Modleing of Electric Tree Progression with Different Barrier Width and Field Studies

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Abstract: Barriers have shown to improve the breakdown voltage and the key factor to for this is field inside the bulk dielectric. In our first part of the work, the barrier was in fixed in only one position nature of tree propagation was studied. Now after changing the position of the barriers, the propagation studies were carried out. Moreover the field inside the bulk dielectric were studied. The field is very low before the tree propagation and has increased upto 40 and 70 times before the breakdown in different cases. Field in the builk dielectric in the case where tree penetrated the barrier is also carried out. The field obtained gives a indication to the pattern of tree progression and is in correlation with tree profile.

Keywords: **Treeing, barrier, field, propagation.**

I. INTRODUCTION

The barrier effects are usually increase in the breakdown voltage and increase in the breakdown time. S. M. Lebedev et al [1] stated that the barrier effect existed in all states of material. The barrier effect was observed for all voltage type and also for different electrode configuration. The breakdown channel length is increased because of the horizontal spreading of the tree branches. At optimum barrier position the effect is found to be the maximum.

The ac and impulse tree characteristics of EVA samples with polymer barrier films and related tree length as a function of applied time under AC voltage is established in [2]. It's stated that without barrier it is a linear curve, (i.e.) tree length keeps increasing as applied time increases. But with a barrier the tree length saturates after some time. For AC voltage, the mechanical property of interfaces plays a vital role in determining the characteristics of tree growth. The barrier effect of tree growth in EVA with polymer barrier films depends not only on the interfacial conditions between EVA and barrier but also on the bulk properties of the polymer barrier films used [3]. The tree can penetrate the barrier only after the tree growth retardation. Otherwise it will develop along the edges of the film. The pressure of the decomposing gas in the tree channel also determines the tree propagation. But the partial discharge remains the main reason for the tree propagation.

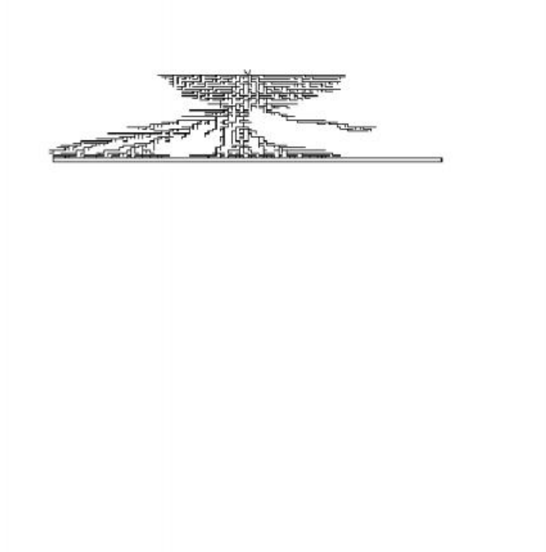
II. SIMULATION

The barrier effect depends on the properties of barrier material such as permittivity and conductivity [1]. It is found that the breakdown voltage, time to breakdown and the tree inception time increases with increase in
$\psi = \epsilon_b / \epsilon_{md}$.
Where, ϵ_b is the permittivity of barrier,
ϵ_{md} is the permittivity of main dielectric. Also that the mechanical properties at the interfaces between the EVA base polymer and the polymer barrier films has good impact in tree structure with the barrier. Using LDPE as insulator and barriers of different polymers are used in the study [4]. Slow down of the electrical treeing is observed. The effect depends on the material used as barrier, their binding force and the interface. Van der waals force which is a weak force is the only force in the interface between the barrier and LDPE. Glass, Mica and PTFE have significantly different bond mechanisms to the epoxy resin. These materials are used as barrier. The propagation of the tree along the barrier is dependent on the type of chemical bond and the shear strength between the epoxy resin and barrier material. For higher the bond strength between the barrier and the epoxy the higher is the resistance to electrical tree propagation [5]. It is also shows that the thickness of the barrier material influences the tree growth. The barrier effect is observed in the insulator irrespective of the medium's phase state, the voltage type, the electrode configuration and inner-electrode distance. When needle-tip is negative, possibility of penetration is high.

