Understanding the Field Conditions Around the Barrier for Electric Tree Propagation

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Abstract: Field studies inside barrier have shown the reason for longer tree progression inside the barrier presented in our earlier work. Field studies on the barrier and outside both upper and lower part of barrier have shown an unique trend which explores a lot of avenues. Field at the top and bottom surface varies as step wise fashion for a certain unique no of iteration of tree progression. Field inside the barrier is always less than above or below the barrier. This suppress the tree progression inside the barrier.

Keywords: **Barrier, field variation, barrier surface, tree.**

I. INTRODUCTION

Electric tree progression in the barrier is well known and has introduced varying interest. The tree progression can be better understood once we know the physical conditions, field variation, material characteristics etc which influences it. As no literature available to study the field inside the dielectric and on the surface of the barrier, the authors have explored the possibilities of understanding it. The outcome has shown that the field on the surface has been consistently maintaining high and low for certain iterations of tree progression. Investigation is on to understand the observed trends. 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. Also the characteristic of the breakdown is also analyzed based of changing various parameters of the insulator (especially of the barrier). The parameters analyzed are position of the barrier (ξ), width of the barrier, material used as barrier [1]. There are four categories of field available in literature. The position of the barrier is analysed for all the four field conditions. Based on the changing of field inside the insulator material, a reason for the breakdown is also given.

II. SIMULATION

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 [2]. 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 branch will spread along the surface of the barrier trying to propagation.

III. RESULTS AND DISCUSSION

A. Field Variation in the bulk dielectric

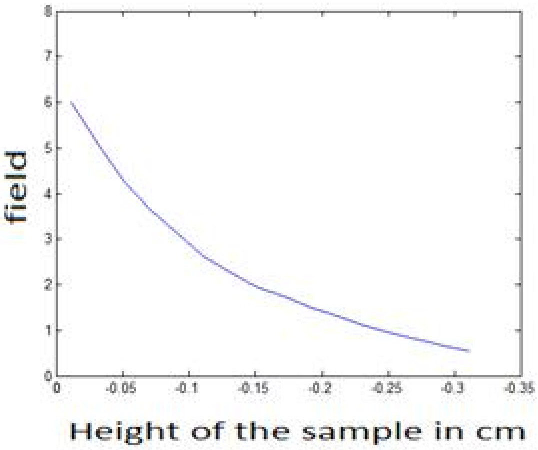
The Electric field variation in the insulator is studied as follows. The fields without barrier and with barrier are compared. The plot showing the field variation is as follows. The field at the barrier is very low (tending to zero before tree inception). So the tree progression stunts on reaching the surface of the barrier. But it progresses along the surface of the barrier.

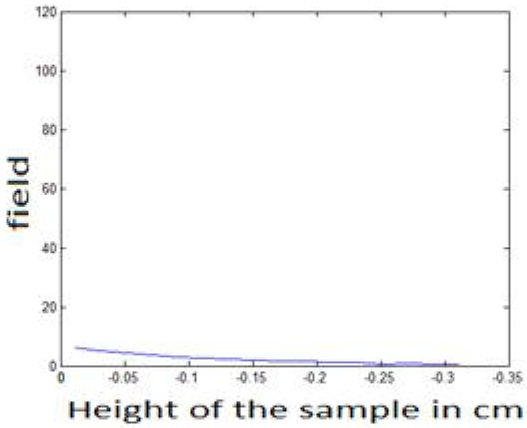
Field variation in the bulk dielectric is shown in fig 1. X axis shows the gap distance from the needle tip starting from zero to a point below the barrier if barrier is present. Fig 1 (a) shows the field is decreasing gradually as the distance is increasing in barrier-less condition, which is very normal as field inversely depends on the distance. The unit of field is V/m in all the cases. With barrier, the field variation is also similar except that field is almost zero along the width of the barrier. However, field was decreasing and increasing gradually from 20 to 35 V/m in without barrier case. The field before the inception is seen to be much low compared to the field after breakdown. This is because the charge gets accumulated in the insulator material. Because of large number of tree segments in the insulator with barrier there is more charge is injected into the dielctric, hence more field is found in the insulator with barrier compared to the one without barrier.

