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Trap and Carrier Transport of Pristine and Aged Silicone Rubber by Surface Potential Measurements

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Introduction

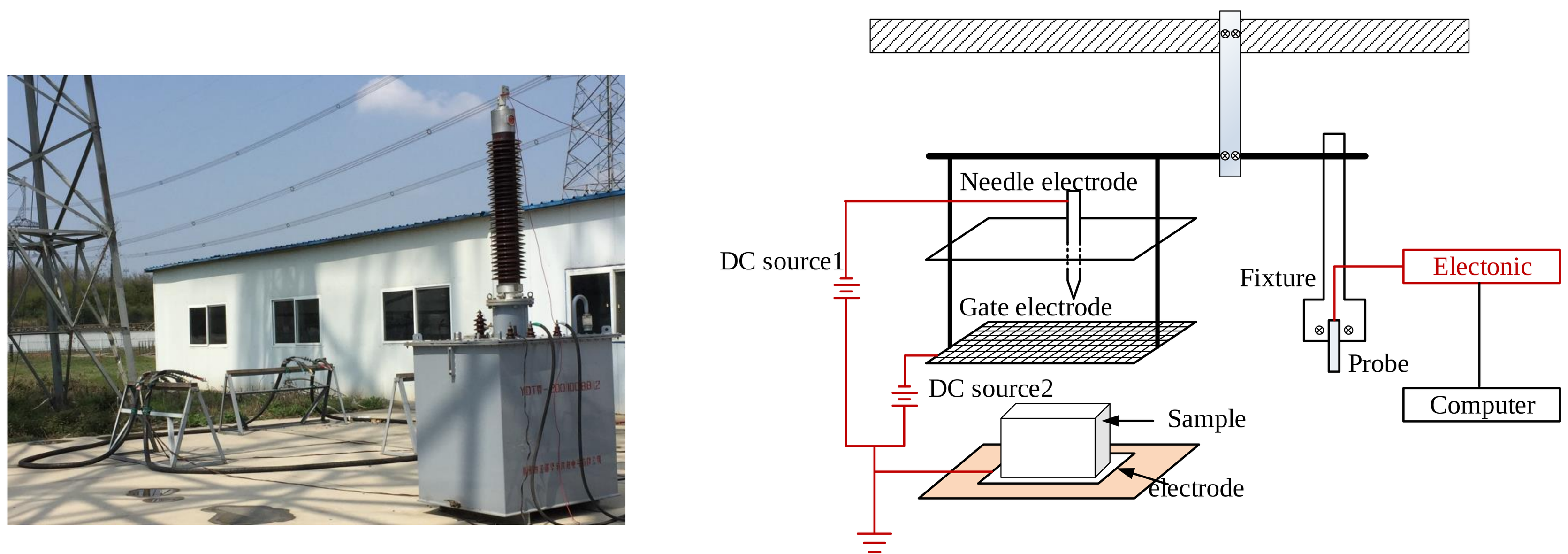
(1) Silicon rubber composite insulator is widely used in the electric power transmission system all over the world. Compared with porcelain and glass insulators, silicone rubber insulators show good performance with lower pollution.

(2) However, during long-time work, charges are easily accumulated on the surface of material, which may lead to flashover and further affect the performance of electric equipment.

(3) Based on surface potential decay measurement, parameters variation can be obtained through surface potential decay tendency, which can be used for explaining the contributions brought by ageing process. Aged sample in this paper refers to aged under ac voltage of 10 kV with 5, 7, 11 and 13 harmonic components for 30 days.

Experimental setups and surface potential decay results

Experimental setups and SPD device schematic.



(a) (b)

Figure 1. (a) Ageing of silicone rubber. (b) Surface potential decay measurement system

Surface potential decay results of pristine and aged silicone rubber.