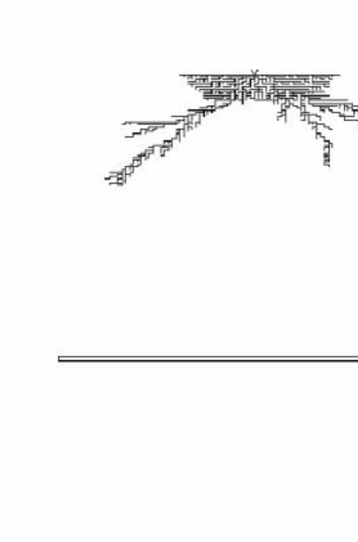
It is assumed that the tree starts from a needle tip and needle-plane electrode geometry is used. The needle is at high potential the ground electrode is at zero potential, and tree branch grows in steps. Each segment is considered as non-conducting and assumes a linear charge density and other details are described in [6]. The effect of a barrier within the insulator is studied by including a barrier material in the geometry of the model. The dielectric strength of the barrier material studied in the experiments by other researchers are greater than the insulator material and hence the same is followed in the simulation. The barrier material used in our simulation is Mica. The tree can never protrude the barrier. The tree branch will spread along the surface of the barrier trying to for propagation.

III. RESULTS AND DISCUSSION

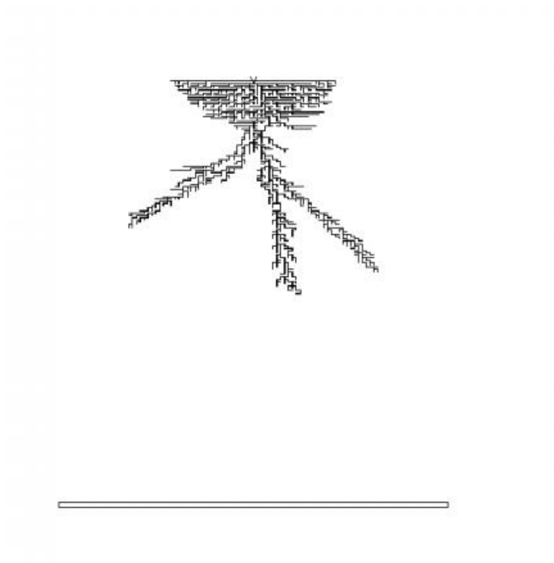
The presence of the barrier in between the dielectric will increase the life time of the insulator as a whole. In this modeling, above statement is proved. In this work, the parameters analyzed are position of the barrier (ξ) and width of the barrier. Simulation is done for all the four types of field available in literature. The position of the barrier is analyzed



(a): ξ=0.15



(b): ξ=0.5



(c): ξ=0.75

Fig. 1 Comparing the different positions of barrier for moderately high field

for Moderately High field conditions. ξ is described elsewhere [1].

A. Tree progression at different position

Figure 1 shows that the tree simulated at different position in the bulk dielectric. As the barrier is close to the needle electrode i.e ξ=0.15 the tree tends to propagate along the surface of the barrier. When the barrier is placed below i.e ξ=0.5 the tree takes a long path. At ξ=0.75, the tree structure is is branchy and take reaches to a very low field state.

