Advances in UHV Transmission and Distribution
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Lecture – 13
Surface degradation studies on composite insulators

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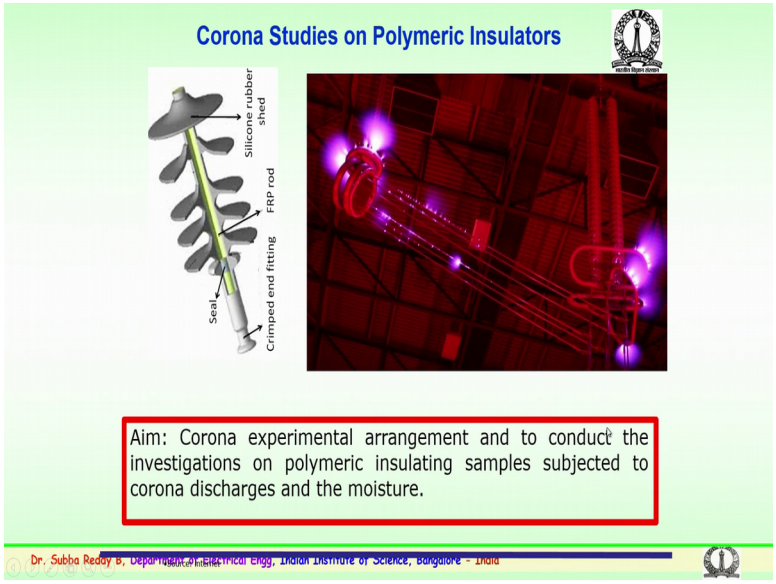

So, the first we would like to look focus on the corona aspects: the corona studies on coronal insulators. So, as mentioned earlier just for information; we have a polymer insulator which mainly comprises of the crimped end fittings, both the side the end fittings are there. Apart from that, we have a fiber glass or rod f r p rod; from the metal to metal and we have silicon rubber or a polymeric sheds which are housed on the silicon rubber insulators.

So, corona which I was mentioning could be of two type, so one is the corona which is coming out from the hardware of the transmission system, the conductors, the corona control rings than the hardware. So, these corona this you can very clearly see here this is the corona control ring, these are the insulators which are suspension; two suspension insulators, twin suspension insulators. The corona which is being generated by the corona control rings continuously will be interacting with the surface of this insulator where; the contiguous bombardment of discharges on the surface could likely to create a surface degradation over a period.

So, how the experimentation and how the activity which will degrade have to be studied, so it is expected that corona experimental arrangement to conduct the investigations particularly on polymer insulating samples. So, either full scale insulators or the actual insulator flat samples, which are the sample same material which will be used for manufacturing of the actual insulators; will be used for the study particularly to conduct investigations.

So, various types of samples to be subjected for corona discharges, during normal conditions there is a dry conditions and also the performance during the moisture. So moisture in the sense a light rain dazzle or a fog, so this aggravates the corona activity. So, where the combination of the corona with the moisture could further degrade the surface of the polymer; so, this has to be a studied in detail which very less information is available in the literature as these insulators are of recent origin, so studies have to be carried out on this aspect.

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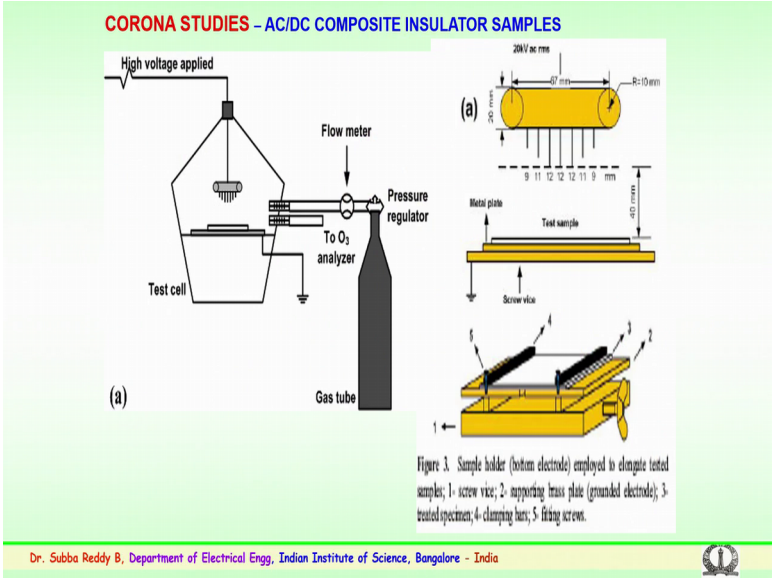

So, corona studies both for AC and DC composite or polymer insulator samples, so it is normally conducted in a experimental arrangement; test cell, where intentionally with a use of a corona needles; the corona various types of a needles could be used either a circular type of needles where of uniform in nature or non uniform type of needles like which looks like a comb type of electrodes.

So, simulation of uneven or you know un-uniform corona, non-uniform corona or uniform corona could be made using by properly selecting the needles and the tests sample will be kept here and continuously the high voltage is applied, the discharges which are corona discharges from the needles will be impinged on the sample here and the performance will be verified with supplying unknown dry air or moisture or the acidic effect could be pumped into the chamber and the effect could be studied over a period of time and the results could be analyzed, how the performance of the sample over a period of time.

Here, we could also measure the leakage the currents which are flowing to the ground; this will also help us to see the performance of the sample. These are various types of the electrodes which are being used, this is the sample electrode stand and this is a mechanical arrangement for the sample; you see that a proper attention is being done. So, this entire block is being kept here or to the sample is fixed and the experimentation is carried out.

