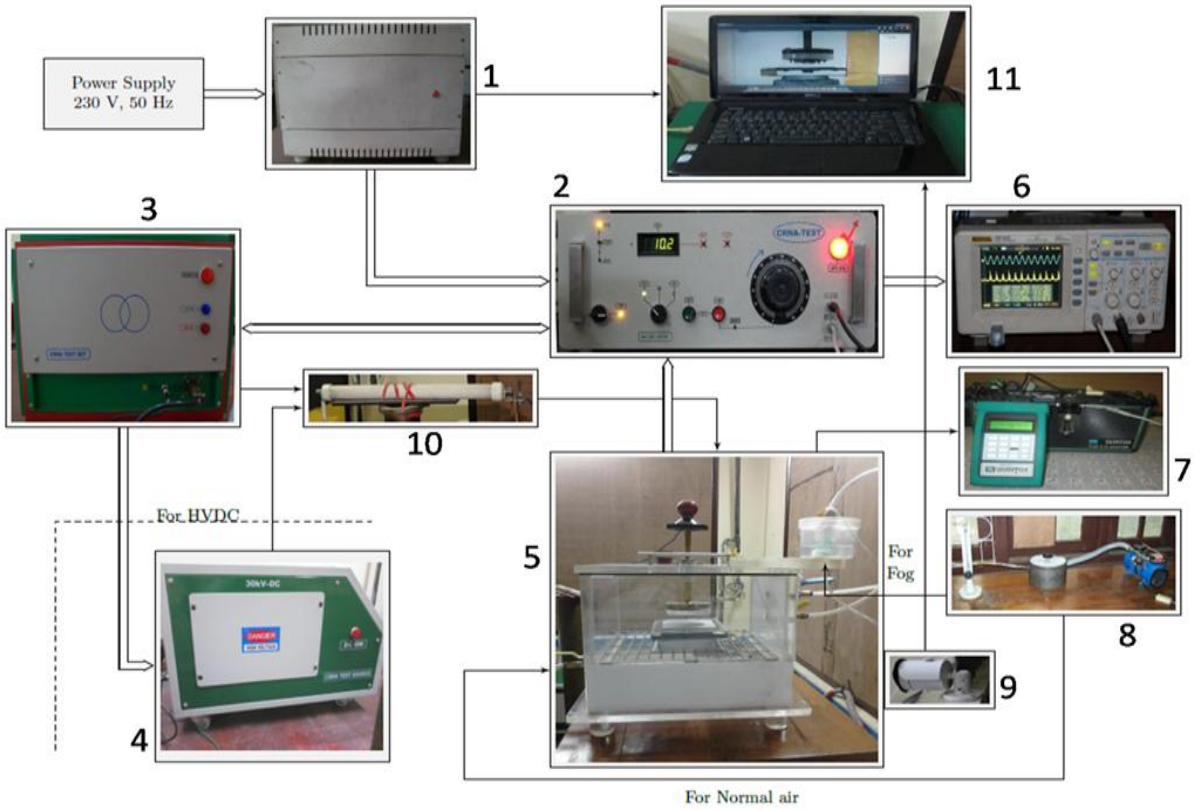


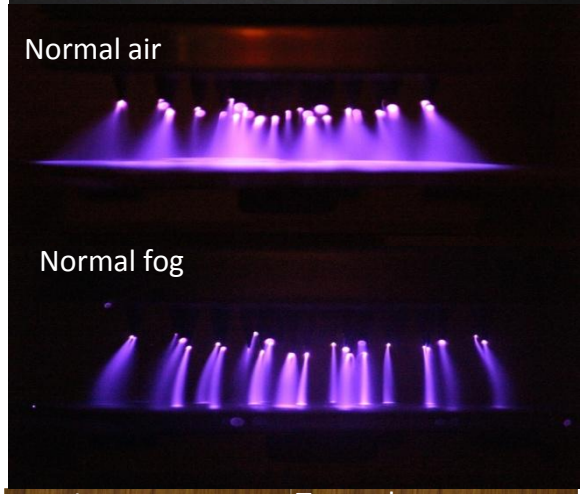


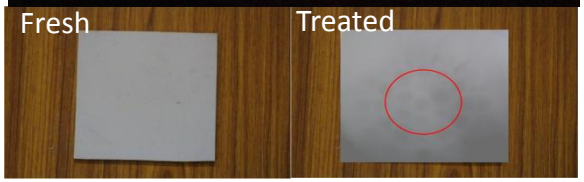


- A methodology is proposed to study the moisture aided corona degradation on polymeric insulating samples.
- An attempt is made to apply the digital image technique to analyze, quantify the corona discharges and the material degradation.