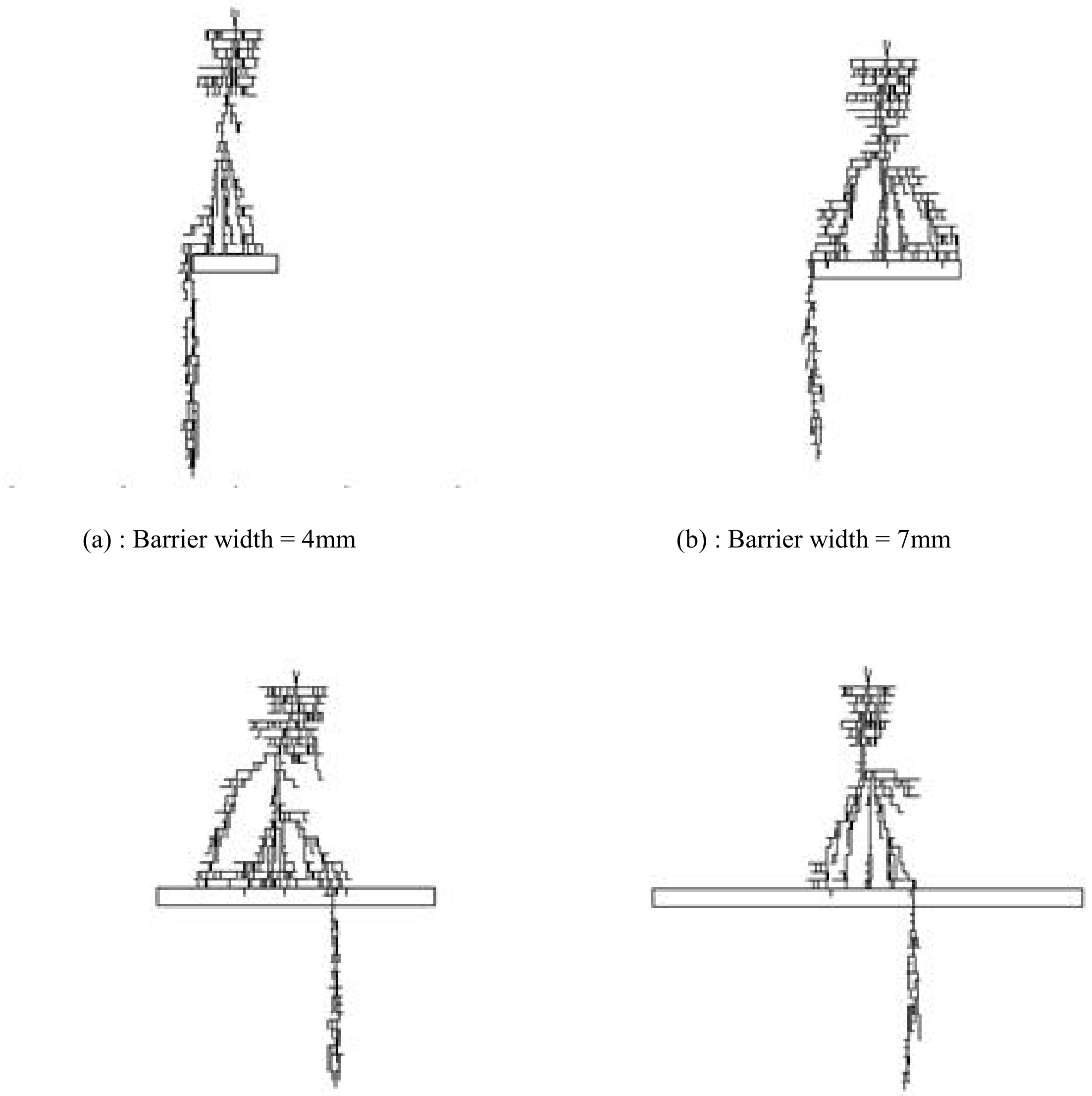
B. Tree Progression for different barrier width

The time to breakdown i.e the number of steps for 4mm width is 537 and for 7mm width it is 880 shown in fig 2. For 13mm it is 878 steps and for 20mm width it is 602. For 4mm width the tree branches slides on the side of barrier and reaches ground electrode in shorter time while the one with 7 mm width takes a longer time. The reason being the nature of barrier in

arresting the tree branches and making it to slide on the surface. This indeed also the effect observed in the literature[5]. Interestingly the barrier with 13mm and 20 mm width, the more wider than of all, shows contrasting outcome. The tree branching has penetrated through the barrier probably because the field inside the barrier is much higher compared to field along the surface. Such is the totally new result obtained which is not published in any literature. The breakdown time differs with changes in the barrier width. The optimum width of the barrier is found to be between 7mm to 12mm which is what published by Lebedev et al[1]. The simulation results for different barrier width are shown. The value of ξ in this case is 0.5.

C. Field in the bulk dielectric with tree Progression

In order to study the field inside the bulk dielectric and also inside the barrier, field values were plotted. Figure 3 shows that the field variation before tree inception and just before the breakdown process. The mean value of the field before tree inception is 1.6545V/m and the mean value of the.