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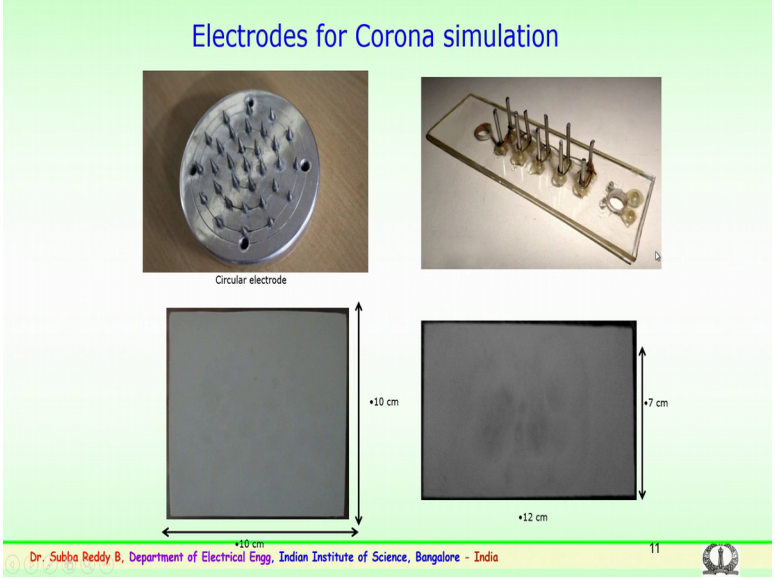

So, some of the methods which are being employed in the lab; so, we have tried to make two types of electrodes. So, one is particularly the uniform type of electrode consisting of 33 needles to simulate the uniform corona. We have other type of electrode which is shown here, this is again non-uniform type of arrangement to create a non-uniform corona, it is not a uniform needles are not employed here. So, we try to come simulate

the corona over a period of time and the discharges are continuously impinged on the sample, this is a flat or rubber samples actual samples which are used for the manufacturing of insulators.

So, it will be impinged over a period of time and that surface degradation is analyzed and studied.

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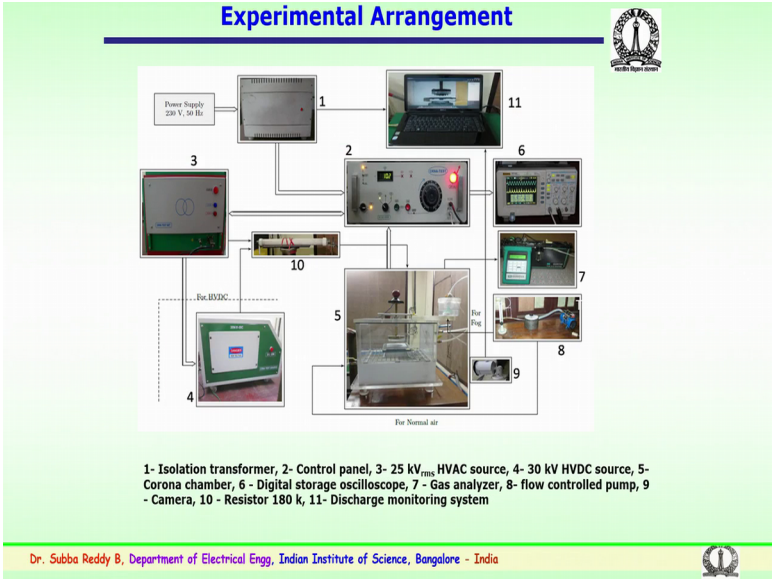

So, experimental arrangement with normally corona experimental arrangement consists of the following. So, we have a corona important is a corona control chamber here; we have a supply, power supply; a control panel we have high voltage AC, high voltage DC. So, for studying of AC voltages or studying the DC voltages both the AC, DC generators are here with a resister to limit the current in case of the flashover happens across the insulator sample here.

The sample is kept here, the high voltage is connected and continuously monitored over 10's of hours, period or 100 hours period and the performance of this samples is checked for AC, DC or we have a facility for this chamber where we can inject the natural air or a fog or a acidic fog and the effect on the samples could be a studied. So, this is a specially a made chamber and the monitoring of these activity of the corona is done in the monitoring system and the leakage current which is also could be is measured using a digital a storage oscilloscope.

And finally, the process that is a corona process, the activity during the corona activity; inside the chamber, the gases which are formed; nitrous oxide and many of these things could be also or we are measuring using a gas analyzer; which the gases found in this chamber. So, very important arrangement for the studies, longer duration studies of the corona performance on the samples.

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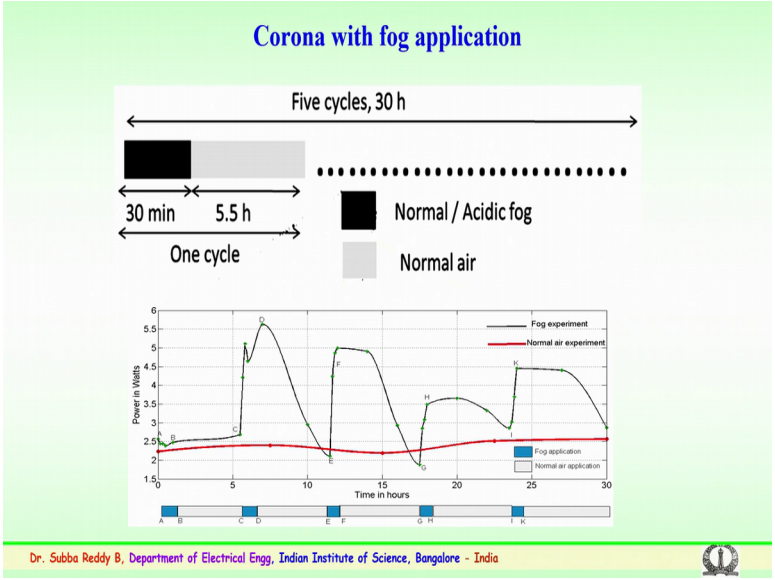

So, how the cycle is being designed that is application of voltage, application of fog could be of normal fog, a mist or an acidic fog which comprises acidic components; which simulates the acid rain. So, this methodology is being adopted; where depending upon the number of hour, say the cycles which is being presently shown is for 30 hours period example, the experiments have been conducted up to 100 hours also. So, for example; if it is a 30 hours; initially 6 hours is considered as one cycle.

So, in 6 hours; 30 minutes, the first 30 minutes is the application of either the normal mist or a fog or in case the experimentation is to simulate acidic form, then the 30 minutes comprises of the acidic fog, supply to the chamber where the sample will be seeing the acidic fog mist on it and the voltage; voltage is continuously applied for the experimentation period; it is a 30 hours, 40 or 100 hours, the entire cycle; the voltage stress will be there, but the fog composition is planned in such a way, it is for 30 minutes then 5.5 hours is a dry conditions where we apply the normal air circulation at a known quantity of air per minute or per second.

