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Synthesis and Application of Ceo$_2$ and Zro$_2$ Nanoparticles for Enhancement of Dielectric Strength of Transformer Oil

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***Abstract:** Power and Distribution transformers are the key devices to maintain power system reliability. Thus in-order to have continuous power supply ,a fault tolerant system is to be developed by avoiding the failures on major devices like transformers. As insulation failure is accounted as 13.0% occurrence of all the faults on transformer, there is always a point of interest to enhance the breakdown strength of the transformer oil. Also to cater to the demand , an increase in the number and unit capacity of high voltage transformers require transformer oil with high oxidation stability and good electric properties. In this work , ceramic nanomaterials zirconia(ZrO_2) and Ceria (CeO_2) are preferred due to their strong insulating property and high relative permittivity. The synthesized nanomaterials of concentration (0.5%wt) are dispersed into the transformer oil by sonication and AC breakdown measurements have been performed on the prepared nano transformer oil. The obtained results clearly indicates a remarkable increase in the dielectric strength of transformer oil filled with ZrO_2 and CeO_2nanoparticle.*

***Index Terms:** Transformer oil; Breakdown strength; Combustion synthesis; Nanoparticles.*

I. INTRODUCTION

Reliable power supply without interruption is very essential in the fast growing global energy market. Power and distribution transformers are the major devices in the interconnected power system where their operation is directly related to the power system reliability. Therefore it is always needed to protect the transformers from the major faults listed in the Table I.[1].

Table I:Major Faults on Transformers

S.No	Type of faults	% of occurrence
1	Lightning Surges	12.4
2	Line Surges/External Short Circuits	21.5
3	Deterioration of Insulation	13.0
4	Overloading	2.4
5	Moisture	6.3
6	Inadequate Maintenance	11.3
7	Loose Connections	6.0
8	All others	27.1

From the above table it was clear that the insulation failure is considered as the third major fault in terms of occurrence on the transformers .So, efforts has to be made to reduce the insulation failures, which indirectly improves the reliability of the interconnected power system. Mineral oil as transformer oil fulfills important functions in the insulating system such as di-electric, heat transfer agent(coolant) and arc quencher. The reliable performance of the transformer oil depends upon the basic oil characteristics, its oxidation stability, stability in an electric field and its compatibility with other insulating materials in the system. Therefore to ensure long and uninterrupted life time service of transformer ,it is pertinent to increase the mineral oil properties like di-electric strength [6]. In recent years , use of nanomaterials for improving the liquid di-electrics is became a thrust area of research [3]. So much of literature is already available in this area and in this paper we demonstrated the effect of dispersing zirconia(ZrO_2) and Ceria (CeO_2) nanoparticles in transformer oil [5]. Also if the dielectric electric strength of transformer oil is improved its loading capacity will also increases[2].

II. MATERIALS AND SYNTHESIS PROCEDURE

In this work , ceramic nanomaterials like zirconia(ZrO_2) and Ceria (CeO_2) are chosen because of their high relative permittivity and good electrical insulating properties. Zirconia and ceria nanoparticles are synthesized by combustion synthesis technique (CS).Combustion method is an easy and convenient method for synthesizing advanced ceramic nano materials. In this technique the desired product is synthesized by self-sustained exothermic chemical reactions at a higher rate due to its own heat release, without taking much energy from furnace. The solution is prepared by reacting zirconium nitrate and cerium nitrate with glycine and distilled water using a magnetic stirrer. The prepared solution is heated up to 150^{o}C for 20 minutes to form clusters. The clusters are calcined using a muffle furnace and finally synthesized nanoparticles are dispersed in to transformer oil using an ultra sonicator. The entire process is shown in the figures 1 and 2.



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Fig.1.Synthesis of Nanoparticles using combustion synthesis.

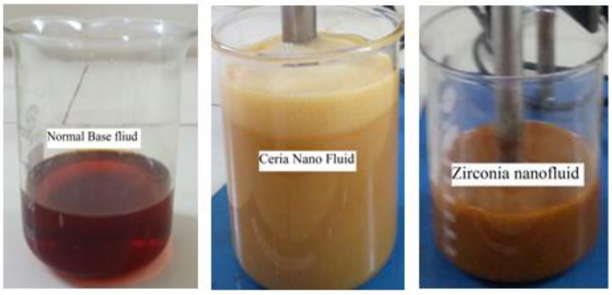

Fig.2.Transformer oil with 05% wt .Ceria and Zirconia of Nanoparticles .

III. CHARACTERIZATION

A. XRD analysis

The X-ray diffraction patterns (XRD) of prepared CeO_2 and ZrO_2nanomaterials were obtained using a diffractometer with Cu target , voltage:40K, current:30 mA producing K_α radiation of wave length $\lambda = 1.5418$ A^o. The XRD of prepared samples are shown in the Figures 3 and 4.

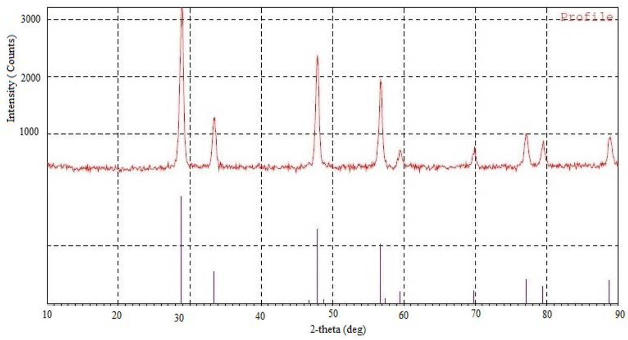

Fig3.CeO2 XRD Pattern .