(a) : Barrier width = 4mm

(b) : Barrier width = 7mm

(c) : Barrier width = 13mm

(d) : Barrier width = 20mm

Fig.2 Tree Progression for different barrier width

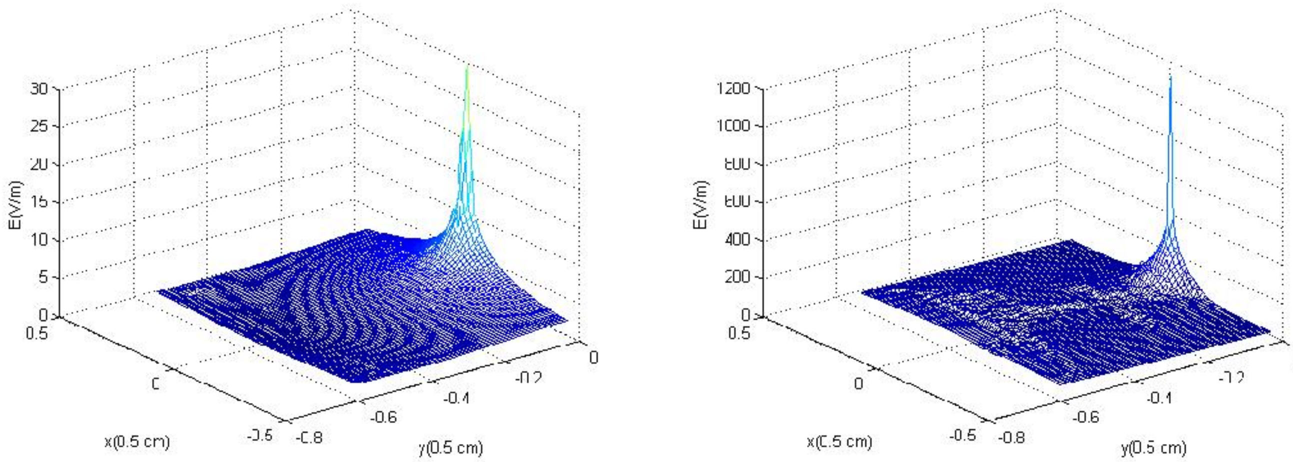
field just before breakdown is 35.7392V/m. The mean value is chosen within the volume domain of interest in the simulation. This field values are for the 4 mm barrier width. From these values it is evident that the field during propagation continues to increase compared to field at tree inception and almost 40 times at the point of breakdown

Fig 4 shows the field variation for 10 mm barrier width. The mean value of the field just before the tree inception is 1.3142V/m and the mean value of the field just before breakdown is 44.3377V/m. The field just before the tree inception is 29 V/m and just before breakdown it is 2040 V/m, which is about 70 times more. This also shows that the field at the breakdown point is much greater than barrier with less width.

Fig 5 shows that the field variation for 20 mm barrier width. The mean field values for before tree inception and just before the breakdown is 1.1894V/m and

