APPLICATION OF NANOTECHNOLOGY IN ELECTRICAL POWER ENGINEERING

[1]**SATCHIDANANDA GHOSH,** Gandhi Institute of Excellent Technocrats, Bhubaneswar, India
[2]**SURYAKANTA DAS,** Sophitorium Engineering College, Khordha, Odisha, India

ABSTRACT

Nanotechnology is one of the fastest growing fields in research and technology. The main interest of nanotechnology is not electrical power engineering but there were a lot of possible applications to improve electrical, mechanical, thermal or chemical properties of electric power equipment. Often the economic aspect is pointed out, but also a higher efficiency or a reduction of losses predicts this new technology a successful appearance in power engineering.

In this paper the state of the art in nanotechnology, the possibilities and applications in electric power engineering were investigated. On the one hand new materials for conductors and on the other hand new insulants and coatings for insulators were taken into account. The aim forhigh voltage insulation systems were to extend the lifetime, to optimize the life cycle costs, to reduce the maintenance expenses, to decrease the size or weight and to increase the efficiency.

As an example of a practical application of nanotechnology the results of a test series with nano-coated porcelain insulators were presented. The nano-coating was applied on the ceramic surface and the long term stability was tested under a thermal and humid cycling procedure in a climate chamber and under natural conditions. As objective criterion for the long term stability the contact angle was observed by optical measurements in defined time intervals. The evaluations of the first test results look very successful, the contact angles of the coated insulators were constantlyhigher for more than 30 degrees over the whole test period.

NANOTECHNOLOGY IN ELECTRICALPOWER ENGINEERING

In wide areas of research and applied science nanotechnology is already present and the immediate connection can clearly be assumed. Just to name two applications medics and biomedical engineers developnanoparticles for tumor markers, physicists and electronic engineers use nanotechnology for semiconductors to develop the super computer. From this point of view it sounds like a contradiction nanotechnology and power engineering, but what does nanotechnology have to do in electrical engineering? Power engineering where Megawatt of Power and thousands of Volts have the formative influence on the daily business, where does a technology of miniaturization of elements find its place in between? There were several prospects for application in power engineering, let me list some examples:

- Improvement of metallic conductors (reduction oflosses)
- Improvements of insulators (raising of electrical insulation, mechanical stability, thermal load behaviour, chemical resistance)
- Miniaturizing of design, reduction of used material, higher reliability
- Improvement of electromagnetic compatibility(EMV)
- Long-term improvement of efficiency and elongation of life time period

Al of these ideas can not be put into reality within days ormonths, it will take a middle-term to long-term period from the idea to research work, over first prototypes and to industrial production and the application by the consumers.

Some researchers and groups were investigating intensive on the break through of nanotechnology for power application. A high state of expectation affords the reduction of ohmic losses at metallic conductors using Carbon Nano Tubes (CNT). In [1] a concept for creating a future ultra-low-resistivity material based on a carbon nanotube metal composite was presented. In a simple effective-medium model it was shown that a room- temperature resistivity 50% lower than Cu is achievable. Figure 1 illustrates the calculated resisti[redacted]y in a compositeof copper and CNT.

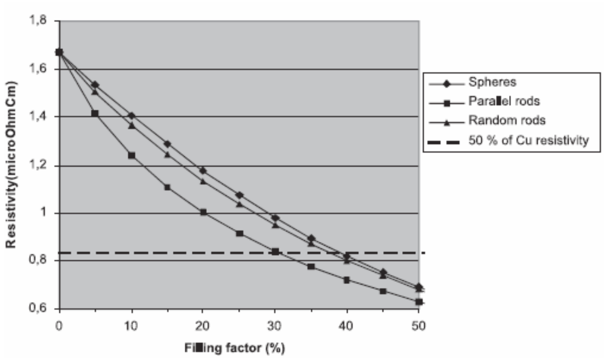

Fig. 1: Calculated Resistivity in a Composite of Copperand Carbon Nano Tubes [1]

