Dielectric and Insulating Technology 2005 : Reviews & Forecasts

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This article reports the state-of-art of TC-DEI (Technical Committee of Dielectrics and Electrical Insulation of IEEJ) activities. The activities are basically based on the activities of 8-10 investigation committees under TC-DEI. Recent activities were categorized into three functions in this article and remarkable activity or trend for each category is mentioned as was done in the article of 2003. Those are activities on asset management (AI application and insulation diagnosis), activities on new insulating and functional materials (Nano composite) and activities on new insulation technology for power transmission (high Tc superconducting cable insulation).

Keywords : insulation diagnosis, insulation design, nanocomposite, thinfilms

1. Overview of the Activities of the Technical Committee on Dielectrics and Electrical Insulation (TC-DEI)

The committee was set up in 1979 succeeding the Permanent Committee on Electrical Insulating Materials upon the reorganization of IEEJ. The activities of the committee have been covering mainly solid and composite dielectric materials and their technologies. The important activity of TC-DEI is the annual Symposium of Electrical and Electronic Insulating Materials and Applications in Systems (SEEMAS), formerly called Symposium on Electrical Insulating Materials.

The annual symposium in 2003 was held as a part of the 7th ICPADM at Nagoya University on June 1-5, 2003. ICPADM stands for "International Conference on Properties and Applications of Dielectric Materials". ICPADM is sponsored by IEEE DEIS and cosponsored by IEEJ. The TC-DEI cooperated and contributed to the conference substantially. The TC-DEI is planning to organize 35th SEEMAS on November 17 and 18 at Shibaura Institute of Technology, Tokyo. The TC-DEI currently (September, 2004) runs ten Investigating Committees (IC's) which organize Technical Meetings. Those committees are categorized into four groups as followings:

[Macro-view of DEI technology related]

- Environment-friendly materials and systems for electric and electronics application (04/04-03/07, Chairman: Y.Suzuoki (Nagoya University))
- Economical evaluation of insulation diagnosis (04/04-03/07, Chairman: N.Hozumi (Toyohashi University of Technology))

[New materials including nano-materials related]

- Application and improvement of organic molecular films and organic/inorganic composites with controlled nano-structures (04/04-03/07, Chairman: F.Kaneko (Niigata University))
- Dielectric and insulating materials for information communication (01/04-12/06, Chairman: K.Fukunaga (National Institute of Information and communication Technology))

- Development of organic electrical and electronic materials with flexible structure to nanotechnology (07/03-06/06, Chairman: M.Iwamoto (Tokyo Institute of Technology))
 - Application of nano-composite materials to DEI systems (10/02-09/05, Chairman: T.Tanaka (Waseda University))
- [Diagnosis of electric and electronic equipment related]
- On-line insulation diagnostic methods of power cable and apparatus (01/03-12/05, Chairman: K. Uchida (Chubu Electric Power Company))
 - Insulation ageing and surge endurance of printed circuit boards (04/02-03/05, Chairman: Y.Yamano (Chiba University))
- [Basic dielectric and breakdown phenomena related]
- Charge behavior and interface of high electric field insulation (07/02-06/05, Chairman: M. Nagao (Toyohashi University of Technology))
 - Discharge evaluation and ageing phenomena on the surface of polymer insulators (04/02-03/05, Chairman: K. Gotoh (Consultant))

2. Activities on Asset Management (AI Application and Insulation Diagnosis)

Recent trends in insulation diagnostic technology for power equipment are basically due to power business liberalization. Through the papers of international conferences certain trends in insulating technology can be conjectured. Large international conference such as CIGRE meeting and ICPADM are some of the best meeting to get the trend information in the engineering research direction. There are many interesting papers concerning insulation technology.

One important trend is introduction of asset management concept to utilize power equipment with minimum costs. In that line, global view of asset management including insulation diagnosis of power equipment or intense environmental standpoint of view such as LCC calculation are positioned properly as shown in Fig.1.

Along with asset management concept, the necessity of data mining and decision support system development was emphasized as shown in Fig.2.

