ORIGINAL PAPER

ICP-MS AND SEM-EDS INVESTIGATIONS OF INSULATING MATERIALS USED IN ELECTRICAL MACHINES

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Abstract. *The insulation of the electric machines represents a main component which can influence the functional parameters. In the past few decades, it has been recognized that the safety margins in the design were excessive and can greatly increase the cost of the rotor and stator. The aim of this study is to investigate two types of insulating materials in order to develop a new material with better properties and longer life time. In this paper, using Inductively Coupled Plasma - Mass Spectrometry (ICP-MS) technique, was investigated the metal content of studied insulating materials in complementary mode with the Scanning Electron Microscopy - Energy Dispersive X-Ray Spectrometry (SEM-EDS) technique.*
Keywords: *insulator, electrical machine, ICP-MS, SEM-EDS.*

1. INTRODUCTION

Accelerated aging of the insulation system of electrical machines may occur due to the different stresses (i.e. thermal, electrical and environmental) that occur during of their operation [1-3]. The main materials used in the construction of electrical machines are conducting materials, magnetic materials and insulating materials [1]. From these three materials, the insulators are very important, because they have the role of dielectric medium, contributes to the mechanical strengthening of conductors parts, as well as in the evacuation of outcomes heat during to the operation in active parts. Insulating materials, lacquers and insulating mixtures, which make up the insulation scheme of electrical machines, must be chosen in according with thermal stresses [3, 4]. The temperature directly affects the life and properties of insulating materials [5] and bearings [6], and affects the efficiency and the magnetic field produced by permanent magnets. Active parts of electrical machines were isolated using materials with insulating properties, such as natural materials (wood, mica, etc.)

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or synthetic (enamels, glass fibers, epoxy resins, pressboard, etc.). Sometimes combined insulations are used (i.e. lacquered glass fiber impregnated with synthetic resin, etc.).

Insulations are chosen depending on the voltage level [6] at which machine working and depending of the thermal class [7] for which is projected. Generally, in the construction of electrical machines, the class temperature of the insulation is given by the insulating materials with the lowest temperature class which are part of the machine scheme [7, 8].

The insulators used for electrical rotating machines may undergo modification of the chemical structure [8] in different operation conditions of the motor. These modifications [9] can occur because the metal ions migrate from the bulk metal to the insulator, or can favor the migration of ions (Fig. 1).

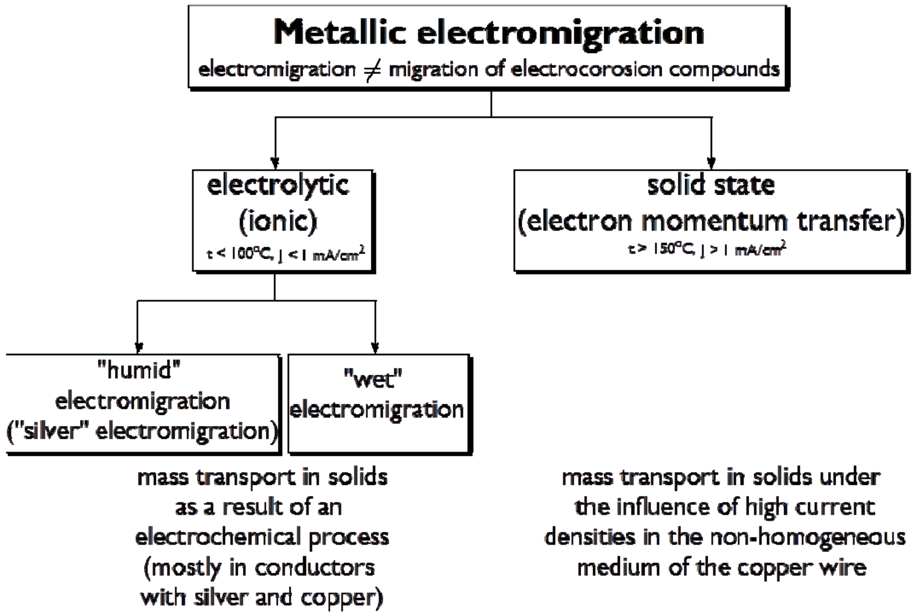

Figure 1. Metallic electromigration from the bulk metal to the insulator.

The insulating materials investigated in these researches were the polyesters, aromatic polyamide saturated with epoxy resins used as lacquer for the copper wires. In this paper, using Inductively Coupled Plasma - Mass Spectrometry (ICP-MS) technique, was investigated the metal content of studied insulating materials used by an electrical machine for three weeks. In complementary mode the Scanning Electron Microscopy - Energy Dispersive X-Ray Spectrometry (SEM-EDS) technique was performed.

