# MODIFICATION OF ELECTROMAGNETIC PROPERTY OF COPPER COATED MILIFE FABRICS

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## Abstract

In this study, milife fabrics (polyester nonwoven fabrics) were used. Three common silanes including octyltriethoxysilane, phenyltriethoxysilane and tetraethoxysilane have been prepared by sol-gel technique to treat the milife fabrics with and without copper coating. The main aim of the study is to protect the conductive copper layer of the milife fabric by the silanization proces. Surface morphology have been measured by scanning electron microscope to prove the deposition of silane, surface roughness was measured by confocal microscope and electromagnetic shielding effectiveness (EMI) have been tested to prove the change in EMI values with respect to silane coating. From the results, it was obvious that EMI of the copper coated milife treated with phenyltriethoxy silane ranging from 40 to 50 dB increases about 80 % of the values of copper coated milife compared to other two silane coatings. In addition, SEM showed that deposition of silane on the fabric surface depending on the different types of silane used for the sol-gel coating.

**Keywords:** Electromagnetic, silane, coating, milife fabrics, copper, modification

## 1. INTRODUCTION

Sol-gel coating is one of the most important emerging technology in textile industry due to its many advantages such as highly effective, adjustable coating thickness, good coating durability, easy combination with various functions and less environmental impacts. Typically, metal oxides starting from a colloidal solution (sol) that acts as the precursor for an integrated network (or gel) of either discrete particles or network polymers are used for the fabrication of materials. Typical precursors are metal alkoxides and metal salts (such as chlorides, nitrates and acetates), which undergo various forms of hydrolysis and polycondensation reactions. Both in liquid and solid phase contained in the formation of a gel-like diphasic system are evolved by the 'sol' in this chemical procedure whose morphologies range from discrete particles to continuous polymer networks. A significant amount of fluid may need to be removed initially for the gel-like properties to be recognized in the case of the colloid, due to slow volume fraction of particles (or particle density) which can be accomplished through a number of ways. The method which is simple is to allow time for sedimentation to occur and then pour off the remaining liquid. A drying process is required in the removal of the remaining liquid (solvent) phase which is typically accompanied by a significant amount of shrinkage and densification. The distribution of porosity in the gel determines the rate at which the solvent can be removed. During this phase of processing, changes imposed upon the structural template will strongly influence the microstructure of the final component [1-4]. In a single precursor component system, interconnected nanoscale porosity can be designed to the final material and hence a high surface area, it depends upon the precursors used and the solvent employed [4,5-7]. For thin films and coatings, the process of sol-gel is accepted as a technology. An alternative to chemical vapour deposition, sputtering, and plasma spray is the sol-gel process. It is shown that sol-gel thin films to be technically sound alternatives and to be commercially viable. For over 30 years, the technology of sol-gel thin films has been used and the process is quite simple. With a solvent and water, a solution containing the desired oxide precursor is prepared and is applied to a substrate by spinning, dipping or draining. Even though most needed to be calcined and densified with heating [8-16], coatings can be at room temperature. As a method to deposit the functional materials to different materials, sol-gel coating was widely used in textile field by many researchers [10,14,15,17]. One of the great advantages of this technique is the possibility of producing transparent, porous solids at a low processing temperature. In order to develop microporous matrices which are excellent hosts for organic dopants, organically modified silica (organosilica) can be processed through the sol-gel method [17-20].

## 2. EXPERIMENTAL PROCEDURE

### 2.1. Materials

Milife fabric (100 % polyester nonwoven fabrics) with or without copper coating have been used for this study. Three types of precursors, octyltriethoxysilane (OCTYL), phenyltriehoxysilane (PHENYL), and tetraethoxysilane (ORTHO) were selected for silane coating. All the silanes were purchased from Sigma-Aldrich, USA. Triacetoxyvinyl silane and nitric acid were used as catalyst, ethanol and deionized water was used for the preparation of sol solutions. The sample description is given in **Table 1**.