This research group called this idea conductor with ultra- low resistivity. This phenomena is possible because the ballistic conducting carbon nanotubes. Their properties can be described that the CNT have an electron mean free pathseveral orders of magnitude longer than metals like Cu andAg. This implies that a system with parallel-connected tubes can indeed have a room-temperature resistivity far below the resistivity of conventional used metal conductors like Al, Cu and Ag.
Imagine if the ohmic resistance could be reduced for some percent, how important would an industrial production of such a conductor be? Not only the electric losses could bereduced and the efficiency of cables improved, also the thermal behaviour would be optimized and the material load reduced. I just want to remember that one of the most dominant ageing factors is the thermal heat on insulation systems according to Arrhenius Law. Beside of the better efficiency also a higher life-time and a better reliability would be given. The conductor of ultra-low resistivity is not realized by now but nanotechnology gives hope to find new ways to realize the dream of all electrical engineers – the loss free electric conduction.
In other fields of nanotechnology the progress of research is faster going on. E.g. in the CIGRE WG D1.16 there were different subjects: “High Field Phenomena in Solid Insulation and Interfaces” reports of the state of the art at Interfaces in HVDC Extruded Cables, Low Voltage and High Field Phenomena, Polymer Nanocomposites and Interfaces in Composite Insulation.
Using nanofillers in electrical insulators the properties of electrical, mechanical or thermal behaviour can beinfluenced between its physical limits. Several test series have shown that the use of nanofillers provide good chances of success. Different physical effects were used to archivethe target, e.g. with nanofillers the surface of the material structure is enlarged huge so that not the surface effect is more dominant as the volume effect. A change of the thermal behaviour, a shifting of melting point, could be the consequence. Or the electrical treeing behaviour is reduced by the nanofillers due to reduction of electrical field strength respectively of longer treeing distances.
In [2] the influence of the nanofiller concentration on the behaviour of materials was shown. With the variation of the nanofiller concentration in insulating materials physical properties as thermal conductivity, resistance to HV arcing, dissipation factor or relative permittivity can be changed within close limits.

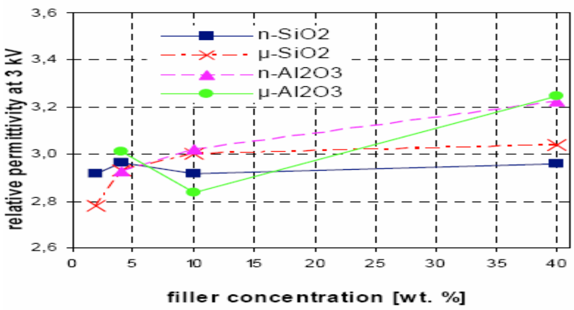

Fig. 2: Influence of filler concentration on the dielectricbehaviour of insulating materials [2]

One of the first come into used nanotechnology products was a material to improve the hydrophobic behaviour of surfaces. The improvement of water repellent surfaces was investigated very well. In [3] one of numerous test series for practical applications in power engineering is described.

HYDROPHOBIC PROPERTIES OF SURFACES

A frequent problem of ceramic outdoor insulators are corona discharges, flashovers or leakage current due to air humidity, rainfall in combination with dust of environmental pollution. Often also industrial pollution, salt fog or sand storms worsen the situation and accelerate the ageing of the porcelain surface [4]. The best flashover behaviour and lowest leakage current shows a good hydrophobic surface of the insulator, which polymer insulators have. In contrast to polymer surfaces ceramic insulators show a poor hydrophobic characteristic. For this reason tries with a silicone coating of the ceramic surface were done with varying success. The main problem was the complicated application and the long term stability of the silicon coating. Since the development of nanotechnological products nanoliquids were used for many applications. In this investigation the applicability and long term stability of nanocoated ceramic insulators should be examined.

For the characterization of the hydrophobic properties of insulator surfaces the contact angle is an objective parameter. For this reason the definitions according to IEC Standard 62073 [5] was taken into account. At a surface which is inclined for an angle the dynamic contact angle consists of an advancing and a receding angle according to Fig. 3. The static contact angle was not of interest for these investigations because insulator caps had an inclination of 15°.

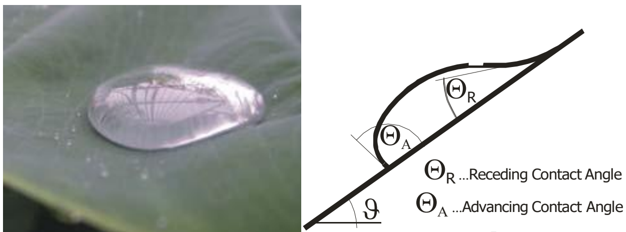

Fig. 3: Dynamic Contact Angle

TEST OBJECTS AND TEST PROGRAM

All tests were applied at the same ceramic insulator type. At eight insulators the test program was applied, two of them were not impregnated with the nanocoating. The impregnation of the insulator surface with the coating was done in according to the application instruction of the nanoliquid producer. Six of the ceramic insulators were aged artificial in a climate chamber with a test program with temperature differences between +60°C and -20 °C and relative air humidity between +93% and 50%. In total more than 70 test cycles were applied during a halve year period of time. At two insulators a natural aging process was applied over several months.

These two insulators were exposed to outdoor climate under summer (up to+25 °C, dry, wet) and winter conditions (snow, -10°C) with natural pollution. The test conditions were tighten up during the halve test time because there could no fundamentally changes be found on the surface and the hydrophobic characteristics. The freezing of the air humidity under zero degree at the insulator surface and the evaporation process under heating should present an accelerated ageing procedure.

CONTACT ANGLE MEASUREMENTS

The receding and advancing contact angle was observed from the beginning of these investigations op to the preliminary test end. The contact angle was determined optical with a digital camera; the pictures were evaluated with graphical software. A sample of the contact angle determination is shown in Fig. 4.

