J Electr Eng Technol.2015; 10(3): 1124-1130
http://dx.doi.org/10.5370/JEET.2015.10.3.1124

ISSN(Print) 1975-0102
ISSN(Online) 2093-7423

Space Charge Behavior of Oil-paper Insulation Thermally Aged under Different Temperatures and Moistures

Yuan-Xiang Zhou†, **Meng Huang***, **Wei-Jiang Chen**** and **Fu-Bao Jin***

Abstract – Moisture and high temperature are the most important factors that lead to the ageing of oil-paper insulation, but the research about space charge characteristics of oil-paper insulation does not take the combined effect of ambient temperature, moisture and thermal ageing into account. The pulsed electroacoustic (PEA) method was used to investigate the influence of moisture and temperature on space charge characteristics of oil paper at different ageing stages. The results showed that moisture could speed up formation of space charge in oil paper when water concentration was low, but the formation was restrained if the water concentration was high. At the beginning of thermal ageing, heterogeneous charge accumulation had predominance, but it gradually changed to homogeneous charge injection with ageing. It was believed that moisture concentration could speed up ageing and enhance charge accumulation on one hand, and accelerate or slow down the establishment speed of space charge on the other hand, therefore, charge accumulation type changed with ageing. The more seriously the oil-paper insulation was thermally aged, the deeper the trap energy level was, hence more space charge was trapped, which could be speeded up by increasing the ageing temperature, but the effect of ambient temperature did not fit the Arrhenius law.

Keywords: Moisture, Oil-paper insulation, Pulsed electroacoustic method, Space charge, Temperature, Thermal ageing

1. Introduction

HVDC transmission has been developed fast recently because of its excellent advantages such as high reliability and low cost. Transformer is a high voltage component in the transmission system and it plays a vital role. Oil paper (or oil-impregnated paper) is widely used as the main insulation material in transformer due to its outstanding mechanical and electrical properties [1, 2]. During the long-time operation, oil paper gradually degrades under the combined electrical, thermal, mechanical and chemical stress, which will lead to its performance sliding down [3, 4]. The degradation can finally lead to the failure of transformer.

Except for the ageing problem, space charge easily accumulates within oil-paper insulation in the service. Space charge is an unfavorable phenomenon for DC apparatus and its accumulation can result in localized electric field distortion, which will affect the property of dielectrics, such as conduction, breakdown and ageing, etc. [5, 6]. Space charge has become an area of growing interest and the pulsed electroacoustic (PEA) method has been widely used for observing space charge dynamics. However, present space charge research mainly focuses on polyethylene and there are fewer literatures about space charge characteristics of oil-paper insulation. R. S. Liu finds that a higher moisture concentration causes a faster formation and deeper penetration of space charge inner oil-paper insulation [7]. R. Ciobanu et al. has investigated the influence of gamma radiation ageing on space charge behaviors [8]. Because oil paper generally presents in the form of multi-layer structure, forming an interface between oil-paper layers, and charge can be easily stored at the interface. Therefore some scholars have paid their attention to space charge dynamics at the interface [9-12]. Effects of moisture [9], temperature [10] and polarity reversal voltage [11, 12] on space charge of multi-layer oil paper have also been studied.

Despite of this, the wonder still remains that what is the relation between thermal ageing and space charge. As oil paper is thermally aged, the inter-unit linkages in cellulose chains are broken and other properties including permittivity and conductivity change [2, 10]. These will affect space charge behaviors. Dielectric response of aged oil paper has been widely investigated, but there are only a few reports on space charge behavior of oil paper with thermal ageing [2, 8, 13], and they do not take the impact of temperature and moisture into account. High temperature is the most important reason for thermal ageing of oil paper, and the higher the temperature, the faster oil paper degrades [14]. As regards moisture, not only does it lead to the decrease of electrical strength, but also accelerates

---

† Corresponding Author: State Key Laboratory of Control and Simulation of Power Systems and Generation Equipments, Tsinghua University, China. (zhou-yx@tsinghua.edu.cn)

* State Key Laboratory of Control and Simulation of Power Systems and Generation Equipments, Tsinghua University, China.