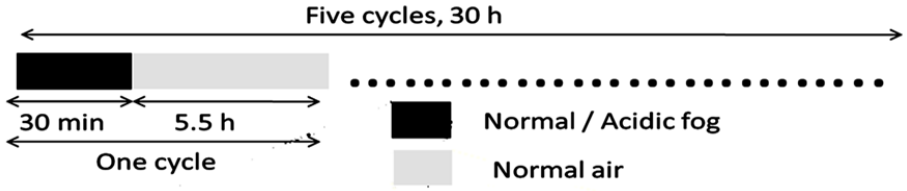
Experimental arrangement



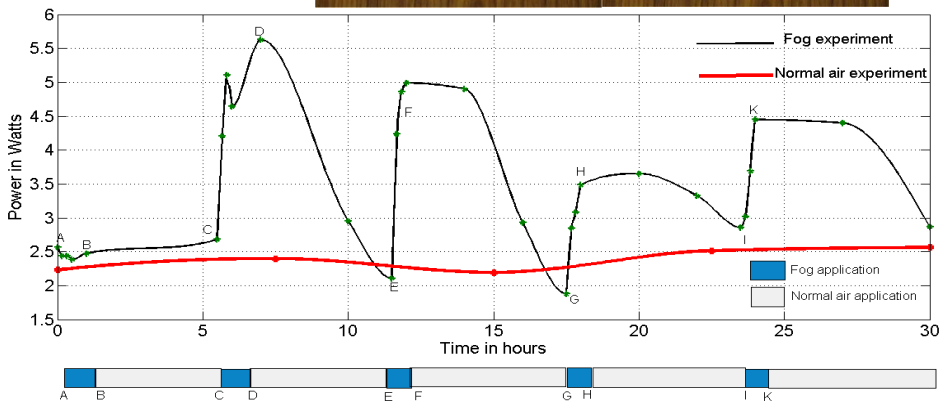




Proposed methodology

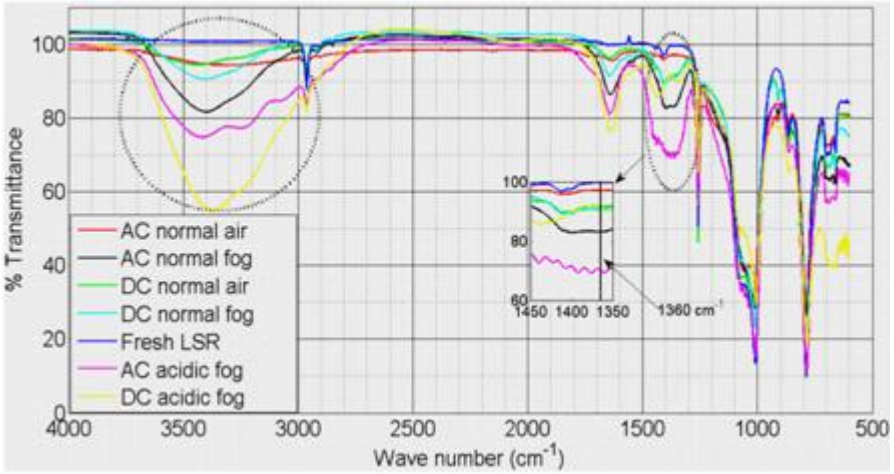


Fog cycle

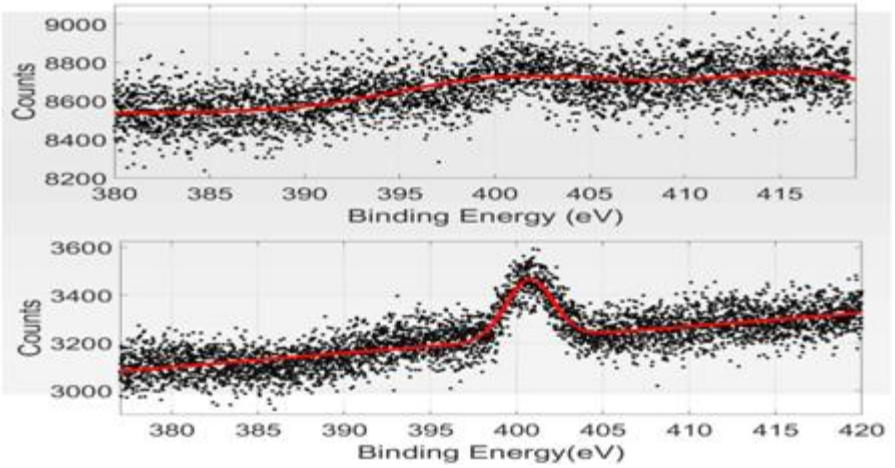


Corona power variation

Material degradation