So, that is continuously supplied during the point of 5.5 hours, so 30 minutes is the normal form and rest this similar cycle is repeated 5, 6, 9, 10 depending upon the total number of hours, so one cycle comprises of 6 hours. So, this is one of the data which gives the power calculation; this y axis shows the power in watts and the time of; in which shows in time; in number of hours, in the x axis, you can see this particular experiment which is carried out for 30 hours shows how the performance of the sample.

So, initially there will be a fog application; later on for the normal conditions how the performance happens and how increases and finally, how the performance after 30 hour. So, this the red color shows the experimentation which has been conducted only for normal air, there is no fog during this experiment of 30 hours; for a comparison purpose, the sample allowed only normal air and electric stress. So, voltage is applied and it is been conducted; you see that not much of variation over the period of 30 hours, a very very marginal increase is being noticed. But, in case of fog or acidic fog you can see the increase in magnitude of the power over a period of time; this graph is shown for the normal fog conditions.

So, a comparison is made between the dry condition and the fog; where the magnitude increases the power which is consumed by the sample, the power flow into the sample is much more in case of fog or acidic fog; this would like to will create a surface changes over a period of time, in case there is a mist with a corona discharges on the surface for a long period of time.

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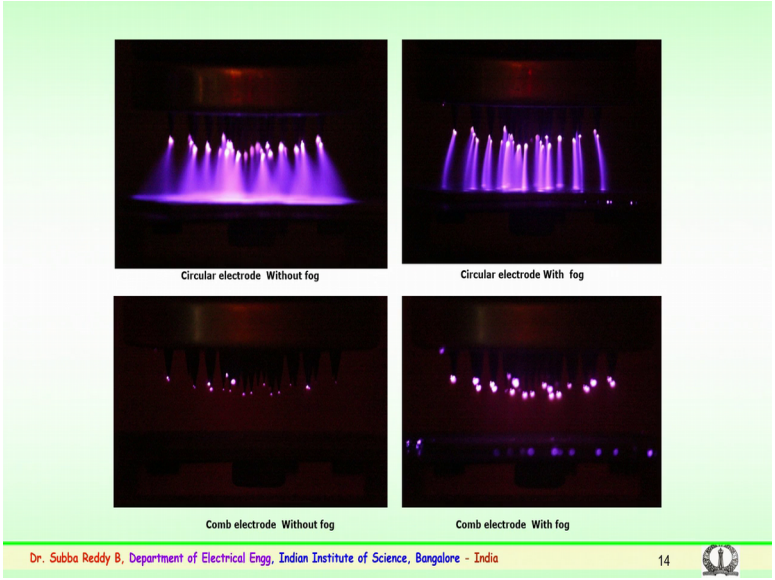

So, during experimentation where normal ambient light; it is very difficult to capture the corona discharges which are being impinged on the sample. So, these could not be taken with the normal photography; the discharges which you are seeing here are being taken with a setting of 30 seconds to capture this. So, the ambient is made completely dark and the photography is taken in such a way with a shutter speed of 30 seconds so that you can capture the discharges.

So, during normal condition these discharges will not be visible; you can see the corona electrodes for a normal uniform type here. So, very clearly all the 33 needles where you see the discharges from the 33 needles are being impinged on this sample, the polymer sample here; it continuously impinges on the sample and depending upon the number of hours the experimentation proceeds, the surface degrades over a period of time. This is for the dry conditions; that is without any application of mist or fog.

Here you can see for the similar electrode one fog is applied into the chamber or may be acidic or a normal fog, then the discharges will completely see that instead of complete spread; you can see a very a narrow type of discharges with higher magnitudes impinging on the sample. This is much more rigorous and much more higher magnitude in comparison to the normal conditions. So, this is again similar pattern which is being taken for comb type of electrode.

So, initially I was in circular type of electrode for uniform discharge generation; when comb for non-uniform, you see the discharges this is for without fog. In case of with fog, the intensity of the discharges increase and which will affect the sample.

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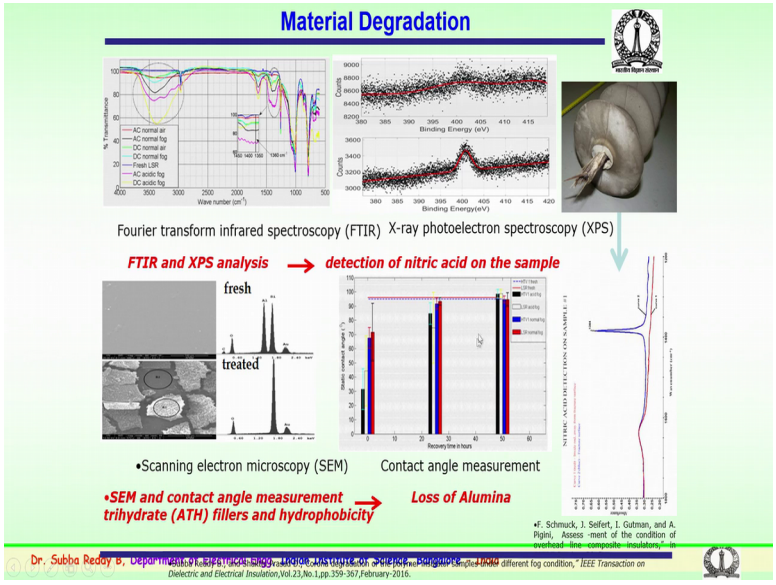

So, the material degradation, so very important I was mentioning for the surface studies various morphological studies; which are being carried out on the surface or to continuously applying the corona moisture or the acidic fog effect, the samples over a period of time; after the experimentation are taken out carefully and these have to be verify the surface changes which have happened or surface morphological happenings have to be properly analyzed.

So, for that I mentioned earlier several type of experiments or several type of analysis are being carried out like FTIR; Fourier Transform Infra Red, spectroscopy XPS analysis then SEM, then TGA, then several of these things. So, few of the information you can see here; the Fourier Transform Infra Red spectroscopy gives the spectrum in this way, where very clearly there is a changes which is very important for us here; this particular thing which happens at a wave number of 1350 to 1370, where it shows depending upon the fog either it is acidic or a normal fog. We have seen that the formation of nitric acid particularly is showing that the fog with the corona activity leads to nitric acid. This is a very dangerous in case this nitric acid formation enters the surface of the rubber insulator, a similar to that there have been reports that bridal fracture could occur.