In order to develop the asset management methods, insulation diagnostic methods are key technology such as insulation condition assessment of the stator windings, condition assessment

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and lifetime extension of power transformers, life assessment of power transformers to prepare a rehabilitation based on a technical-economical analysis, condition based evaluation of net transformers -experience from a new ranking procedure, the impact of economic and reliability considerations on decisions regarding the life management of power transformers, life cycle assessment of substations, asset management in a deregulated

Fig. 1. Selected processes, techniques related to asset management⁽¹⁾

Fig. 2. Decision diagram for diagnostic data analysis to categorize the insulation condition in one of the three condition classes⁽²⁾

Fig. 3. Life-cycle costs with different diagnostic parameters⁽³⁾ (failure loss: 100, replacement expense: 1, diagnosis expense: 0.1)

environment, development of asset management services.

As an example of asset management consideration, life cycle cost of cable maintenance was estimated in terms of diagnosis interval and replacement criterion as shown in Fig.3. This result indicate there must be the maximum cost effective maintenance procedure for each power equipment depending on its insulation degradation characteristics or risk behavior and therefore to develop proper asset management for each equipment and system becomes one of the most important issues that insulating technology concerns.

3. Activities on New Insulating Materials (Nano Composite)

There are many research works on nanocomposite material developments including organic and inorganic materials. One direction is to modify the conventional polymer with nanomaterials to change their mechanical, electrical and others. As for one example of organic material improvement, epoxy resin (diglycidyl ether of bisphenol-A, DGEBA) was modified with silicate nano particle to improve mechanical property.

Figures 4 and 5 show the TEM photograph of the compsite materials and their mechanical property. With the nano particle, the mechanical property (glass transition temperature) was improved. Along with this kind of material modification, polymer crystalline structure was modified as shown in the figure.

Research work on improvement of inorganic material and new functional materials have been also intensively carried out. One

(a)(b) : DGEBA containing 6 wt% of silicate A
(c)(d) : DGEBA containing 3 wt% of silicate B

Fig. 4. TEM micrographs of DGEBA/silicate A and DGEBA/silicate B⁽⁴⁾

(●,○) Pure epoxy, (▲,△) DGEBA containing 3 wt% of silicate A
(■,□) DGEBA containing 6 wt% of silicate A
(◆,◇) DGEBA containing 3 wt% of silicate B

Fig. 5. Dynamic mechanical properties of nanocomposites⁽⁴⁾

Left : High Resolution TEM imaging gave no evidence for crystallization phenomena within the amorphous dielectric oxide layer
 Right : Small Angle Electron Diffraction pattern of the dielectric oxides exhibited an amorphous structure with monoclinic Nb₂O₅ short range ordering

Fig. 6. TEM micrographs before (a) and after (b) annealing⁽⁵⁾

Fig. 7. Volume effect on PD inception electric field strength (PDIE) for LN2/PP insulation system⁽⁶⁾

example was nano structure improvement of Nb₂O₅ for capacitor material. With annealing process, the amorphous structure at the interface appeared and it exhibited better dielectric characteristics. Utilizing HRTEM (Fig.6 left hand side) and energy-filtered electron diffraction (Fig.6 right hand side), it could be shown that the Nb₂O₅ layer formed by anodic oxidation is completely amorphous and homogeneous.

Those research results indicate the importance of nano structure in dielectric and insulating material when one would like to improve the function of the materials.

4. Activities on New Insulation Technology for Power Transmission (High Tc Super Conducting Cable Insulation)

For the optimization of electrical insulation design for High

Temperature Superconducting (HTS) cable, evaluation of electrical insulation characteristics especially for butt gap of LN₂ impregnated cold dielectric (CD) plays an important role and steady progress was reported.

Steady research progress was reported. A new idea to determine insulation design based on statistical stressed liquid volume (SSLV) is proposed. Supposing the existence of LN₂-impregnated thin areas between PP laminated paper layers associated with the surface roughness on the papers, SSLV was defined on the basis of the discharge probability with consideration of electric field distribution in the electrode system. As the result, SSLV between insulation layers was found to be larger than that of butt gaps for different layer-configurations. PDIE decreased with the increase in SSLV, as shown in Fig.7. This result indicates the insulation thickness design under PD-free condition.

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