** State Grid Corporation of China.

Received: November 13, 2014; Accepted: November 25, 2014

ageing [15]. Therefore the effect of temperature and moisture on space charge behavior of oil paper with thermal ageing is worth studying.

In this paper, oil-paper specimens were thermally aged under different moistures and temperatures. After ageing, space charge characteristics were researched by the PEA method. The influence of temperature and moisture was then analyzed.

2. Experimental Details

This section described how to prepare oil-paper specimens and some details of space charge measurement by the PEA method.

2.1 Preparation of specimens

The kraft insulation paper was impregnated with new 25# Karamay HV transformer oil through a strict process. Similar details of the process could be found in [9-12]. After it, the moisture concentration within the insulation paper specimens was less than 0.1% (mass fraction) and they were divided into two groups. The first group was put into some sealed vessels, which were then placed in temperature controlled boxes with a ±1℃ control precision. The accelerated thermal ageing temperatures (meant the ambient temperatures of ageing) were chosen as 70℃, 90℃, 110℃ and 130℃, respectively. The second group was used for making specimens with different moisture concentrations. Firstly, oil-paper samples were put into different containers. Secondly, different amount of water was dropped into different containers mainly according to the moisture equilibrium curve proposed by T.V. Oommen. There were five kinds of moisture concentrations at 25℃: 1%, 3%, 5%, 7% and 9%. Lastly, water concentration in oil and paper were measured after moisture distributions reached equilibrium. The theoretical and measured water concentrations of samples were listed as Table 1. Specimens with different moisture concentrations were then put into different sealed vessels separately and thermally aged in a temperature controlled box. This temperature was set as 110℃.

Moisture concentration during thermal ageing had been measured, as shown in Fig. 1. It could be seen that moisture fluctuated with ageing time, which was coincident with present literature, but the value was close to the initial value.

Table 1. The theoretical and measured water concentrations of oil-paper specimens

Theoretical water concentrations of paper (%)	1	3	5	7	9
Theoretical water concentrations of oil (μg/mg)	3	9	15	21	27
Measured water concentrations of oil (μg/mg)	0.28	8.6	16.1	20.8	22.8
Measured water concentrations of paper (%)	0.09	3.6	6.1	7.2	8.6

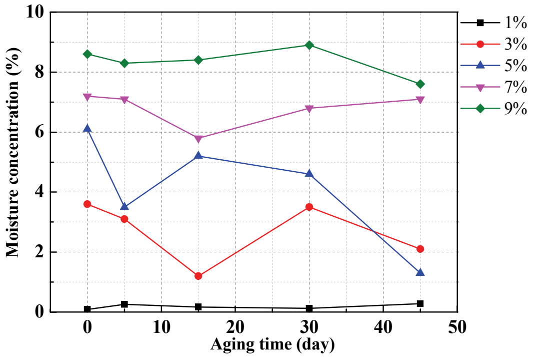

Fig. 1. Moisture concentration inner oil-paper samples vs. aging time during thermal aging.

2.2 Space charge measurement

The PEA method has been one of the widely used techniques for space charge measurements. After ageing, space charge distributions within oil-paper samples were measured by the PEA method at room temperature. Details of the PEA method could be found in [16]. The pulse width of our system was of about 5 ns and its frequency was of 1 kHz. For each test, 5 virgin samples were measured to eliminate the chance of accidental results. And for each data, 400 pulses were applied to filter background noise and ensure data reliability. Each sample was polarized under 10 kV/mm electric field for 30 min firstly and then it was short circuited. Space charge profiles were measured during both polarization and depolarization.

3. Results and Discussions

3.1 Effect of moisture

Fig. 2 illustrated space charge distribution profiles of unaged samples with different moisture concentrations at