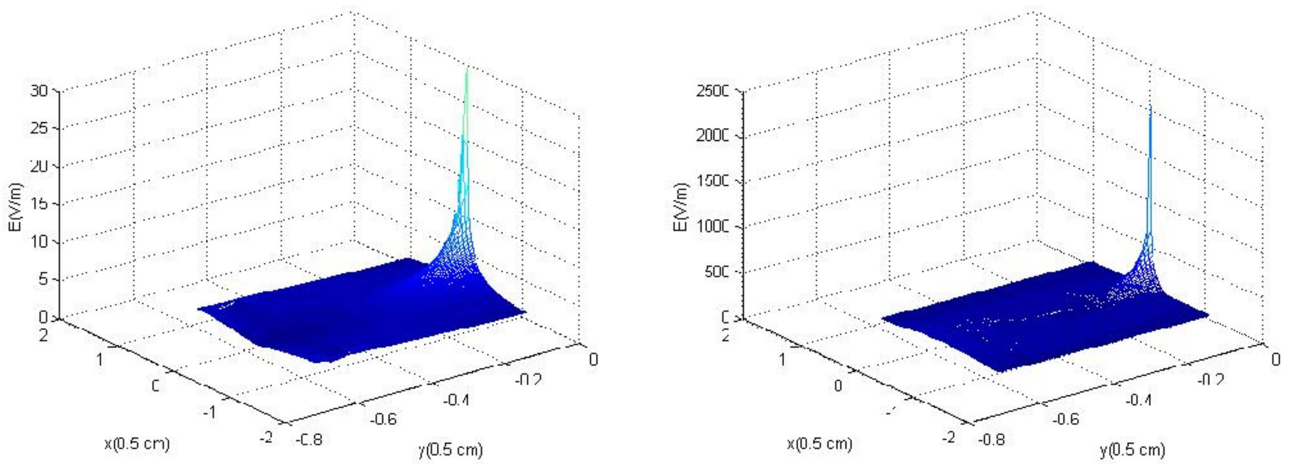
15.0393V/m. When compared to the 4mm and 10 mm field variation with 20mm barrier width the mean field value and also the field in the bulk dielectric is much less i.e 20 times more. The tree propagation through the barrier reduces the field in the bulk dielectric. This is also clearly seen from the fig (b), the peaks and crests along the central region conveys the increase in the field.

Thus for all the cases the field inside the insulator increases with increase in the tree progression. The reason behind this is that the tree branches acts like a tube-like structure which will move space- charge from the needle-tip to the tree-tip. The charge density at the tree-tip is high. As more number of tree branches emerges the space-charge increases and hence the field inside the insulator increases.



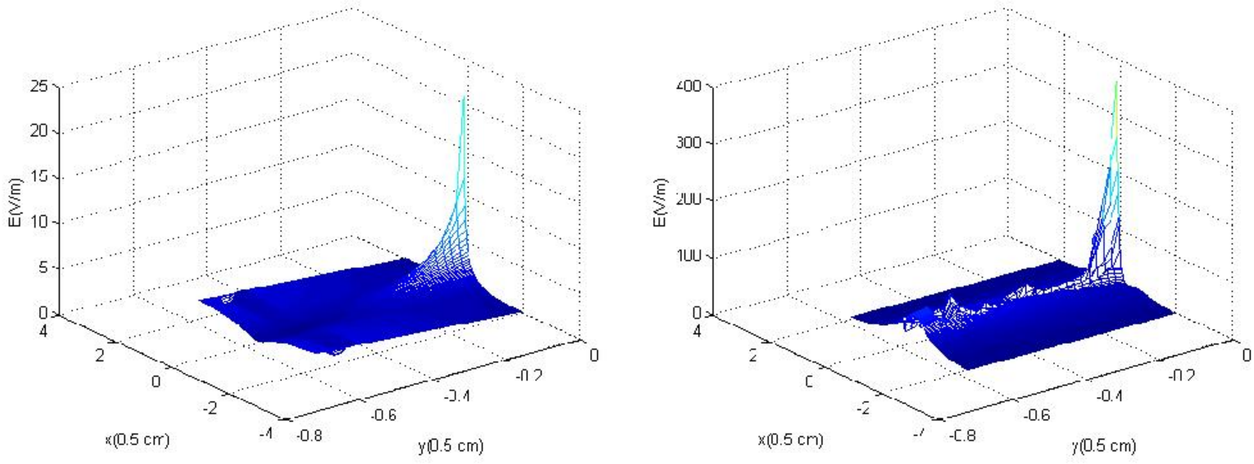
(a) Field before tree inception (4 mm Barrier Width) (b) Field just before breakdown (4 mm Barrier Width)