So, this bridal fracture is one of the input because of the formation of nitric acid which could enter the surface inside the other glass rod and the failure of the fiber glass rod could happened. So, this gives the X-ray; XPS analysis, where it shows the number of counts versus the binding energy. So, we see that there is a difference for the fog and for the normal type of application that is without fog; you see a peak which is being generated particularly during the 400 to 405; that is a 395 to 400; binding energy electron volt level which shows significant information about the happenings on the surface.

Then the scanning electron microscope gives the information of the surface changes, you can see this is for the surface new; a fresh surface this surface whatever you are seeing is after that corona impingement on the sample and after the treatment. So, this clearly shows there is a cracks which are being formed on the sample which have been reflected here in the analysis.

Similarly, contact angle measurement very important; hydrophobicity, performance of the insulators have been measured over a period of time and this has been very clearly given here for various types of materials and their performance over a period of time. So, fresh with moisture and with acidic fog; the performance has been seen and how the recovery has happened over a period of time. So, recovery time verses the static angle that is angle which the sample shows, when the water droplet is been put on the rubber sample. There is a standard for the hydrophobicity measurements, the performance is verified and it is being estimated, so this is very important aspect for the detection of the hydrophobicity effect and how the performance of the hydrophobicity effect.

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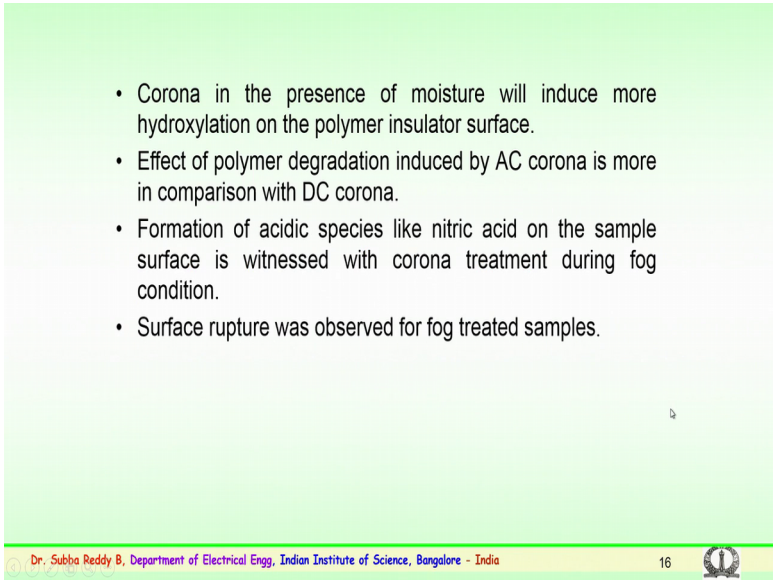

So, we have seen that corona in the presence of moisture will induce more hydroxylation on the polymer insulator surface; very important point. The effect of polymer degradation induced by the AC corona, in comparison to DC corona is higher. So, experiments have been carried out for both AC and DC voltages and the comparison has been made and the effect particularly degradation effect is seem to be higher in case of when the application of AC corona on the sample in comparison to the DC corona, this is because of the surface charging, a space charge which is a being formed on the surface could be one of the reason for the lesser degradation in comparison to the AC corona.

The formation of acidic species has mentioned; particularly like the nitric acid on the sample surface was observed during the corona treatment, particularly the fog condition there is a normal mist condition. So, this could lead to the surface rupture in degradation over a long period of time. So, this surface rupture was also observed for both the type of fog treated; that is the normal fog and also acidic fog that treated samples.

Similar phenomena could occur in the field, so once this phenomena occurs; the loss of hydrophobicity or the hydrophoby properties of the material could be weakened and the sample is likely to degrade in a faster; in the field.

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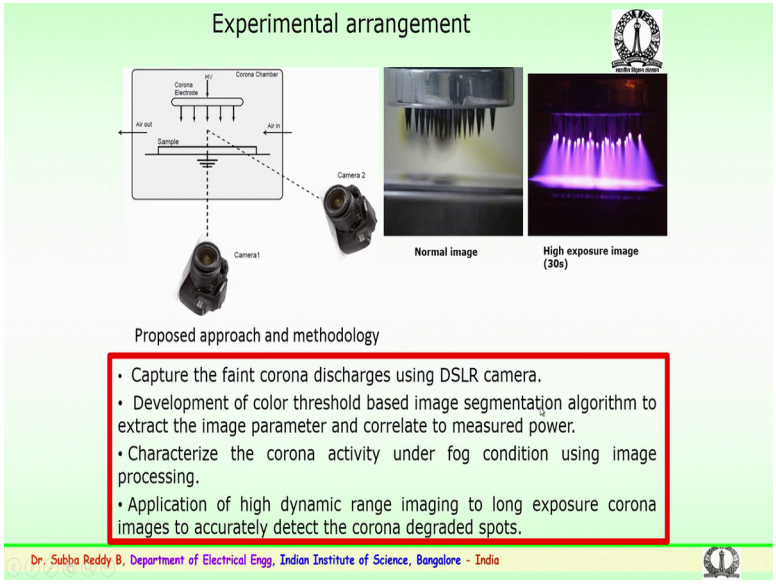

So, further the measurements of the corona or the performance of this in the field is normally employed by looking into the corona, discharges by employing a UV cameras or corona de core cameras, where you could see the corona discharges which are impinging on the sample. A similar experiment or an approach particularly with using the normal DSLR cameras was also tried out in the laboratory to see whether the power during the corona activity could be estimated by; I employing a image processing techniques.

So, a small attempt has been made to find out the possibility of this; for that try to use a DSLR cameras, try to place at different angles as shown here; so, the information has been try to capture and method has been formulated. So, initially to capture the faint corona discharges this DSLR cameras were used with, decided camera settings and the time for capture. Then the development of color thresholding based image segmentation algorithm was developed, particularly to extract the image parameters and try to correlate to the measured power; that is a power which we have measured in the laboratory.