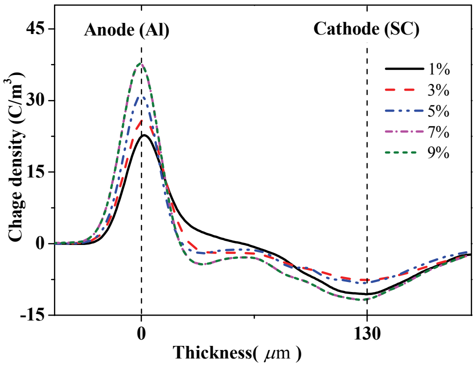

Fig. 2. Space charge distribution curves of unaged samples with different moisture concentrations at the end of polarization

the end of polarization. It could be seen that there was homogeneous charge accumulation adjacent to the anode once the moisture within the oil-paper samples was less than 1%, which actually was less than 0.1%. But there was heterogeneous charge accumulation near the anode when the moisture concentration was larger than 3%, and the larger the moisture concentration, the more the heterogeneous charge accumulation. Oil paper is a kind of liquid-solid dielectric, which contains much ionization material [17]. If the external electric field was low, homogeneous charge injection was not obvious, so hetero-charge predominated within the trapped charge. But the applied 10 kV/mm electric field was large enough for homogeneous charge injection [11]. Hence there was evident homocharge accumulation near the anode. As regards heterocharge accumulation inner specimens with higher moisture concentrations, it was firstly reported in 1997 [18]. It was thought to be caused by the influence of moisture on carriers' movement and dielectric polarization then. But there is still no complete explanation so far and more investigation is required.

It is generally accepted that moisture can accelerate space charge accumulation within oil paper [18], but the moisture concentration is usually less than 5%. Fig. 3 showed time-dependent variations of maximum negative charge density magnitudes near the anode. Sample with 1% moisture concentration was not shown in Fig. 3 because there was no negative charge near the anode (seeing Fig. 2). The negative charge density magnitude increased with polarization, but it increased first and then decreased with the increase of moisture concentration. That meant that if the moisture concentration was less than 7%, a higher moisture concentration was helpful for the equilibrium establishment of space charge. While if it was larger than 9%, it would affect contrarily.

Due to the moisture concentration, space charge behavior changed with ageing, which could be seen clearly from Fig. 4.

After it had been aged for 5 days, space charge behavior inner oil-paper samples with 9% moisture concentration showed no difference to that of unaged one (Fig. 2). As thermal ageing went on, homogeneous charge accumulation appeared near the anode and space charge cloud near the anode moved towards the cathode. That meant space charge accumulation type changed with ageing. It is known that trapped charge is de-trapped after removing the applied voltage. The carriers bounded in the shallow traps are released earlier than the carriers bounded in the deep traps for oil paper when the applied voltage is removed. If the carriers are not trapped again, trap energy level E_t and trap energy density N_t can be calculated according to Eqs. (1) and (2) [19, 20]. It is worth mentioning that the acquisition of them is bases on isothermal charge equation and there have been some assumptions. Details can be found in [20].

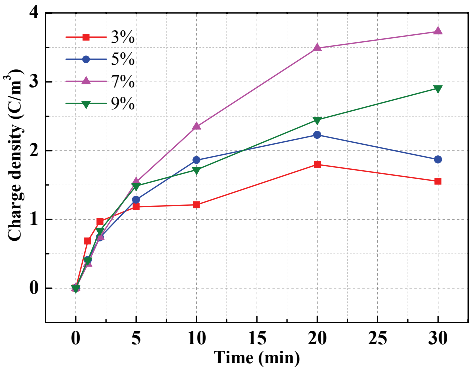

Fig. 3. Variations of the negative charge density amplitudes inner unaged samples with different moisture concentrations

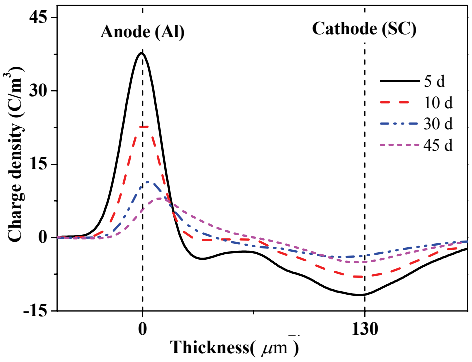

Fig. 4. Space charge distribution curves of samples with 9% moisture concentration at the end of polarization vs. ageing days

$$E_t = kT\ln vt \qquad (1)$$
$$N_t = \eta_2 t\exp(-t/\tau)/(\eta_1\tau) \qquad (2)$$

where k is the Boltzmann's constant, $k = 8.568\times10^{-5}$ eV/K, T is the absolute temperature, v is the frequency of electron vibration, $v = 3\times10^{12}$ s^{-1}, η_1 and η_2 are constants, τ is the decay constant of charge density during depolarization, and t represents decay time. Because the increase of trap density was known, it was not shown here anymore, namely η_2 kept unchanged for all conditions.