In the case with barrier, the field was high at needle tip close to 120 V/m, decreasing to a certain point before the barrier, was increasing just above the barrier showing a kind of inverted V shape. This may be attributed to dynamics in the interface between the barrier and the bulk dielectric. Further within the thickness of the barrier, the field gets low sharply and increases below the barrier. This may be due to increased permittivity (ε_r = 7) of the barrier compared to bulk dielectric which is taken as 4.

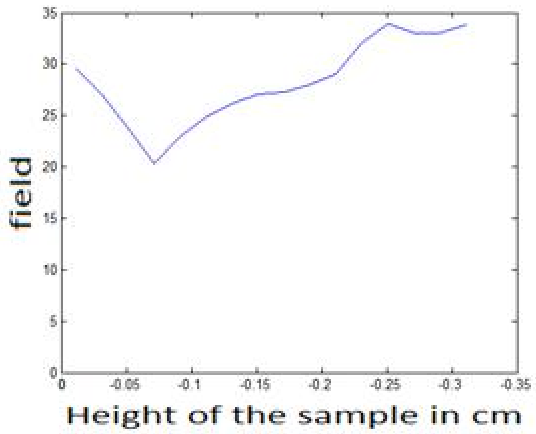
B. Variation of Field inside the Barrier

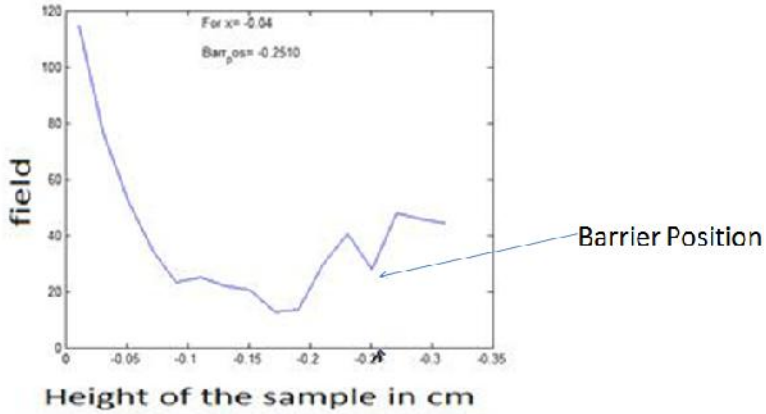
The blue box in the fig 2 (a) represents the barrier and red line shows the along which the field is calculated. Fig 2(b) shows field variation along the red line which also passes through the middle of the barrier for different number of iterations. The field inside the barrier also increases over all with increase in the number of tree branches. Another





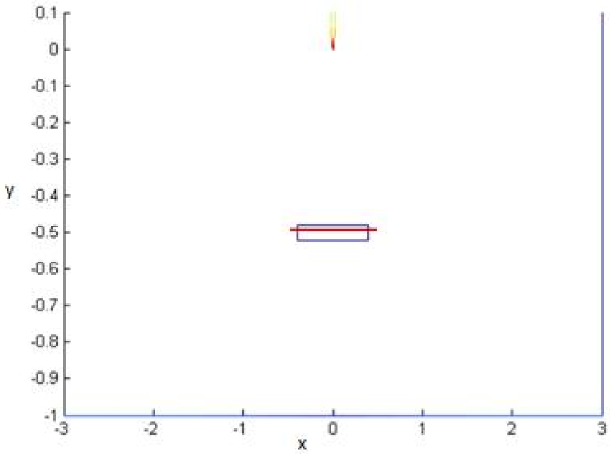
(a): Without Barrier (without tree inception) (b): With barrier (without tree inception)

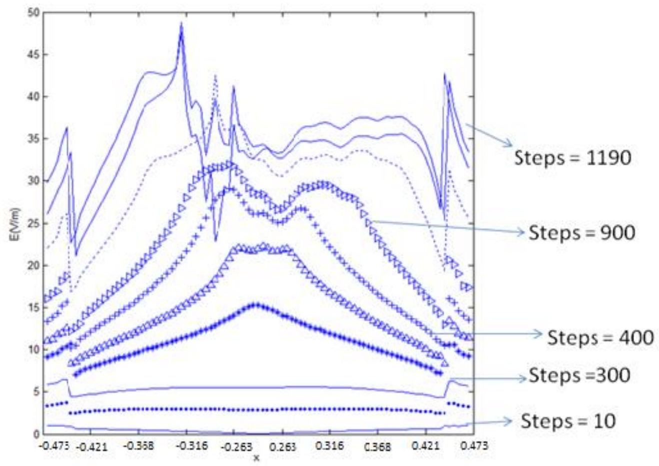




(c): Without barrier just before breakdown (d): With barrier just before breakdown