So, this image technique was used to see how the correlation could be carried out and it was also characterized; with lot of characterizing the corona activity, particularly the activity under a both mist and fog condition, using the image processing the techniques. So, further application of high dynamic range imaging was also attempted; particularly to long exposure corona images and it was seen whether accurately this could help in

detecting the corona degraded spots. So, therefore it has been made towards this and some encouraging results have also been obtained. So, this will help as a alternate tool to estimate the surface degradation or a surface properties in the field conditions.

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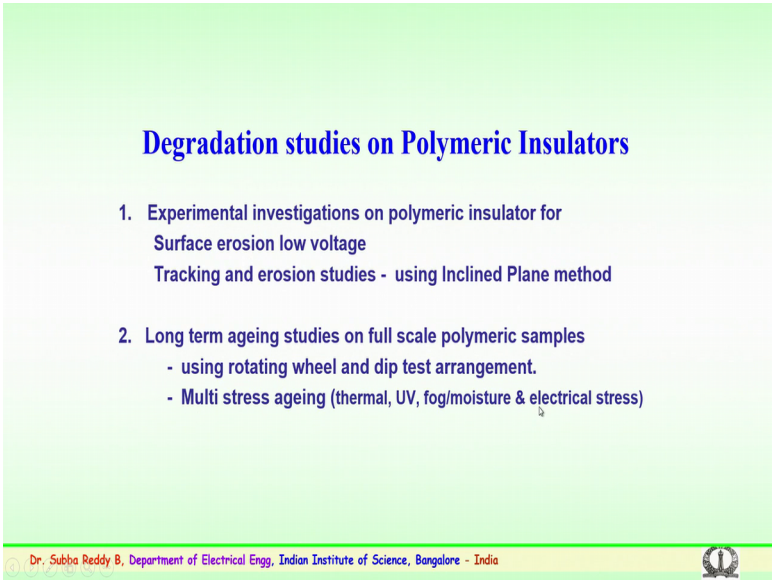

So, that was about the corona activity on the polymer insulator samples. So, further degradation of the polymer insulators could be on because of the surface erosion or tracking or both tracking and erosion. So, this experimentation is normally carried out in the laboratory using an inclined plane, arrangement in case of tracking and erosion.

And for surface erosion, we use a different a type of arrangement; where we simulate this for a low voltage; with two different electrodes are very; where a gap distance is minimal and apply a low voltage of 500, 600 or up to 1000 volts and the discharges; during the discharge our contaminant is dropped from the distance which is being specified and experimentation is being conducted for a number of droplets and it is being verified whether depending upon the water droplets, the discharges which are happening on the surface do create erosion or surface or roughness or tracking.

So, this experiment we will be discussing apart from the inclined plane arrangement or tracking erosion studies, importance of that and how it is being conducted in the laboratory. Further to that, the long term ageing studies; very important on full scale polymeric insulator samples. This long term ageing is normally conducted either using a pollution chamber, where the salt fog arrangement is being continuously sprayed; that is

salt fog is continuously sprayed on the sample and the voltage is applied continuously for 1000 hours; that is one experiment.

The second being use of a rotating wheel and dip test arrangement, a very important experimental facility has to be created for this; where the wheel rotates on a specified time and during the process, the insulator dips in the contamination. It has four phases where it has to cross to the high voltage, so this we would be looking how the rotating wheel experimental facility will help in estimating the long term ageing studies. Further, a multi stress which has a combination of several of the stresses is similar to the field like thermal, UV, fog, moisture, rain, electrical stress, pollution many more.

So, these have to be simulated and the closed environment and have to be performed on the polymer samples; this will help in the giving an idea of the long duration which is being in the field; so this important studies for the evaluation of a polymer insulators in the field.

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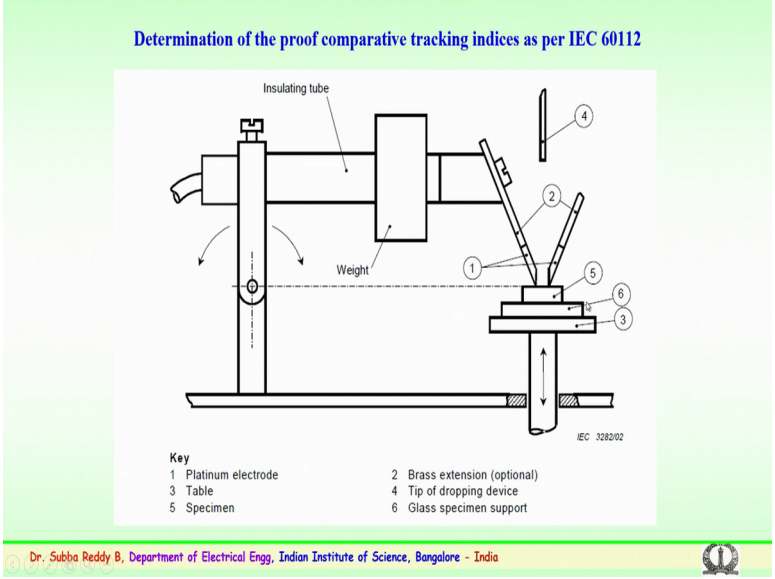

The first one is the determination of the proof of comparative tracking and this stand is as per IEC 60112 standard. Basically, you have on a experimental arrangement which is fabricated; here you have two electrodes that is where the electrodes are of platinum edges with a brass electrode arrangement. Then, you have the weight to see the proper mechanical force which is kept on the sample; this is the sample. The fifth which shows

the specimen or the silicon rubber or the sample which is to be under test and below that is a glass specimen support for the sample and this is a small stand.

So, the entire arrangement has to be fabricated for studying the comparative tracking index, this is with reference to IEC 60112 and those standards.