This measuring procedure has been done for several points during the test and with different size of water drops beginning from 1 µl up to 100 µl in steps of 5 µl. The results of receding and advancing contact angle have been recorded. The water drops were produced with a biomedical pipette where the drop size can be adjusted continuously between one and 200 µl. The measuring results were verified by applying the same water drop size two times.

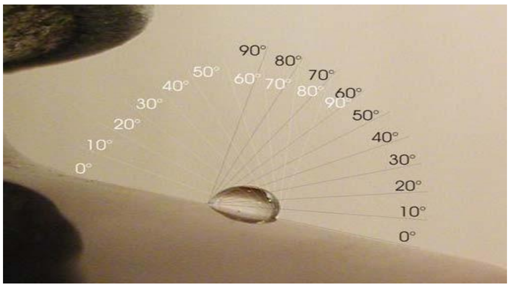

Fig. 4: Contac Angle Determination

RESULTS

The results of the tests and contact angle measurements can be summarized as follows: The condition of the surface did not worsen, the nanocoating passed the test very successful, no changes could be observed. The contact angle kept almost constant over the whole test period.

Fig. 5: Interfacial tension at a water drop size of 1µl, 50 µl and 90 µl with nanocoating (left) and without coating (right)

Between the coated and the non coated ceramic surface a big difference in the hydrophobic characteristic was observed. Fig. 5 illustrates the difference of the interfacial tension of coated and non coated insulators at different water drop sizes. The pictures on the left side show the shape of drops of the surface treated insulator. It is clear to see that the contact angles were much higher than at the untreated surface on the right side.

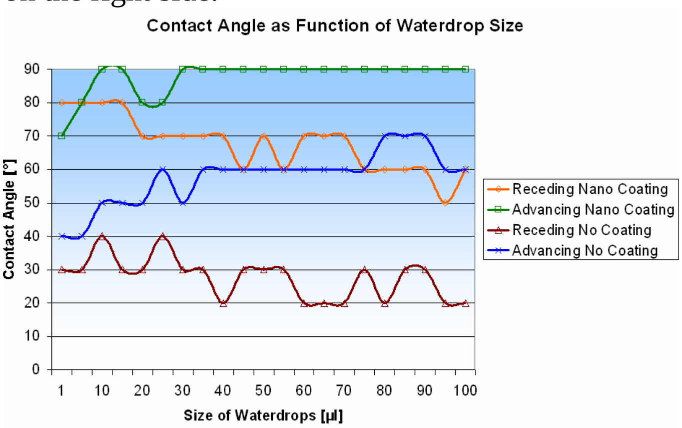

Fig. 6: contact angle characteristic of nan[redacted]ated and non coated ceramic surfaces

The observed contact angles in dependence of the water drop size were illustrated in Fig. 6. The advancing contact angle of the nanocoated insulator was almost constant at 90° for all water drop sizes, the receding contact angle showed a light degrading characteristic for bigger water drop volumes. The behaviour for the non coated surface showed a light increasing characteristic for the advancing angle and a light falling tendency for the receding angle.

SUMMARY

Nanotechnological innovations were present in wide areas of electrical engineering. In electrical power engineering the actual state was demonstrated with different projects in the research and development, in special the ultra low resisistivity conductor, the influence of nanofillers for insulating materials and the coating for hydrophobic surfaces were discussed.

The hydrophobic properties of six nanocoated and two non coated ceramic insulators were tested under accelerated ageing conditions. Between the coated and the non coated surfaces a difference of the measured contact angles of 30° in average was observed. This value meets very well with recently published contact angle measurements [6], [7] of polymer surfaces. The nanocoating showed no degradation after more than 70 ageing cycles within six month of test duration. The application of the nanosurface is very simple and can be done at new and also at installed insulators.

References

[1] O. Hjortstam, P. Isberg, S. Söderholm, and H. Dai, Can we achieve ultra-low resistivity in carbon nanotube-based metal composites?, Applied Physics A, Vol. 78, No. 8, 2004

[2] S. Rätzke, J. Kindersberger, Erosion Behaviour of Nano Filled Silicone Elastomers, ISH 2005, paper C09

[3] T. Andritsch, Nanotechnology in Electrical Engineering,
Diploma Thesis 2006, TU Graz

[4] M.Awad, H.Said, B.A.Arafa, A.Nosseir, Long Term Aging of Silicone Rubber Insulators due to Sandstorms,
CIGRE 2000, Paper 15-2005

[5] IEC/TC 62073, 2003-06: Guidance on the measurement of wettability of insulator surfaces

[6] F. Exl, J. Kindesberger, Contact Angle Measurement on Insulator Surfaces with Artificial Pollution Layers and Various Surface Roughnesses, ISH 2005, Paper D-47

[7] J. Wu, C. Cornelissen, A. Schnettler, Investigation on the flashover performance of nanostructured insulating surface with „Lotus-Effect®" under wet conditions, ISH 2005, Paper D-15

[8] http://www.tycoelectronics.com/

[9] http://www.nanogate.de/

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