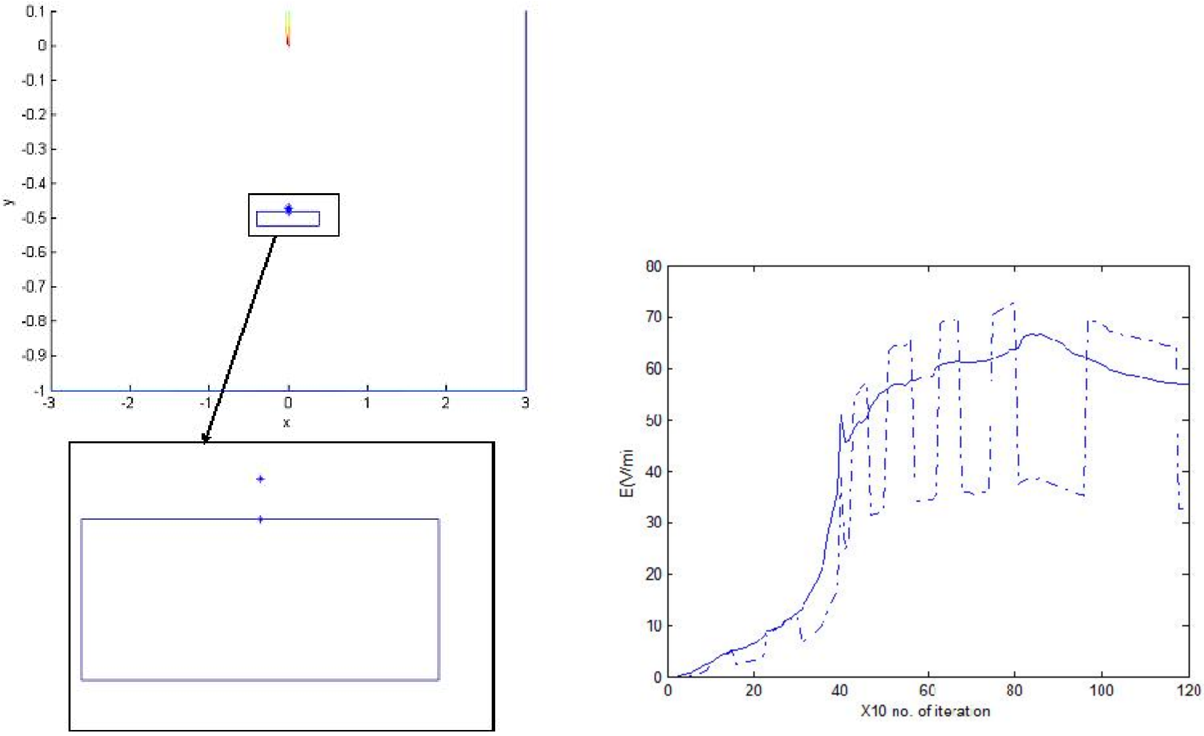
Fig 1 Field Variation in the dielectric medium