Fig. 5 was the calculated trap energy distributions of samples with 9% moisture concentration. After thermal ageing, trap density and trap depth increased. Space charge injection and movement slowed down. Recombination became weak and more charge was trapped [20]. Therefore the homogeneous charge accumulation became more and more obvious. As mentioned above, moisture was the main reason of heterogeneous charge accumulation. It suggested that the effect of moisture gradually became weak while that of ageing became strong with ageing.

Since both moisture and ageing affected space charge accumulation nature, so that when the change occurred would depend on moisture and ageing status. Because the absolute amount of total charge could not show the sign of charge, it was not chosen. While the change of

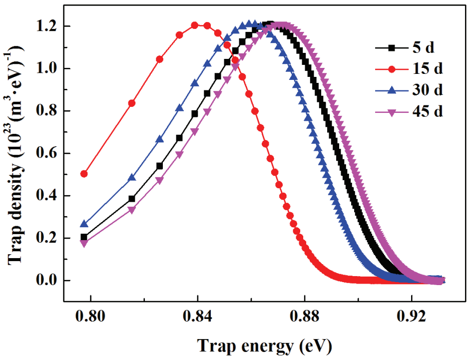

Fig. 5. Trap energy distributions of oil paper with 9% moisture concentration during thermal ageing

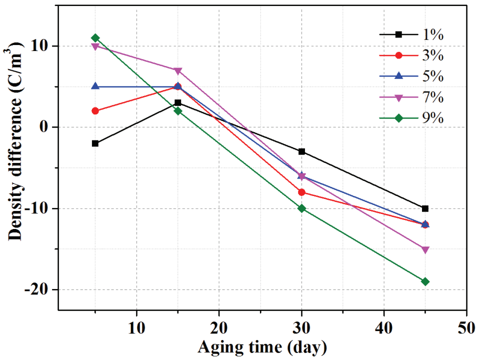

Fig. 6. Ageing day-dependent variations of the difference of space charge density amplitudes at the anode of samples with different moisture concentrations

charge density at the anode could approximately show the change of space charge accumulation and sign. Therefore Fig. 6 displayed ageing day-dependent variations of the difference of space charge density amplitudes at the anode of samples with different moisture concentrations. Positive value meant heterogeneous charge accumulation, while negative value meant homogeneous charge accumulation.

We could find that homocharge injection took place in specimens with 1% moisture concentration all along. After specimens had been aged for 20 days, homogeneous charge injection occurred, no matter how much the moisture concentration was. For specimens with 3% moisture concentration, heterocharge accumulation increased when they had been aged for 15 days. Then heterocharge accumulation gradually decreased and finally became homocharge accumulation. If the moisture concentration was between 5% and 9%, heterocharge accumulation quickly changed to homocharge accumulation with ageing. In addition, when the moisture concentration was lower than 7%, the increase of moisture concentration resulted in the delay of that change. While a 9% moisture concentration would bring forward that change.

Trap energy distribution of aged for 5 days oil paper with different moisture concentrations was presented in Fig. 7. We could obtain that if the moisture concentration was low, the increase of it can increase trap depth and trap density. And if it was high enough, the increase of it made no difference. Apart from affecting trap distributions and charge accumulation type, moisture can speed up ageing [15]. Hence if moisture concentration was low (3%~7%), the influence of moisture predominated and that of accelerated ageing was weak, the increase of it postponed the change of charge injection type. While for specimen with higher moisture concentration (9%), not only did the accelerated ageing play a dominant role, but also moisture slowed down the steady state establishment of space charge. That change consequently occurred earlier.