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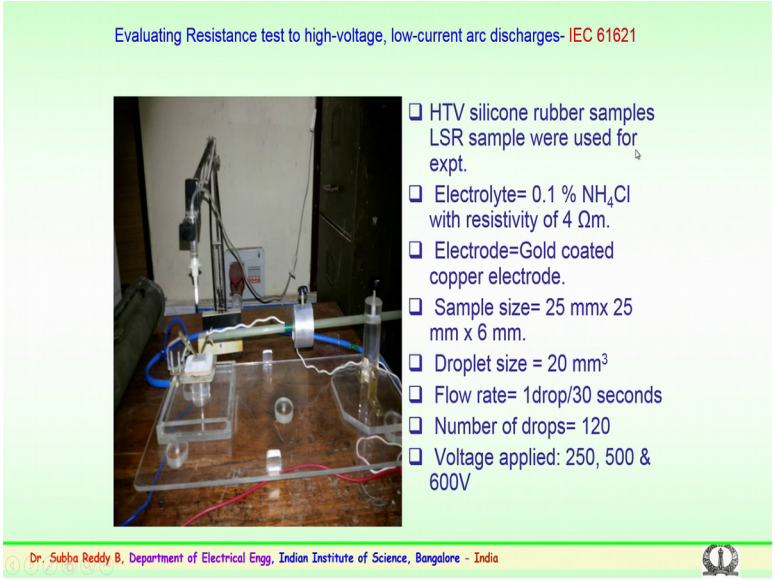

So, we have tried to fabricate a similar arrangement; you can see here two electrodes specially a gold coated electrodes have been used; at a known distance and the droplets which the contaminants which are supposed to be dropped at a regular intervals, this is a dropper arrangement and the voltage is applied continuously over a period of time; until the number of drops are being continuously at a regular intervals and you can see that HTV silicone rubber samples or the sample which is kept here could be of high temperature volcano silicone rubber or the liquid silicone rubber which is used for bushings.

So, in the present case two types of samples were used for experimentation; the electrolytic or the contaminant consisted of 0.1 percent NH4CI with a resistivity of 4 Ohm per meter. So, the contaminant then electrode as mentioned it was gold coated, a copper electrodes very important; the sample size was 25 mm by 25 mm by 6 mm in thickness. The droplet size was 20 millimeter cube; where a small droplet has to fall in between the electrode, the flow rate of the droplet is one drop for 30 seconds. So, you have two drops in a minute which are falling on the sample during the electrical stress.

So, the voltage applied between the electrodes where from initially 250 volts, then 500, then 600 volts. So, the voltage levels was changed the droplets were 120 in numbers, the surface changes happened over the 120 droplets was studied and the evaluation of the resistance was done.

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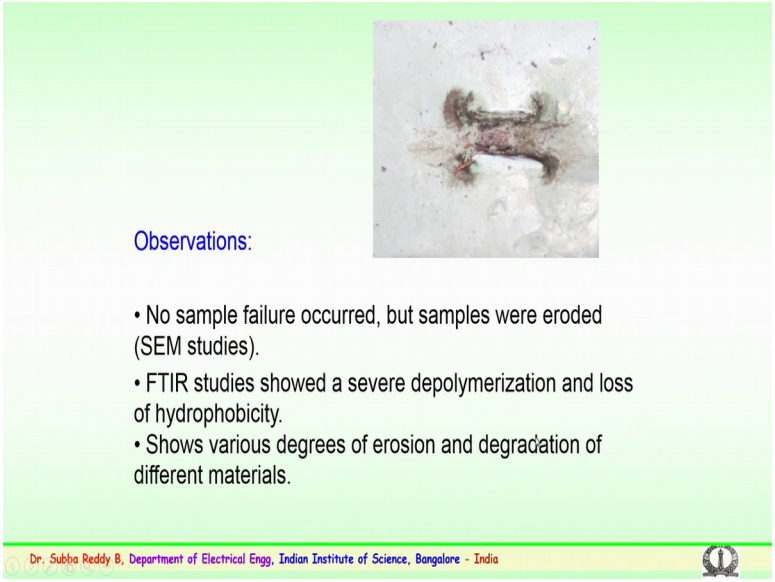

So, this is how some of the observations where between the electrodes; the sample, there is a erosion which has been observed so, but no sample failure occur during the process. All the samples were observed to be eroded and when the scanning electron microscopy studies were carried out and the studies from the Fourier transform; infrared study showed that a severe depolymerization and loss of hydrophobicity; particularly the water repellent activity of the rubber had lost the property.

This was observed after the experimentation and also the studies showed that various degrees of erosion, the degree of erosion, the depth of erosion, the changes on the surface was different for different type of materials which have been used. We have tried to use several types of materials including the liquid silicon rubber. So, the degradation was in a different, for a different a type of materials for this study.

So, this is one of the experiment which was conducted a similar thing is observed in the laboratory.

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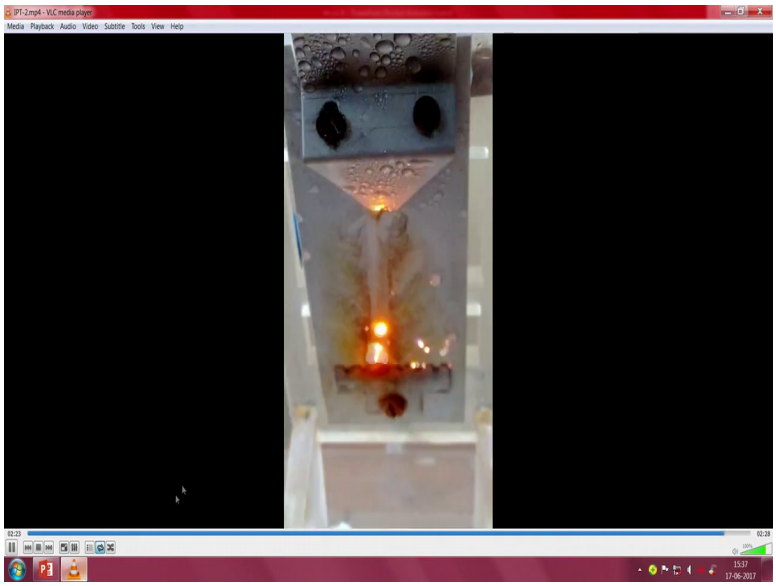