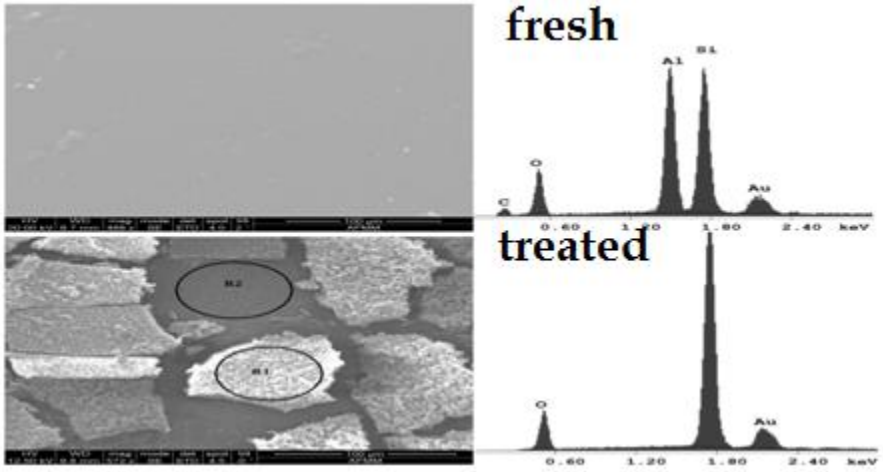


Fourier transform infrared spectroscopy (FTIR)



X-ray photoelectron spectroscopy (XPS)

FTIR and XPS analysis → detection of nitric acid on the sample surface



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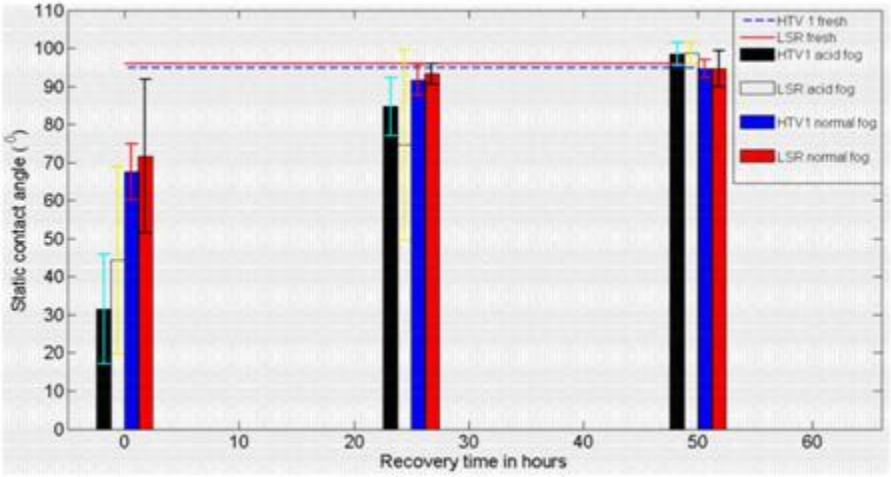