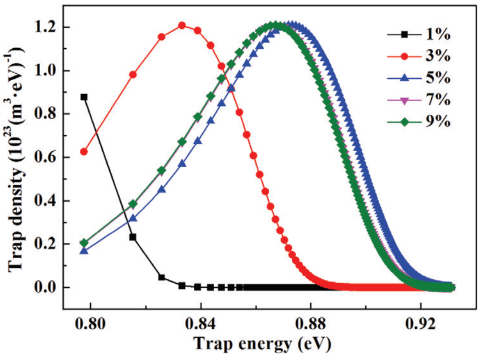

Fig. 7. Trap energy distribution of aged for 5 days oil paper with different moisture concentrations

3.2 Effect of temperature

Fig. 8 showed space charge distributions at the end of 30 min polarization of oil-paper samples that had been aged for different days at 130℃.

It was clearly demonstrated that space charge behaviors varied with thermal ageing. For samples that were not aged seriously, namely aged for 10 days, charge density at the anode decreased a little and space charge cloud near the anode moved a little further inside. But there was no obvious change of charge density at the cathode. For 20-day-aged samples, charge density at both the anode and cathode decreased a lot, but space charge cloud near the anode did not move any at all. After 30 days ageing, charge

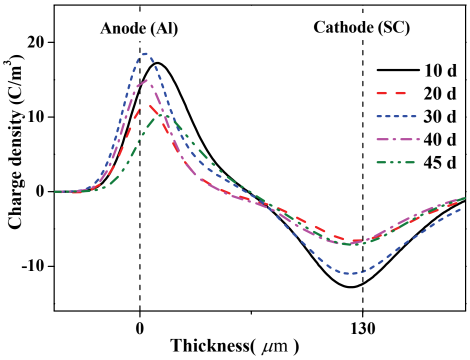

Fig. 8. Space charge distribution curves at the end of polarization of oil-paper samples aged for different days under 130℃

density at the anode was larger than that of 20-day-aged samples, and so was the movement of space charge cloud adjacent to the anode. When oil-paper samples had been aged for 40 days, charge density at the anode and cathode decreased again, and there was also no evident movement of space charge cloud. But when the thermal ageing continued for 5 more days, charge density at both the anode and cathode further decreased and the movement of space charge cloud was more evident. That meant space charge behavior was different at different ageing status, but the relationship between them was not linear. Actually charge density at electrodes and space charge cloud movement fluctuated with ageing.

Due to the resolution of the PEA method and capacitive charge density at the electrode-dielectric interface, space charge characteristics under polarization might not fully show the influence of thermal ageing. While space charge characteristics under depolarization could reveal trap characteristics better. Trap energy distributions of oil-paper samples aged for 10 days under different temperatures were illustrated as Fig. 9.

It could be seen that trap density and trap depth increased with ageing temperature after oil paper had been aged for certain days. Trap energy distributions of samples aged under 70℃ and 90℃ were similar to each other, and traps were mostly shallow traps. Trap energy of the largest trap density was about 0.77 eV. That of samples aged under 110℃ and 130℃ were 0.80 eV and 0.87 eV, respectively. It meant that the higher the ageing temperature was, the faster oil paper was aged and the deeper trap energy level was. Hence space charge injection and migration were affected, and recombination weakened, so there was more charge [20]. As a result, charge injection and space charge cloud movement were more obvious.

The corresponding trap distributions of samples that had been aged for 45 days were illustrated as Fig. 10. After such a long time ageing, difference caused by ageing temperature and ageing status was very clear. The higher the ageing temperature, the deeper the trap energy level. The increase of trap depth weakened recombination and led to more charge accumulation. Compared to Fig. 9, we found that thermal ageing could also deepen the trap energy level. In addition, the difference between trap distributions of samples aged under 70℃ and 90℃ was more and more obvious with ageing.

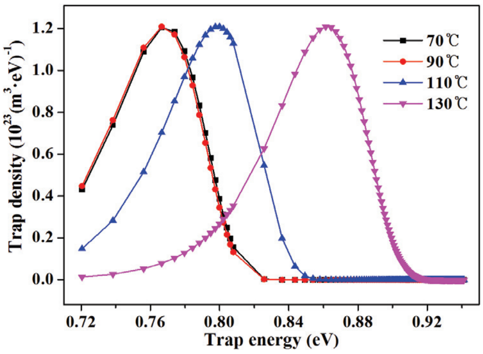

Fig. 9. Trap energy distributions of oil-paper samples aged under different ageing temperatures for 10 days