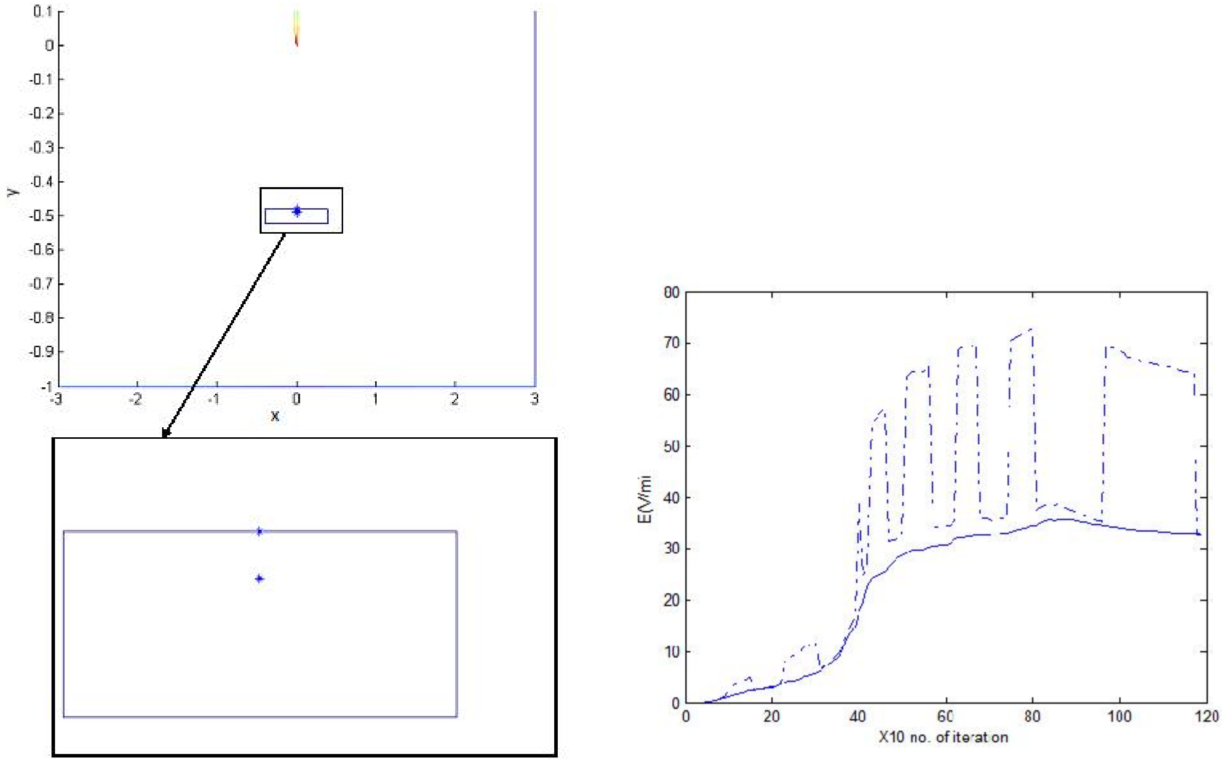
(a): Barrier and the line along which field is obtained (b): Variation of Field along the middle of the barrier

Fig 2: Position of barrier and field variation around the barrier



(a) Selection of two points, on surface and above (b): Field variation in the two points

Fig 3: Field variation in the two points: On the top of the barrier and above the barrier.



(a) Selection of two points, on surface and below (inside)

(b): Field variation in the two points : On the top of the barrier and inside the barrier

Fig 4: Field variation in the two points: On the bottom surface of the barrier and below the surface.

A. Fields on the top of the barrier and at points above and below it

Consider the points shown in the fig 3(a). To see the two points, one on the surface of the barrier and other just above the barrier distinctly, the portion of the figure is zoomed. The

According to fig 3(b) shows unique variation of field at the barrier surface and above the barrier. The width of the barrier is 4 mm. In figure 3 (b) the broken lines indicates the field at a point on the surface of the barrier and the continuous line indicates the field at the point above the barrier. The point on the barrier surface have the field values fluctuating from high value to low value and then from low value to a high value. The field at the point above the barrier is increasing upto 60 V/m. The reason is not yet understood by the authors and are investigating.

The same analysis is made for a point inside the barrier instead of the point above the barrier. Fig.4(a) shows the points that are considered. The Field plot of the two points are given in the fig 4(b).

It is observed that the field at the top of the barrier is toggling between the high and low field values which are same as present above. The field below the barrier shows increasing trend upto 30 V/m which is almost half of the field value above it. This is an important conclusion as to why the tree takes more steps/time once it penetrates through the barrier.

Similar analysis is made on the bottom of the barrier and the results are shown in figure 5 and 6. The dotted line in

field at these two points are plotted in Fig 3(b).observation is that the field along the barrier is decreased, however it is on rising and lowering trend on either side of the barrier, which gives the clue why the tree branches slide along the barrier surface.

figure 5 and 6 corresponds to the point on the barrier. In Figure 5 the continuous line corresponds to the point inside the barrier. And in the Figure 6 the continuous line corresponds to the point below the barrier. The plot is drawn for 1198 steps. The other observation is that during a certain iteration over which the field is maintaining high at the top surface of the barrier, the field at the bottom surface of the barrier is also more or less maintained the same. The reason for this also not understood. Attempt is being made to explore on these issues.