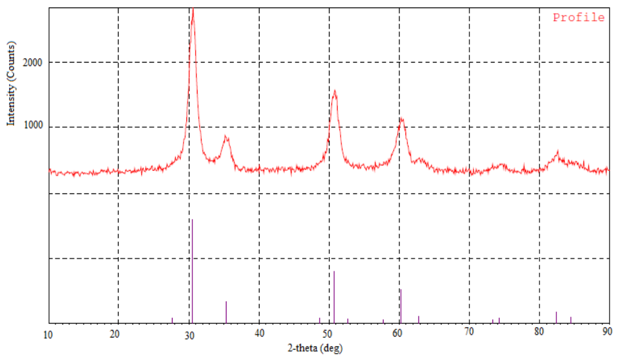

Fig4.ZrO_2 XRD Pattern

The XRD pattern of $CeO_2$and ZrO_2sample resembles with JCPDS file no 75-0076 and JCPDS file no17-0923, also the crystalline size prepared samples is determined using Scherrer formula : $D = \frac{0.94\,\lambda}{B\ Cos\theta}$, where D is the crystalline size in nanometers, B is full width half maxima of maximum intensity peak and θ is the angle corresponding to peak. The size of the CeO_2 and ZrO_2 samples are estimated as 9.114nm and 5.4nm respectively.

B. SEM analysis

To obtain the surface morphology of prepared samples, SEM images of CeO_2andZrO_2nanomaterialswas taken at an operating voltage of 20KV at 25000x magnification are shown in the figures 5 and 6. Porous structure is observed in Ceria and flakes structure is seen in zirconium.

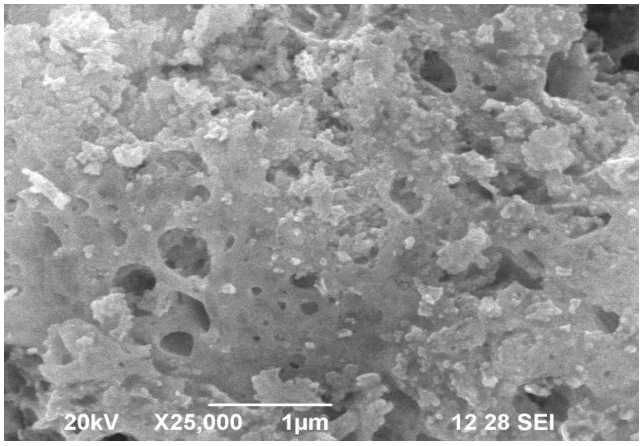

Fig.5.Surface morphology of CeO_2 nanomaterials .

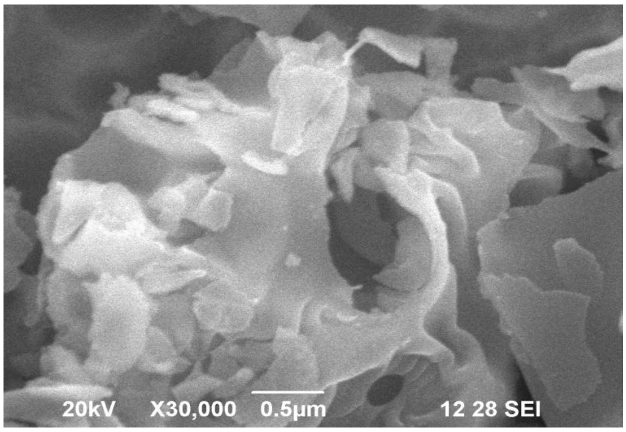

Fig.6.Surface morphology of ZrO2 nanomaterials .

IV. EXPERIMENTAL SET UP

A. **AC Breakdown Voltage**

Dielectric strength of transformer oil is also termed as break down voltage (BDV) where the oil loses its insulating property when subjected to high electrical stress between two electrodes. Minimum breakdown voltage is termed as the point where the transformer oil can be used safely and in general the standard value is considered as 30 KV [4]. A standard BDV measuring instrument shown in the figure 7 which consists of oil beaker in which oil to be tested is filled between two mushroom shaped electrodes separated by 2.5mm gap is used for breakdown voltage measurements. The oil between the electrodes is subjected to electrical stress by applying high voltage at a rate of 2KV/s across the electrodes.

Fig.7.Standard BDV measurement Kit.

0.5% of weight of ceria and zirconia nanoparticles are dispersed in to the transformer oil and dielectric strength of transformer oil filled with ceria and zirconium nanoparticles is experimentally determined using BDV kit in the laboratory .The results are tabulated in the Table II.

Table II: Results of AC Break down Voltage

Samples	Breakdown Voltage (kV)	% Increment
Pure	36.0	-
0.5%wt. CeO_2	50.0	38.88
0.5%wt. ZrO_2	42.0	16.66

V. CONCLUSIONS

In this work, CeO_2 and ZrO_2 based nano transformer oil is prepared using solution combustion synthesis procedure. The breakdown strength of transformer oil filled with 0.5% wt. of CeO_2 and ZrO_2 is measured using standard BDV instrument. Experimental results clearly shows a significant increment in the dielectric strength of transformer oil , 38.88 % for CeO_2 and 16.66% for ZrO_2 nano fillers. Further with this insulating oil, transformer loading capacity will be improved which ultimately increases transformer life time.

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