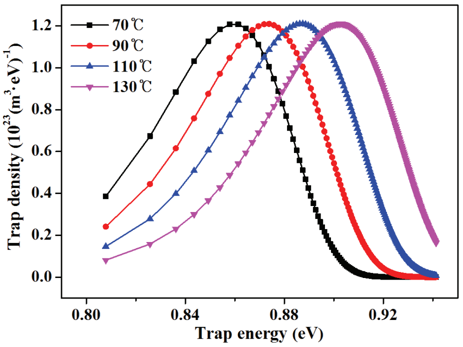

Fig. 10. Trap energy distributions of oil-paper samples aged under different ageing temperatures for 45 days

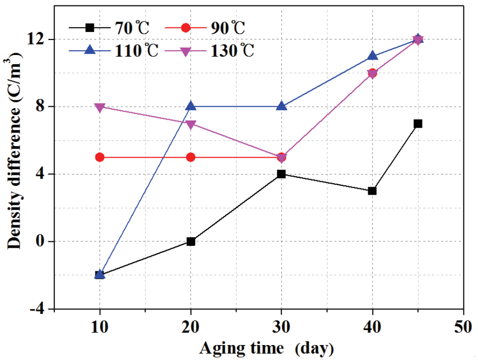

Fig. 11. Ageing day-dependent variations of the difference of space charge density amplitudes at the anode of samples aged under different ageing temperatures

Fig. 11 presented ageing day-dependent variations of the difference of space charge density amplitudes at the anode of samples aged under different ageing temperatures. Similar to results above, negative value meant heterogeneous charge accumulation, while positive value meant homogeneous charge accumulation. We could see that homogeneous charge accumulation occurred after samples had been aged for 20 days under the four different temperatures, and the injection speed gradually increased later on. Although the value increased with ageing, that of samples aged under 70℃ was always the smallest one, while that of samples aged under 130℃ was generally the largest. It not only indicated that space charge accumulation increased with ageing, but also declared that space charge behavior was sensitive to the ageing temperature.

The Arrhenius law is a widely used ageing model, which can be expressed as follows:

$$f(T) = f_c \exp(-E_a/kT) \tag{3}$$

where $f(T)$ is used to represent ageing status, E_a is the necessary energy for ageing, f_c is a constant [21]. The activation energy of oil paper is about 111 kJ/mol [22], hence the Arrhenius law can be simplified to:

$$f(T) = f_c \exp(-13351/T) \tag{4}$$

It could be obtained that oil paper aged for 10 days at 130℃ was approximately equal to that aged for 56 days at 110℃. Whereas trap energy level of oil paper aged for 45 days at 110℃ (Fig. 10) was already deeper than that aged for 10 days at 130℃ (Fig. 9), and a similar result was shown in Fig. 11. That meant space charge behaviors of oil-paper aged under different temperatures did not fit the Arrhenius law very well.

4. Conclusion

This paper studied space charge behavior of oil-paper insulation. Kraft paper was firstly thermally aged under different moisture concentrations and temperatures. After ageing, space charge distributions were measured by the PEA method. The following conclusions could be drawn:

Due to the influence of moisture on trap distributions, the increase of moisture concentration within oil paper will speed up the formation of space charge, if the moisture concentration is not too large. Otherwise, it will take longer time for space charge to reach stationary conditions.

Moisture and ageing both affect space charge behavior of oil-paper insulation, so space charge accumulation type changes with ageing. It gradually changes from heterogeneous charge accumulation to homogeneous charge accumulation. And the higher the moisture concentration, the slower the accumulation type changes, when moisture concentration is low. But it will accelerate the change of that accumulation type if moisture concentration is high.

Trap depth increases with thermal ageing, so more and more charge is trapped. And this is accelerated by the increase of the ambient temperature of ageing. Space charge behavior of oil-paper insulation is therefore sensitive to the ambient temperature of ageing, but it does not fit the Arrhenius law well.

Acknowledgements

This work is supported by National Basic Research Program of China (973 Program) (2011CB209400) and Program of State Key Lab of Control and Simulation of Power Systems and Generation Equipments ("Research on the key techniques of space charge measurement system"), and thanks for the support.