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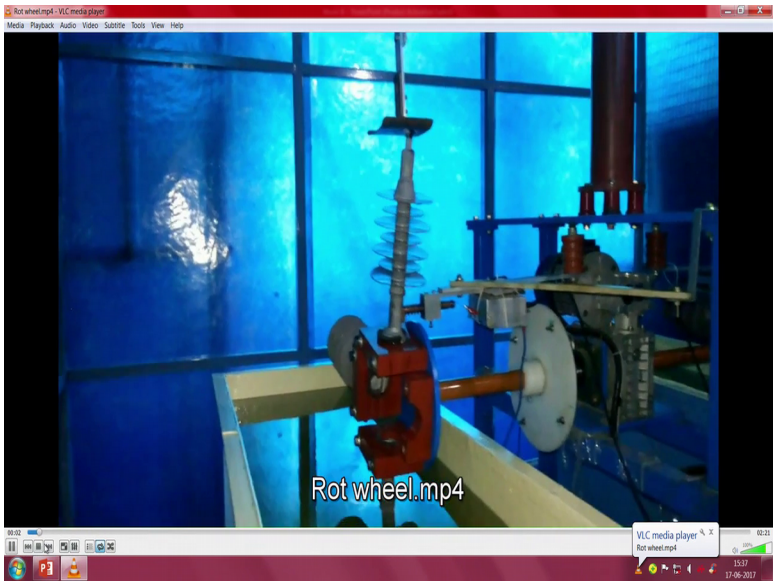

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Where we can see the erosion of the sample, here you could see the droplet; which is falling here. During the formation falling of the droplet, you can see the fumes, the voltage, the water droplet you see; that the voltage is maintained over a period of time and so this was a performance of the experiment.

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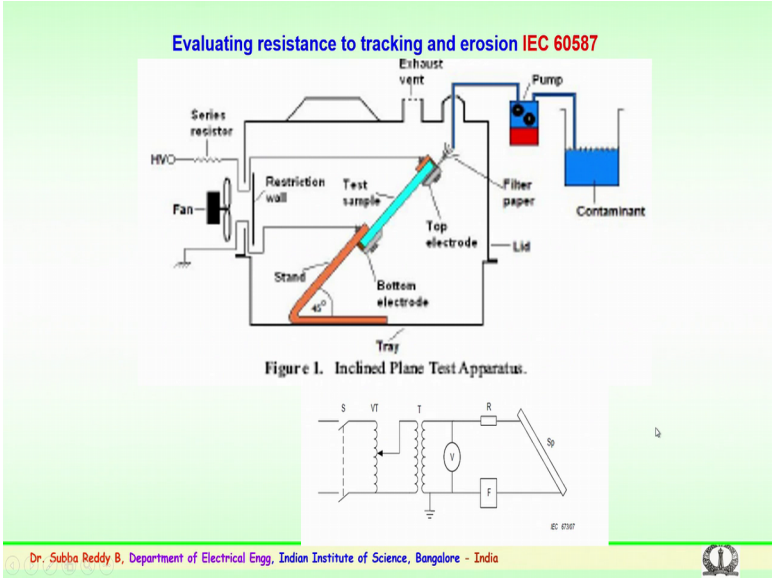

Further to evaluate the resistance to tracking and erosion, there is a standard which is being mentioned 60587 is a IEC, which clearly gives to perform the experimentation on the silicon rubber or high temperature vulcanized rubber; where very clearly the 45 degree arrangement has to be made to fix the sample, this is a sample which is being fixed with a 45 degree arrangement. The test sample sees here, this is the bottom electrode, this is a top electrode and the top electrode is connected to a pump peristaltic pump where the water droplets at a regular interval has to be in contact, where the water droplets goes on the surface of this insulator sample and the voltage, high voltage is applied between the high voltage; a top electrode and the bottom. The voltage, again it is a known; either it is a 3.5 KV or a 4.5 KV as per the standard information.

So, this is how the arrangement is to be made for studying the inclined plane experimentation for both AC and DC application. The standard very clearly specifies for AC application, DC application; the standard has not been a void, but experimentation have been carried out to see the performance for TC also.

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So, this shows the laboratory evaluating resistance to tracking as per the 60587, which also knows the inclined plane arrangement. So, we have tried to make both for AC and DC, so DC; this shows the arrangements for the AC experimentation. The second one this shows the arrangement for DC arrangement, so DC the standard has not been evolved.

So, AC experimentation standard have been evolved, so these are the arrangements of the electrode; these are the electrodes, this is a sample holder and the sample which is being fixed at a known distance. This arrangement; the prospect sheet at a 45 degree angle, where the sample is mounted on this with a electrode arrangement is shown here; this is how the fabrication has been done to make the sample and the arrangement as per a 60587 standard.

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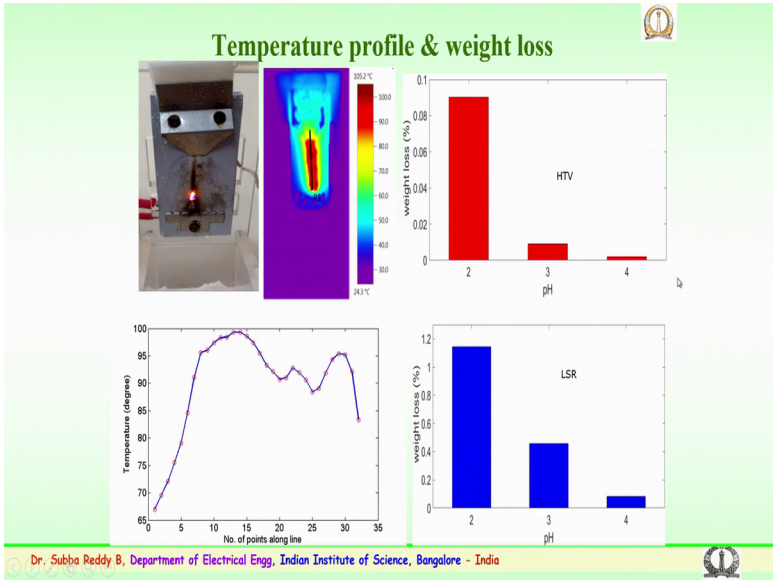

During the process experimentation has been conducted for 3 to 6 hours continuously and the sample performance has been monitored. The level of surface degradation and the erosion which has been taken place during the application of voltage has been continuously monitored. Both electrically by measuring the leakage currents and also by using a thermal imager, basically to find out the temperature properties that is temperature changes on the surface; on the entire surface during the voltage application. So, this shows a typical thermal image; camera thermal imager obtained camera photograph showing the variation of the temperature profile on the surface.

So, this shows the number of points on the temperature at different locations; these are for two types of samples, one is for high temperature vulcanized; the second is for liquid silicone rubber. Over a period of time, after the experimentation; the weight loss of the sample have been measured for various conductivities and it was observed that as a conductivity increases or the pH increases, the weight loss as shown here.