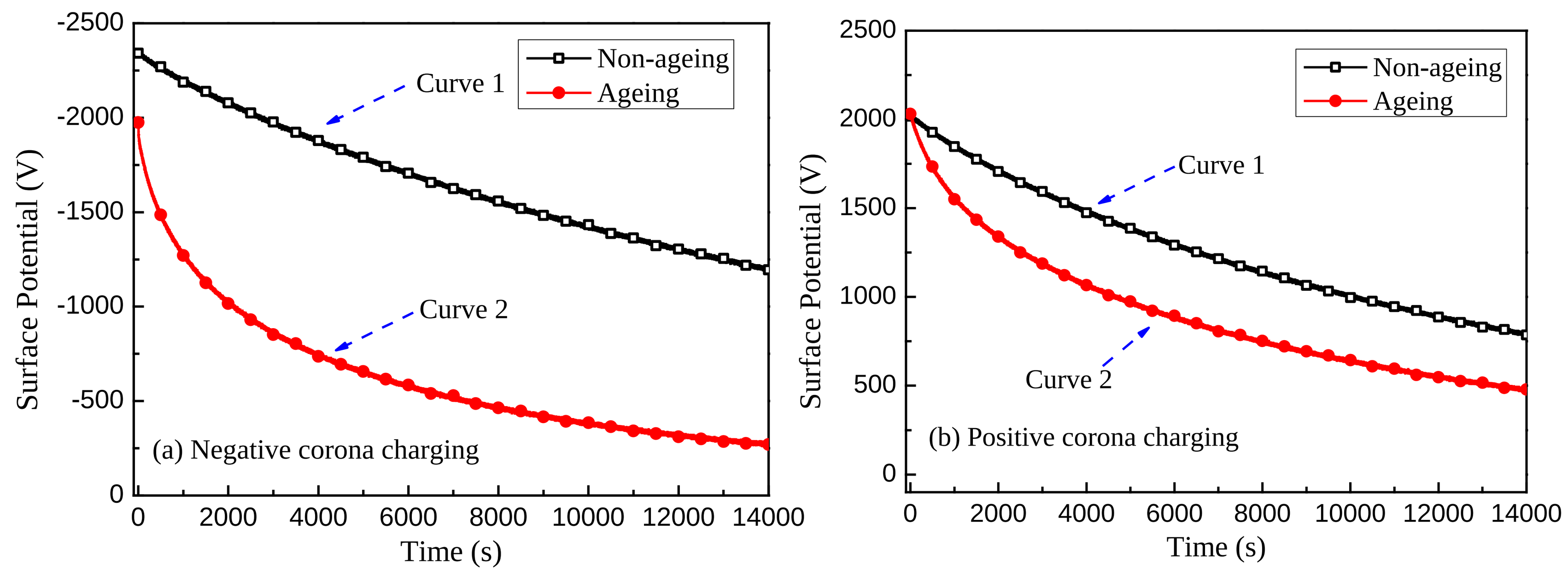


Figure 2. Surface potential decay curves of pristine and aged SiR samples after (a) Negative corona charging and (b) Positive corona charging.

Trap distribution and carrier mobility

Trap distributions for electrons and holes.

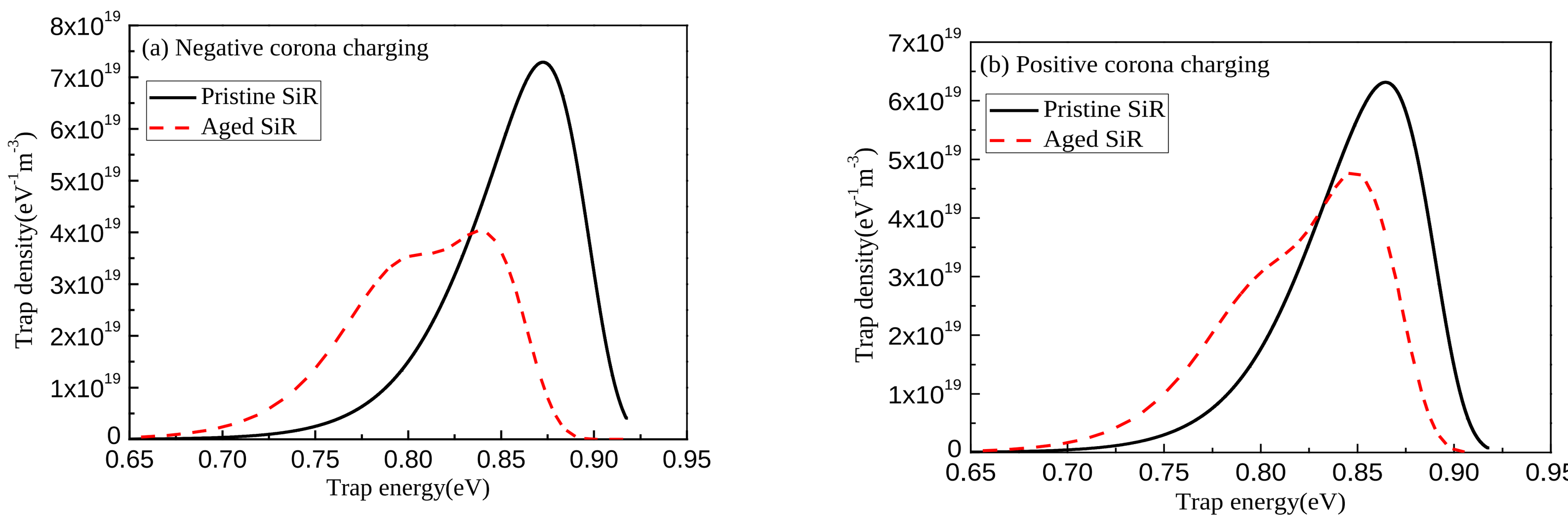


Figure 3. Surface trap distributions for pristine and aged SiR samples after (a) Negative corona charging and (b) Positive corona charging.

Surface trap energy level:

$$E_{ST} = k_B T \ln\left(\nu_{ATE} t\right)$$

Surface potential density:

$$N_{trap}\left(E_{ST}\right) = \frac{\varepsilon_0 \varepsilon_r}{edL} t \frac{\partial \phi_s(t)}{\partial t}$$

Carrier mobilities of electrons and holes.