2. EXPERIMENTAL PART

Two different types of insulators (aromatic polyamide and polyester film saturated with epoxy resin) have been chosen for this study: Multilayer polyester fiber- MPF and Flexibile 3-ply insulating material of polyester film – FPF (Fig. 2). These insulators were collected before (MPF and FPF) and after (MPF’ and FPF’) being used on electrical machines.

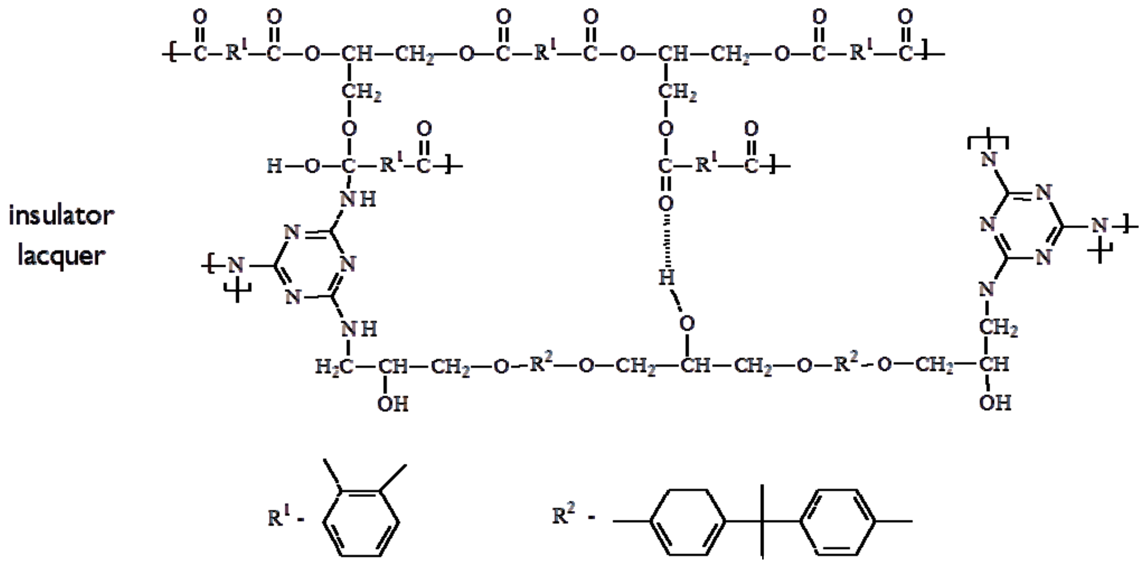

Figure 2. The structural formula of the insulator lacquer.

For ICP-MS measurements the samples were digested on a hot plate with a mixture $HNO_3 : H_2SO_4 = 1 : 1$ by using a TOPwave Microwave-assisted pressure digestion. The digested sample is filtered and diluted to volume (i.e. 50 mL). The analysis and quantification of trace elements including Cu, Pb, Zn, Cr, Cd, Al, Ni, Co, Fe, Mn in liquid mineralized samples was performed by using iCAP™ Q ICP-MS device. Measurement is performed using internal standard and 7 level calibration. Blanks are recorded for each step of the digestion and dilution procedure.

The insulator samples were analyzed before and after being used on electrical machines by SU-70 Hitachi SEM-EDS. For SEM-EDS analysis was not necessary preliminary preparations of samples. The obtained results provided enough information for further analysis.

3. RESULTS AND DISCUSSION

The metal contents of analyzed insulator samples are presented in Fig. 3. With the ICP-MS technique were detected small modifications of concentration of metals in the insulator. Thus is possible due to the mechanism for the electromigration in the insulator (Fig. 1). The concentrations of iron, copper, zinc and lead are the ones that vary the most in the insulating lacquer. The noticeable differences in concentration in the fiber epoxy resin insulator appear at iron, copper and zinc. The polyester insulator has major changes of iron and zinc concentration. These results suggest that the electromigration process, which is a long-term process, starts by transferring metallic ions between the conductor and insulator as a starting phase.