Fig 3: Electrical field inside the bulk dielectric



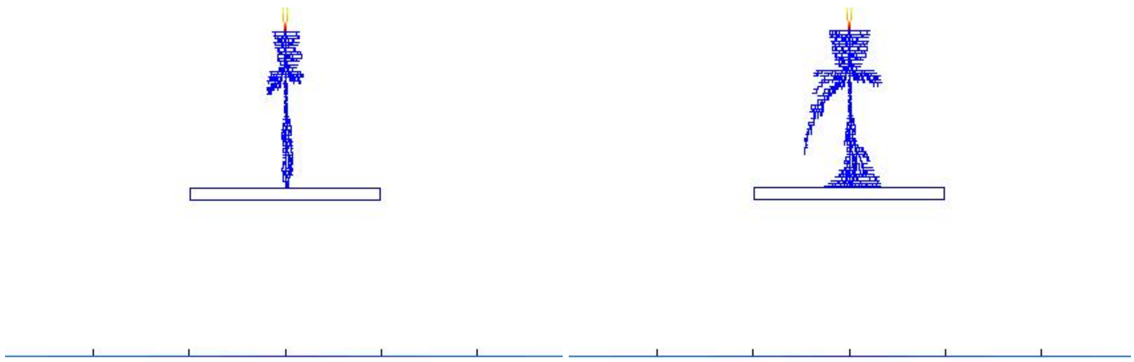
(a) Field before tree inception (10 mm Barrier Width) (b) Field just before breakdown (10 mm Barrier Width)

Fig.4: Increasing Electrical field with tree progression

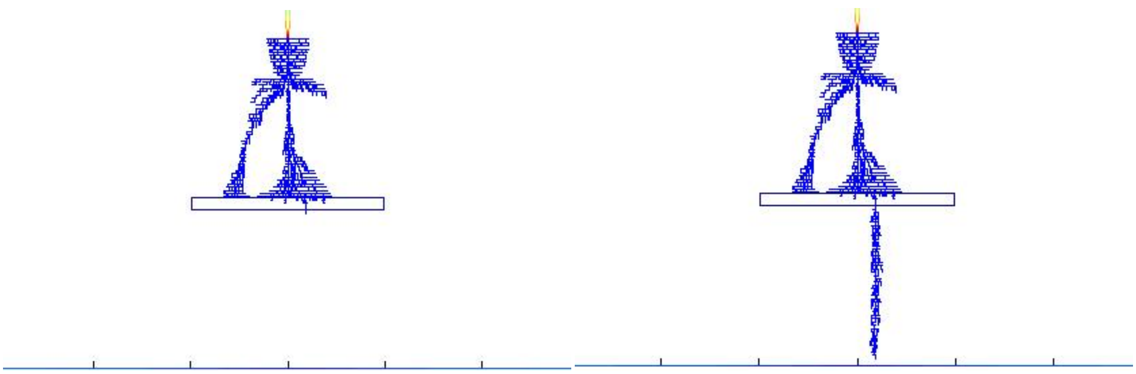


(a) Field before tree inception(20 mm Barrier Width) (b) Field just before breakdown (20 mm Barrier Width)

Fig 5 Electrical Field as tree penetrates through the barrier



(a) After 700 Steps (b) After 1450 Steps



(a) After 1800 Steps (b) After 2134 Steps

Fig 6 Tree progression in 10 mm Barrier Width

D. Explanation of Tree Propagation in 10 mm Barrier Width

Figure 6 shows the step by step tree growth in the needle plane configuration with 10mm barrier width. The 10mm Barrier width is found to have higher breakdown time. The tree propagation in this geometry is analyzed as follows. The tree starts its propagation and reaches the barrier at 700 steps. Then it takes 750 steps to penetrate the barrier top (i.e.) at about 1450 steps the tree penetrates the barrier. The tree penetrates the barrier bottom at 1800 steps. The 1100 steps after 700 to 1800 steps will be spent in spreading along the top of the barrier. The value of ξ in this case is 0.5. The study is going on to understand the field inside barrier.

IV. CONCLUSION

The key factor for improvement in the breakdown voltage is the field inside the bulk dielectric. The barrier was in fixed in only one position nature of tree propagation was studied earlier and now with different position of the barriers, the propagation studies were carried out. The field inside the bulk dielectric were studied and it shows that it is very low before the tree propagation and has increased upto 40 and 70 times before the breakdown in 4mm and 7mm width barriers. Stress is given to the case in which tree penetrated the barrier. The field obtained gives a indication to the pattern of tree progression and is in correlation with tree profile.

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