The other fact observed from figure 5 and figure 6 is that the field inside the barrier is always low when compared to the field outside the barrier. This is shown in fig 7. This is very important reason for tree not penetrating the barrier.

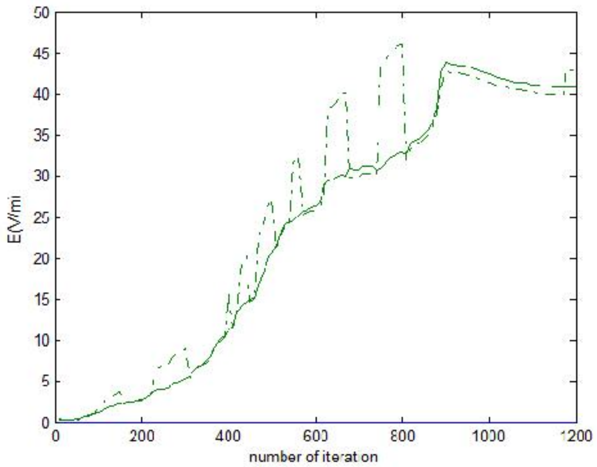


Figure 5: Field Variation in the points on the bottom of the barrier and inside the barrier

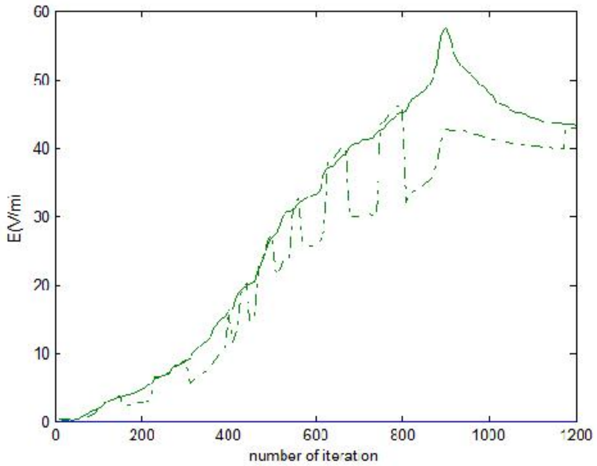


Figure 6: Field Variation in the points on the bottom of the barrier and below the barrier

B. Field at points inside the Barrier and outside the barrier and on the barrier

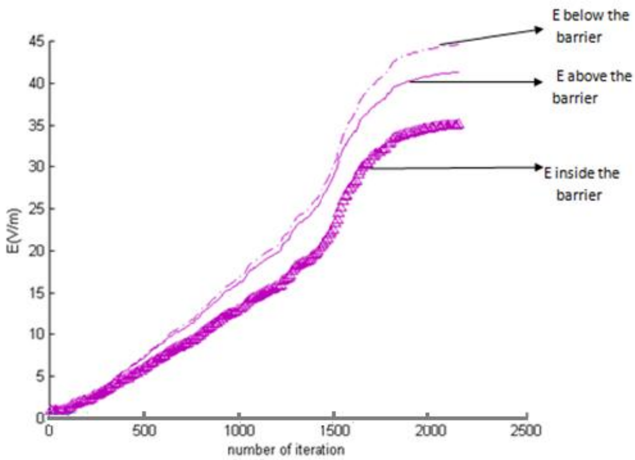


Fig 7 Electrical Field above, inside and below the barrier

The Electrical field inside the barrier is always lower than the Field outside the barrier (i.e.) above and below the barrier (Figure 3.7). The tree branches inside the barrier are considerably less compared to the tree branches outside it. Initially the field difference is found to much less but as tree propagates the difference between the field inside and outside is much significant.

IV. CONCLUSION

Field study has opened many avenues for predicting the tree shape and the tree propagation within the barriers. The interesting trend observed needed understanding. The reason for tree not penetrating under small barrier conditions is due to the lower field conditions inside compared to outside both upper and bottom portion of the barrier.

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