Contact angle measurement

SEM and contact angle measurement → Loss of Alumina trihydrate (ATH) fillers and hydrophobicity

Digital Image Processing: Corona Analysis

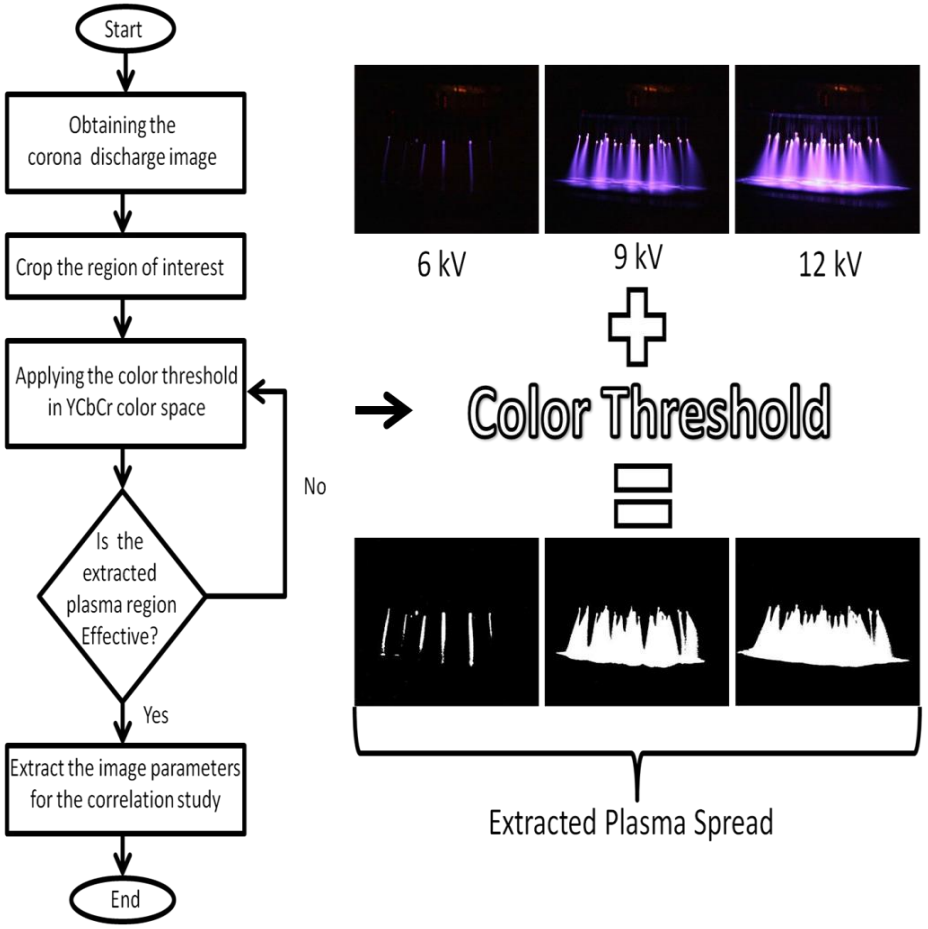

Image processing algorithm

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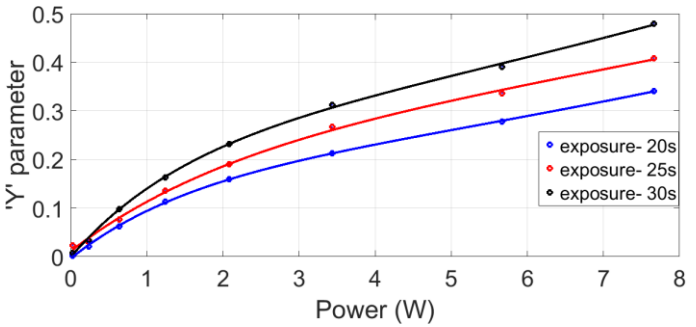