Carrier mobility (Method 1):

$$-\left(\frac{d\phi_s}{dt}\right)_{t=0} = \frac{\mu}{2}\left(\frac{\phi_s}{d}\right)^2_{t=0}$$

Carrier mobility (Method 2):

$$\mu = \frac{d^2}{\phi_s t_t}$$

Table 1 Carrier mobility estimated by Method 1

SiR sample	Carrier mobility of positive charges ($m^2V^{-1}s^{-1}$)	Carrier mobility of negative charges ($m^2V^{-1}s^{-1}$)
Pristine	2.6×10^{-13}	1.0×10^{-13}
Aged	6.1×10^{-12}	1.5×10^{-12}

Table 2 Carrier mobility estimated by Method 2

SiR sample	Carrier mobility of positive charges ($m^2V^{-1}s^{-1}$)	Carrier mobility of negative charges ($m^2V^{-1}s^{-1}$)
Pristine	3.2×10^{-13}	1.8×10^{-13}
Aged	5.5×10^{-12}	1.7×10^{-12}

Conductivity

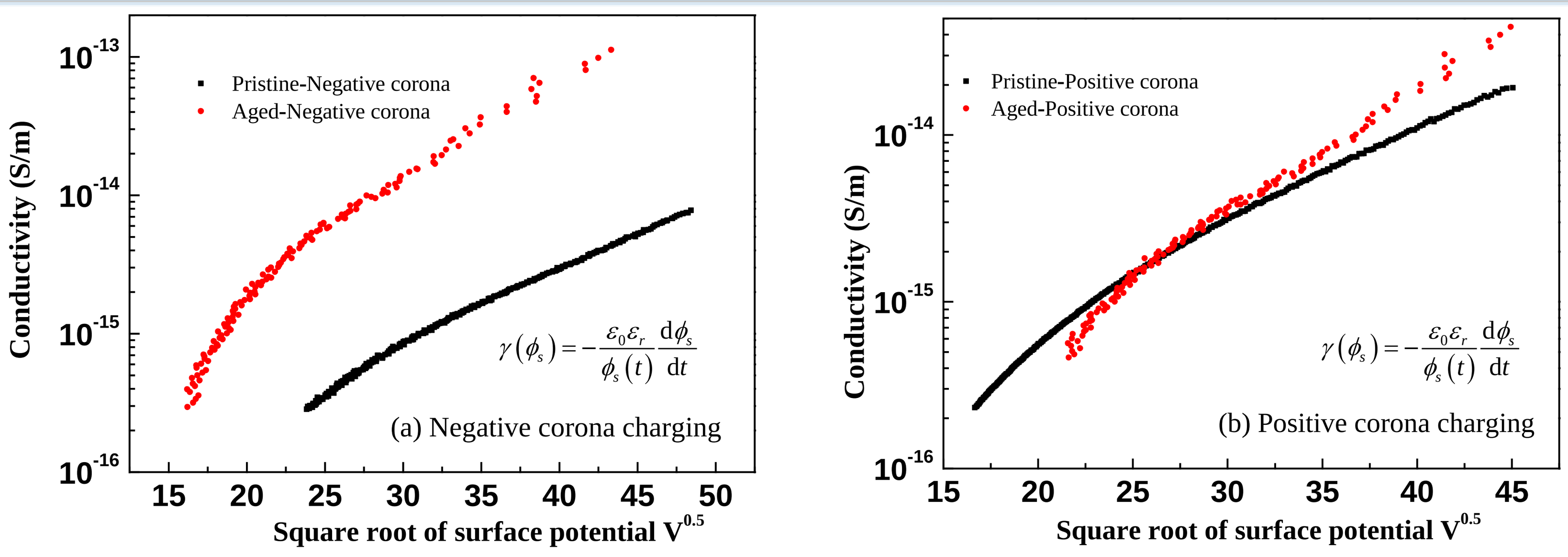


Figure 4. Conductivity as a function of square root of surface potential (a) Negative corona charging and (b) Positive corona charging.

(1) Conductivity decreases with a decrease in surface potential, which is resulted by decrease in built-in electric field.

(2) Conductivity in aged silicone rubber is higher than that in pristine one, which indicates charges in aged rubber migrate faster and further proves the conclusion that shallow traps increase in material.

(3) Variation of conductivity is resulted by influence brought by trap distribution and can be demonstrated with carrier mobility.

Conclusion

(1) Surface potential decays faster in aged silicone rubber than that in the pristine one and more hole traps than electron ones exist in both aged and pristine material.

(2) More shallow traps appear in the aged silicone rubber compared with pristine one, which allow electrons migrate easier, carrier mobilities for positive and negative charges are higher in aged silicone rubber than those in pristine one.

(3) Conductivity decreases with a decrease in surface potential, and it turns out that conductivity in aged rubber is higher than that in pristine one, which also indicates the influence by trap distribution.