References

[1] M. Lessard, L. Van Nifterik, M. Masse, J. F. Penneau, and R. Grob, "Thermal ageing study of insulating papers used in power transformers," in *Electrical Insulation and Dielectric Phenomena*, 1996, pp. 854-859.

[2] S. Q. Wang, G. J. Zhang, H. B. Mu, D. Wang, M. Lei, Suwarno, Y. Tanaka, and T. Takada, "Effects of Paper-aged State on Space Charge Characteristics in Oil-impregnated Paper Insulation," *IEEE Trans. Dielectr. Electr. Insul.*, vol. 19, pp. 1871-1878, Dec. 2012.

[3] D. Linhjell, L. Lundgaard and U. Gafvert, "Dielectric response of mineral oil impregnated cellulose and the impact of ageing," *IEEE Trans. Dielectr. Electr. Insul.*, vol. 14, pp. 156-169, Feb. 2007.

[4] T. V. Oommen and T. A. Prevost, "Cellulose insulation in oil-filled power transformers: part II maintainning insulation integrity and life," *IEEE Electr. Insul. Mag.*, vol. 22, pp. 5-14, Apr. 2006.

[5] Mizutani T, "Space charge measurement techniques and space charge in polyethylene," *IEEE Trans. Dielectr. Electr. Insul.*, vol. 1, pp. 923-933, Oct. 1994.

[6] Fukuma M., Nagao M., Kosaki M. and Kohno Y., "Measurements of conduction current and electric field distribution up to electrical breakdown in two-layer polymer film," in *Electrical Insulation and Dielectric Phenomena*, 2000, pp. 721-724.

[7] R. S. Liu, Jaksts A., Tornkvist C. and Bergkvist M., "Moisture and space charge in oil-impregnated pressboard under HVDC," *in Proceedings of the 6th IEEE Conference on Conduction and Breakdown in Solid Dielectrics*, Vasteras, Sweden, 1998.

[8] R. Ciobanu, I. Prisecaru, and S. Aradoaei, "PEA measurements upon cellulose materials submitted to gamma radiation," *in Proceedings of the 8th International Conference on Solid Dielectrics*, Toulouse, France, 2004.

[9] Jian Hao, George Chen, Ruijin Liao, Lijun Yang and Chao Tang, "Influence of Moisture on Space Charge Dynamics in Multilayer Oil-paper Insulation," *IEEE Trans. Dielectr. Electr. Insul.*, vol. 19, no. 4, pp. 1456-1464, Mar. 2012.

[10] Chao Tang, George Chen, Ming Fu, RuiJin Liao, "Space charge behavior in multi-layer oil-paper insulation under different DC voltages and temperatures," *IEEE Trans. Dielectr. Electr. Insul.*, vol. 17, no. 3, pp. 775-784, Aug. 2010.

[11] Y. Zhou, M. Huang, Q. Sun, Y. Sha, F. Jin, and L. Zhang, "Space charge characteristics in two-layer oil-paper insulation," *J. Electrostat.*, Vol. 71, pp. 413-417, Jun. 2013.

[12] H. Meng, Z. Yuanxiang, C. Weijiang, S. Yanchao and J. Fubao, "Influence of voltage reversal on space charge behavior in oil-paper insulation", *IEEE Trans. Dielectr. Electr. Insul.*, Vol. 21, pp. 331 -339, Feb. 2014.

[13] W. Sicheng, L. Jian, Z. Lin Jie, W. Yan, H. Zhiman, and B. Lianwei, "The properties of space charge in

oil-paper insulation during electrical-thermal ageing," *in High Voltage Engineering and Application* (*ICHVE*), 2012, pp. 269-273.

[14] M. Darveniza, T. K. Saha, D. J. T. Hill and T. T. Le, "Study of degradation of cellulosic insulation materials in aged power transformers by electrical and chemical techniques," *In Electric Energy Conference*, Brisbane, Australia, 1992.

[15] Du, Y., Zahn, M., Lesieutre, B. C., Mamishev, A. V., and Lindgren, S. R., "Moisture equilibrium in transformer paper-oil system," *IEEE Electrical Insulation Magazine*, vol. 15, pp. 11-20, Jan.-Feb. 1999.