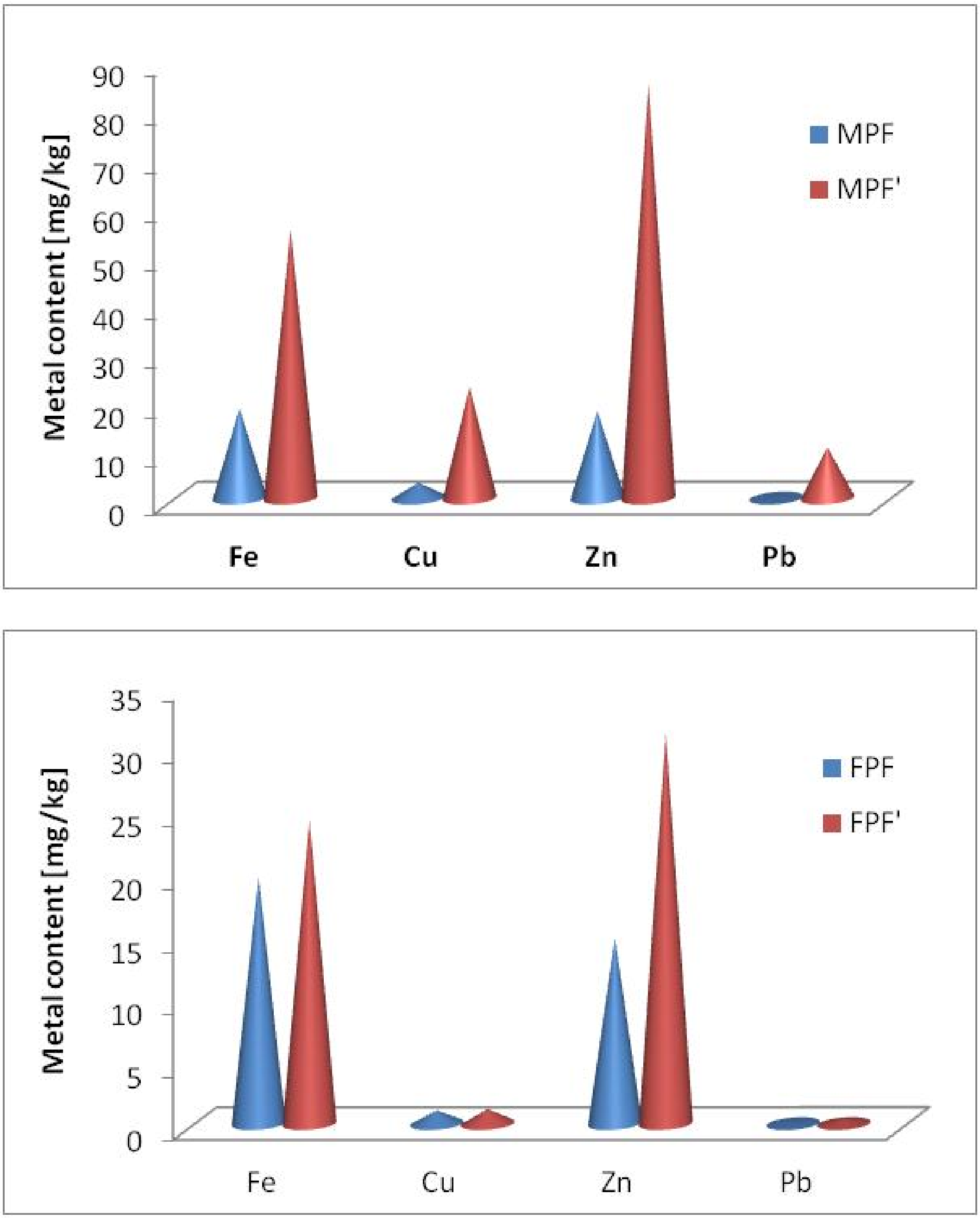

Figure 3. Metal content of analyzed insulator samples.

The obtained SEM images for the insulator samples are presented in Figs. 4 - 7.

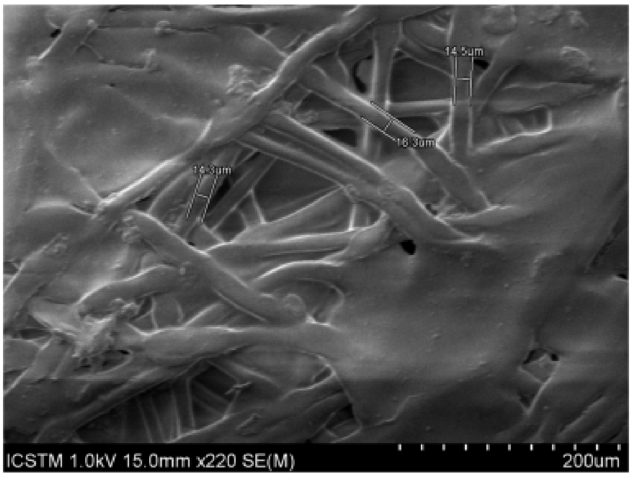

Figure 4. SEM image of MPF sample.