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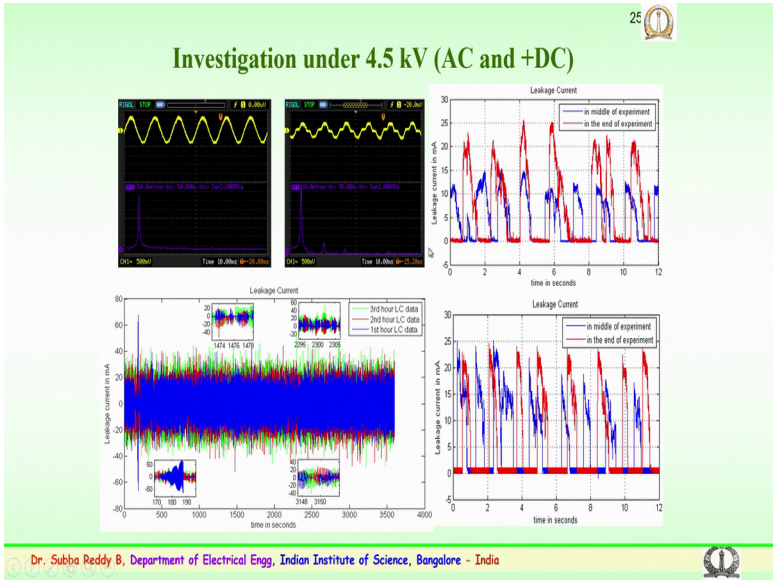

So, this is how the performance particularly for the inclined plane arrangement has been done. During the process, the leakage current and the various samples this one of the experimentation is conducted for 4.5 kilo volts; both for AC and DC application. You can see the discharges during the process and this discharges which are of continuous in nature have been again recorded using a national instruments module, where long duration data could be captured and used for analyzing the data.

So, we have seen various types of leakage current data here for 1, 2 or 3 hours which shows the increase in a magnitude for a different timestamp and this shows the leakage current in milliamps and time in seconds during the middle of the experiment, typical during the some other period.

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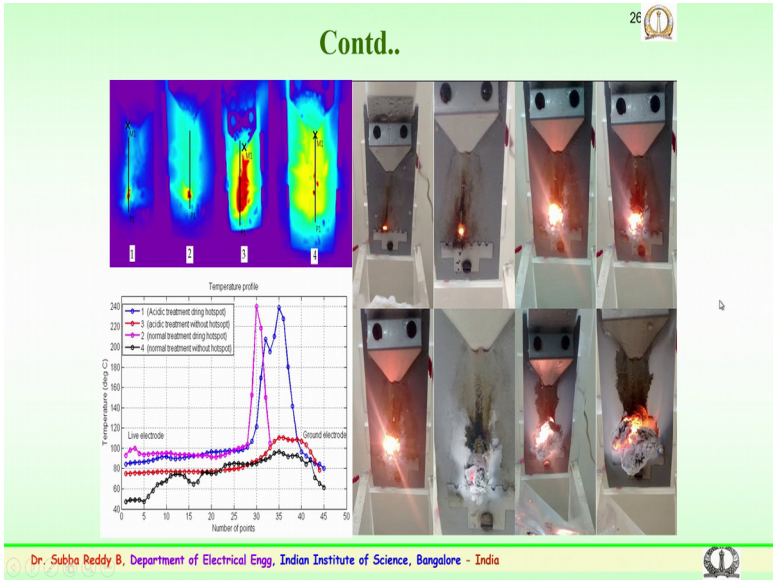

So, this is how the performance is monitored and this gives the experimental performance for various types of samples. You can see the surface rupture or surface erosion which is happening on the samples at different locations, this is a ground electrode; you can see over a period of time because of the continuous the flow of contaminant the surface the electric stress the discharges happen in how the erosion happens near the surface; near the ground end.

So, this is very important experiment which gives the idea the erosion and the surface degradation happening over a period of time with suitably making arrangements both for AC and DC have been carried out and also the temperature has been measured during the process. Here this gives the temperature profile; temperature versus the number of points and we have given both for a normal case acidic and points and you can see the variations at different locations also.

So, very important aspects; sometimes the electrodes are also damaged because of the experimentation and the petting on the electrode, not only sample rupture; there is a hole on the surface rubber samples which happen during the process.

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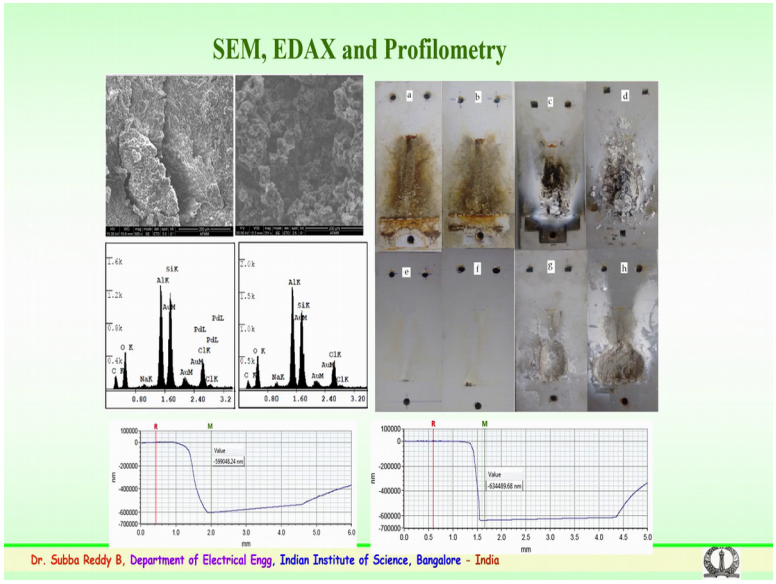

So, here further analysis was conducted after the electrical stress application on this samples. It was seen that the surface morphological studies conducted using scanning electron microscope, X-ray diffraction analysis and the profilometer. Profilometer is normally used for the measurement of depth of the erosion; that is a surface depth, erosion depth which has happened and it is very clearly visible that various types of the changes on the surface are being shown here. Some studies, very clearly reveal that the crack formation on the samples and further the erosion depth varies; depending upon the surface locations and how the rupture has happened, so these depends upon the different samples.

So, various samples are being given here; some 8 different samples which have withstood both for AC and DC, have been compared and the studies have been conducted.