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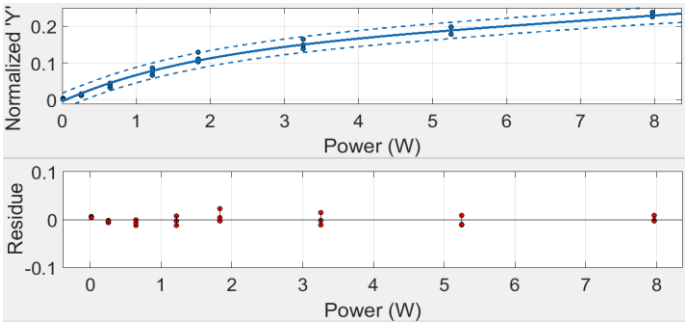
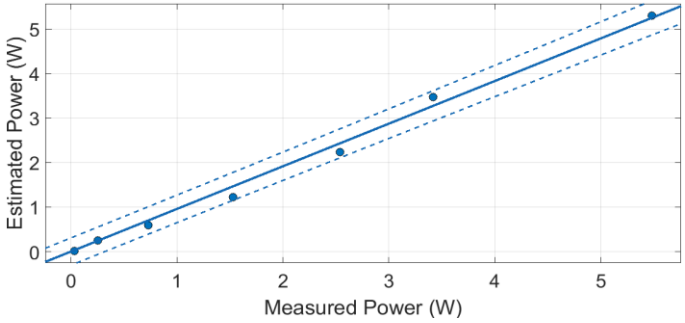
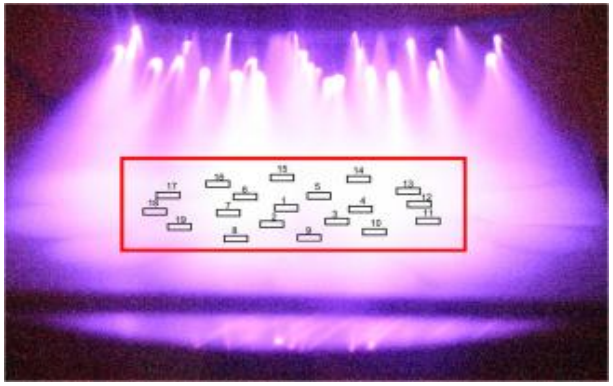


Normalization

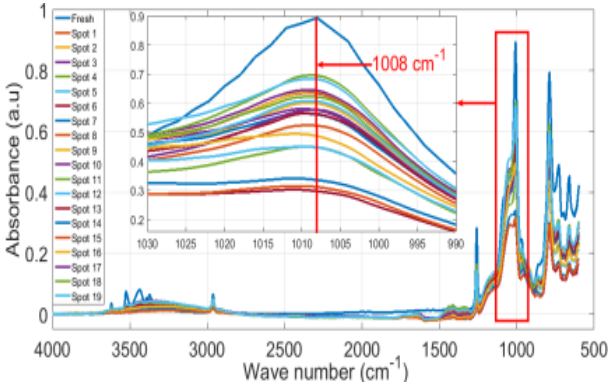


Estimation of corona power

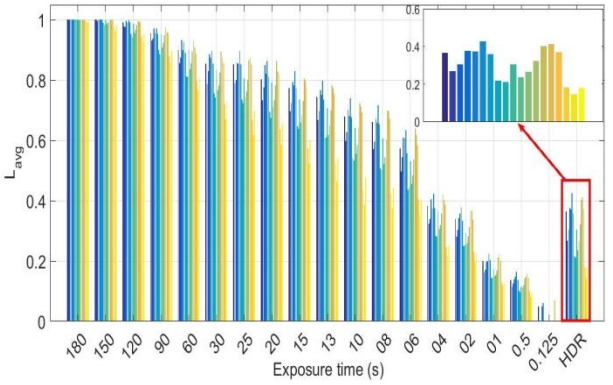
High dynamic range (HDR) imaging technique