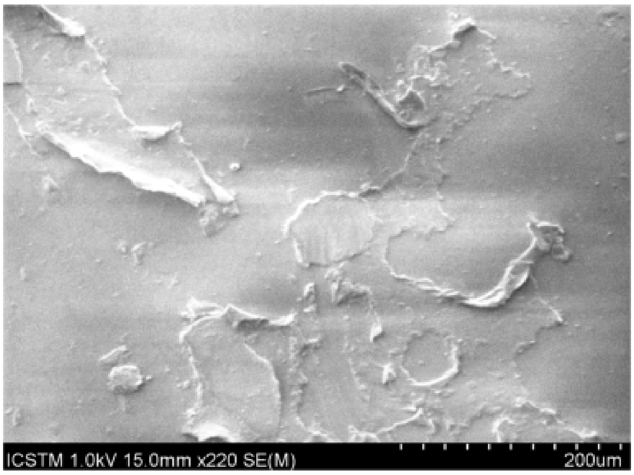

Figure 5. SEM image of MPF' sample.

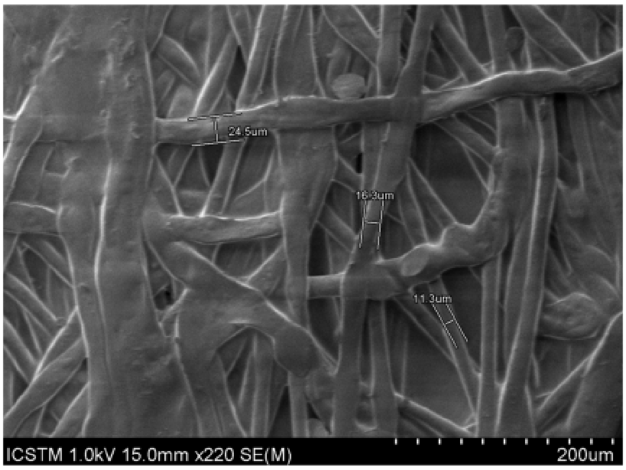

Figure 6. SEM image of FPF sample.

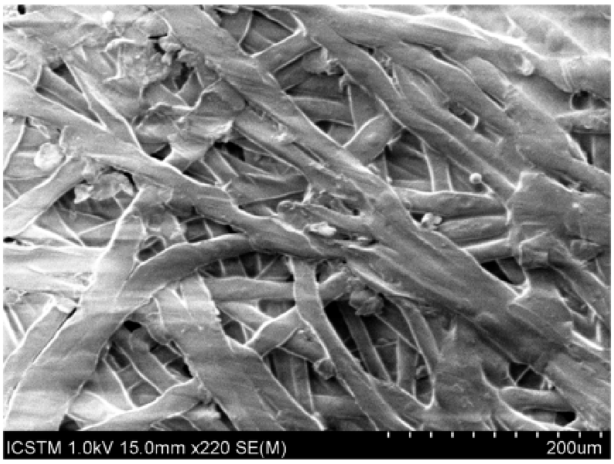

Figure 7. SEM image of FPF' sample.

From SEM images it been noticed that the dimension of the fibers have changed and the structure had become more compact. Considering the fact that insulator samples were used by an electrical machine for three weeks, their behavior is different. MPF fibers became an exfoliated monolayer with an obvious growth in aluminum and oxygen concentration. Also the carbon content is reduced and nickel. On FPF, the layers have remained almost the same and the fibers kept the structure as before.

The samples fibers have changed and the structure had also modified after being used as insulator on electrical machines. For MPF sample, the intensity bands correspond to polyethylene terephthalate and polyester increasing after usage. The behavior of the FPF sample is different for the same intensity bands, considering the fact that isolator samples were used by an electrical machine for three weeks. The MFP sample became an exfoliated monolayer with an obvious growth in aluminum and oxygen concentration, while carbon and nickel content is reduced. On the other side, the FPF sample layers have remained almost the same and the fibers kept the structure as before.

The elemental maps and the elemental content [%] of the analyzed insulator samples obtained by EDS are presented in Figs 8 -11 and Table 1.

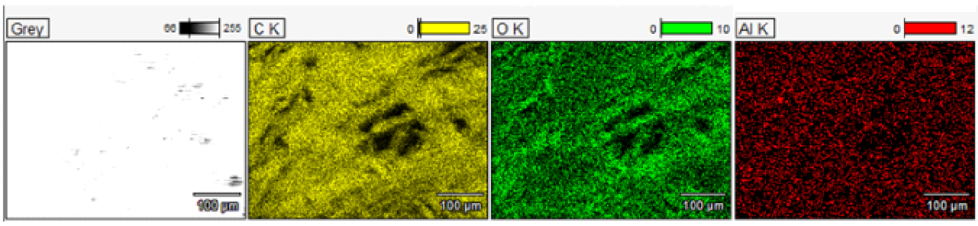

Figure 8. The EDS elemental mapping for MPF sample.