[16] T. Maeno, T. Futami, H. Kushibe, T. Takada and C. M. Cooke, "Measurement of spatial charge distribution in thick dielectrics using the pulsed electroacoustic method," *IEEE Trans. Dielectr. Electr. Insul.*, Vol. 23, pp. 433-439, Jun. 1988.

[17] Zhou Y., Wang Y., Li G., Wang N., Liu Y., Li B., and Cheng H., "Space Charge Phenomena in Oil-paper Insulation Materials under High Voltage Direct Current," *J. Electrostat*, vol. 67, pp. 417-421, May. 2009.

[18] P. Morshuis and M. Jeroense, "Space charge measurements on impregnated paper: a review of the PEA method and a discussion of results," *IEEE Electrical Insulation Magazine*, vol. 13, no. 2, pp. 26-35, May.-Jun. 1997.

[19] ZHOU Yuanxiang, HUANG Meng, CHEN Weijiang, SUN Qinghua, SHA Yanchao and ZHANG Ling, "Interface space charge characteristics in multi-layer oil-paper insulation under DC voltage," *High Voltage Engineering*, vol. 39, no. 6, pp. 1304-1311, Jun. 2013. (*in Chinese*)

[20] Jian Li, Yan Wang and Lianwei Bao, "Space Charge Behavior of Oil-Impregnated Paper Insulation Ageing at AC-DC Combined Voltages," *J Electr Eng Technol.*, Vol. 9, No. 2, pp. 635-642, Mar. 2014.

[21] M. C. Lessard, L. Van Nifterik, M. Masse, J. F. Penneau, and R. Grob, "Thermal Ageing Study of Insulating Papers Used in Power Transformers," in *IEEE Conference on Electrical Insulation and Dielectric Phenomena*, San Francisco, USA, 1996.

[22] A. M. Emsley and G. C. Stevens, "Kinetics and mechanism of the low-temperature of cellulose," *Cellulose*, Vol. 1, No. 1, pp. 26-56, Mar. 1994.

Yuan-xiang Zhou He was born in Fujian Province, China, in 1966. He received the B.E. degree from Tsinghua University, Beijing, China, in 1988, the M.E. degree from the Electrical Power Research Institute, Beijing, in 1991, and the Ph.D. degree from Akita University, Akita, Japan, in 1999. From 1999 to 2000, he did research for the National Institute for Resources and Environment, National Institute of Advanced Industrial Science and Technology, Japan, as a New Energy and Industrial Technology Development Organization Fellow. He is currently a Professor with Tsinghua University. His interests include organic and inorganic dielectrics, high-voltage technology and environmental protection, electrical equipment, and on-site detection and diagnosis. Dr. Zhou is the Deputy Secretary-General of China Electrotechnical Society.

Meng Huang He was born in Hubei Province, China in 1988. He received the B.Eng. (2011) degree in electrical engineering from Tsinghua University, Beijing, China. Now, he is a Ph.D. candidate in the Department of Tsinghua University, China. His research activities are mainly in the field of oil-paper insulation dielectric, high voltage technology and space charge measurement.

Wei-jiang Chen He was born in Shandong Province, China, in 1958. He received the B.E. degree in electrical engineering from Hefei University of Technology, Hefei, China, in 1982 and the M.E. degree in high voltage and insulation technology from the China Electric Power Research Institute (CEPRI), Beijing, China, in 1985. He was the President of Wuhan High Voltage Research Institute, Wuhan, China, from 2005 to 2008. He has been the Vice Director of UHV Department of State Grid Corporation of China since 2008, taking charge of constructing ultra-high-voltage (UHV) transmission lines of SGCC. His research interests include overvoltage protection, UHV transmission, insulation coordination, and surge arresters and electromagnetic environment in power systems. Mr. Chen is the Chairman of the HV Professional CSEE and Chairman of China EMC Standardization Technology Committee.

Fu-bao Jin He was born in Xining city, Qinghai Province, China, in 1981. He received the B. E degree and M. S. degree in electrical engineering from Harbin Institute of Technology, Harbin, China, in 2004 and 2007. He is currently pursuing the Ph.D. degree in Tsinghua University, Beijing, China. His interests include dielectric insulation and surface discharge in transformer insulation system.