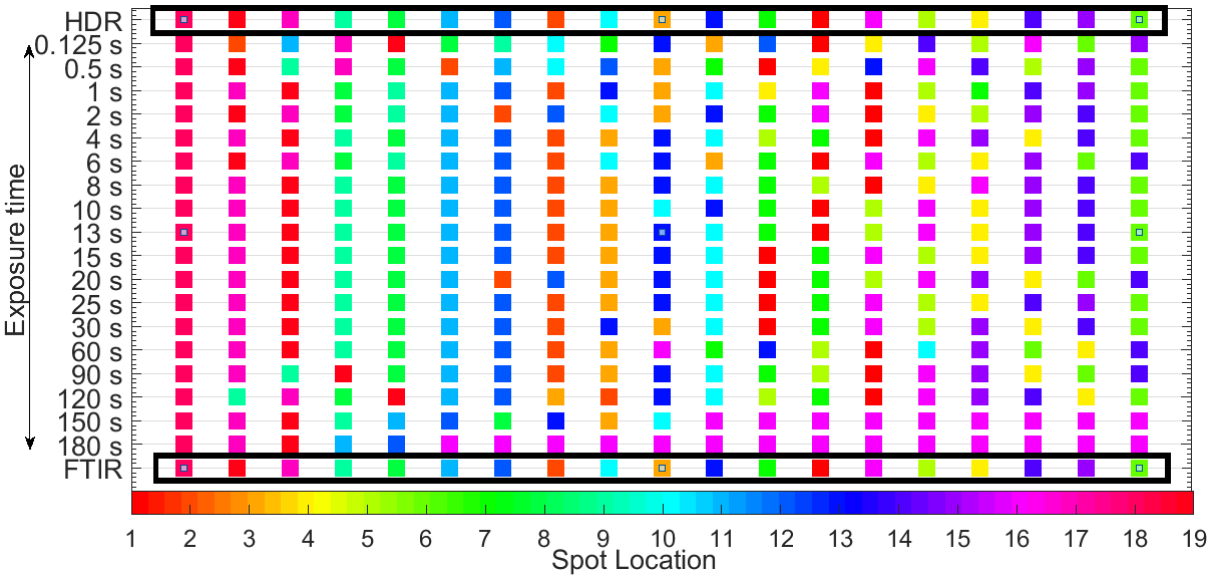
Sample with corona exposed spots



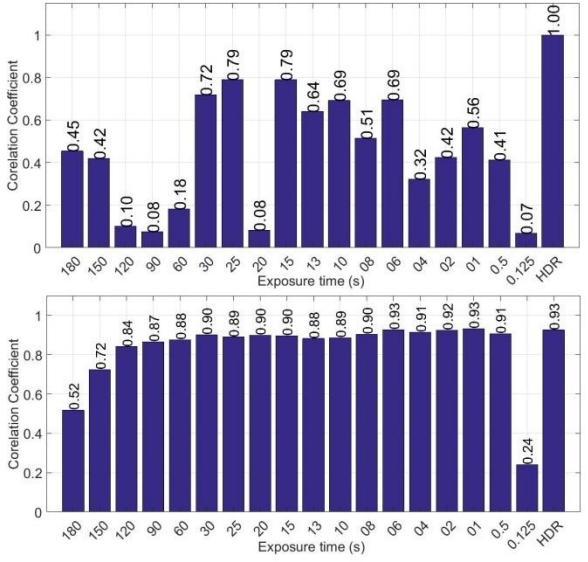
FTIR spectrum



Luminance component variation



Degradation pattern



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Summary & Conclusions

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- The corona power estimated from 'Y' parameter provides a good correlation with the measured values.

- HDR imaging provides true correlation whereas the conventional images resulted in pseudo-correlation.

- Attempt has been made to apply DIP as low-cost solution for corona detection and analysis.

Publications

1. Subba Reddy B., and Shakthi Prasad D.,"Effect of Cold fog on the Corona Induced Degradation of Silicone Rubber Samples," *IEEE Trans. on Dielectric and Electrical Insulation*, Vol.22, Issue3, pp.1711-1718, June 2015.

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Thank You