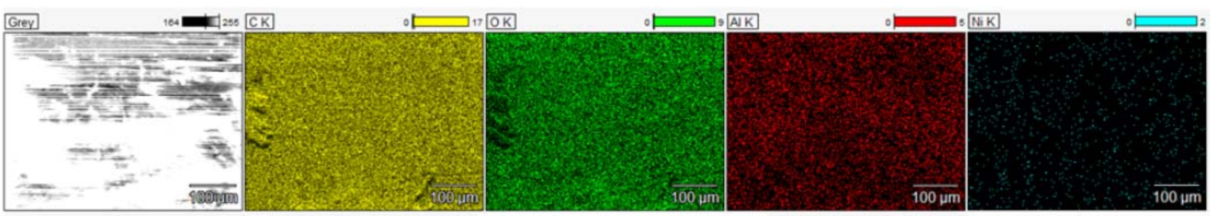

Figure 9. The EDS elemental mapping for MPF' sample.

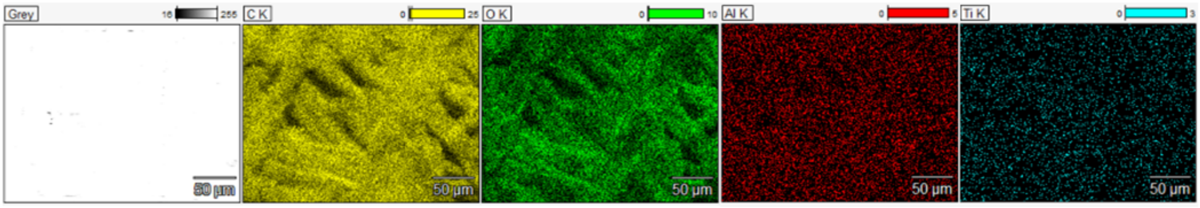

Figure 10. The EDS elemental mapping for FPF sample.

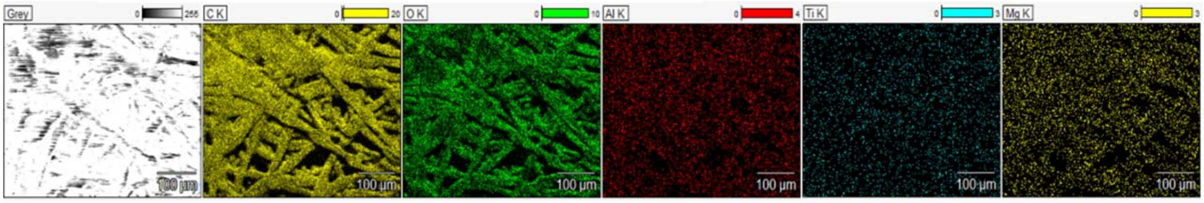

Figure 11. The EDS elemental mapping for FPF' sample.

Figs. 8-11 show several uniform distributions of elements on the surface of studied insulator samples. In sample MPF' is observed the nickel migration (comparative with sample MPF), while in sample FPF' (comparative with sample FPF) the magnesium migration is remarked.

Table 1. Elemental content [%] of analyzed insulator samples by EDS.

Element	MPF	MPF'	FPF	FPF'
C [%]	65.27 ± 0.30	57.67 ± 0.26	61.16 ± 0.28	60.23 ± 0.29
O [%]	34.22 ± 0.23	41.83 ± 0.26	38.62 ± 0.23	39.37 ± 0.26
Mg [%]	nd	0.03 ± 0.01	nd	0.03 ± 0.01
Al [%]	0.11 ± 0.01	0.33 ± 0.01	0.07 ± 0.01	0.10 ± 0.01
Ti [%]	nd	nd	0.06 ± 0.01	0.11 ± 0.01
Ni [%]	nd	0.07 ± 0.02	nd	0.09 ± 0.01

4. CONCLUSIONS

Two different types of insulators (aromatic polyamide and polyester film saturated with epoxy resin) have been investigated in this study: Multilayer polyester fiber and Flexibile 3-ply insulating material of polyester film. These insulators were collected before and after being used on electrical machines. In this respect two techniques were performed Inductively Coupled Plasma - Mass Spectrometry (ICP-MS) and Scanning Electron Microscopy - Energy Dispersive X-Ray Spectrometry (SEM-EDS). The results show that the behavior of insulator materials used by an electrical machine for three weeks is different.

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