**Table 1** Sample description of nonwoven fabrics

| Type of fabric | Sample code | Fabric conditions | Thickness (mm) | | Fabric density (g.m$^{-3}$) | |
|---|---|---|---|---|---|---|
| | | | ***Mean*** | ***CV%*** | ***Mean*** | ***CV%*** |
| Milife | A | Copper coated | 0.110 | 06.42 | 38.88 | 1.68 |
| | B | Without Copper coated | 0.072 | 11.62 | 11.12 | 4.33 |

### 2.1.1. Silica sol-gel synthesis and coating

The silica sols were prepared by mixing different precursors with catalyst and solvent, the mixing can be done with proper proportion of silane, catalyst, water and solvent by 32:1:100:320 molar ratios respectively. Many studies could be conducted to optimize this proportions. The mixture was stirred until a clear solution was obtained when the crystals of the catalyst was dissolved. Later, the deionized water was added to the above mixture by using the syringe pump at the speed of 1 mL.h$^{-1}$. Triacetoxyvinyl silane can be used as catalyst in terms of OCTYL and PHENYL coating (it has the dual functions like a catalyst, certainly it will be the third precursor) because it slowly releases the acetic acid during the hydrolysis reaction and ensures to avoid the rapid hydrolysis, whereas $HNO_3$ has been used for preparing the sol with **Tetraethoxy silane.** The solution was continuously stirred for 24 hours at room temperature to allow the complete hydrolysis of precursors. The fabrics were dried in atmospheric condition and then cured at 110 °C for 10 minutes. Before measurement, the coated fabric was left in atmospheric condition for 24-48 hours to ensure complete stabilizing of the silica matrices.

### 2.2. Methods

The surface morphology of control and sol-gel coated fabrics were observed by using TS5130 Vega-Tescan scanning electron microscope (SEM). Laser scanning confocal microscope (LSCM analysis of copper coated fabric, Olympus OLS 3100 model laser scanning confocal microscope was employed to measure surface properties of control and coated fabrics. Surface roughness and other related properties were calculated according to the ISO 4287:1997 standard. Infrared thermography measurement was conducted by using thermal camera. A vertical hot plate maintained at constant temperature around 40˚C was used as heat source, the specimen was flatly attached onto the hot plate with the help of a frame tool, and after 2 min thermal images were taken by thermal camera at a distance of 40 cm from the hot plate. The room temperature was kept at 25 ± 2°C. A thermal image reveals the amount of radiation emitted by the heat plate through the fabric. The thermal insulation value can be computed via the following equation (1);

$$I = \left( \frac{B - F}{B - R} \right) \tag{1}$$

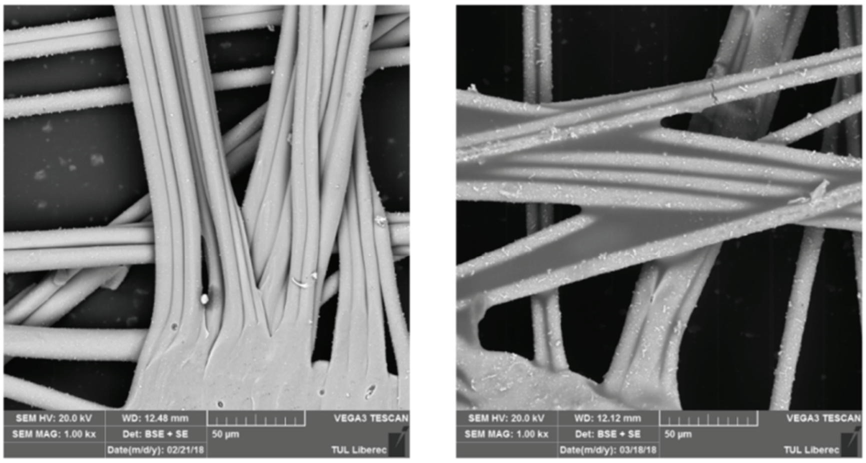
where *B*- Instrument temperature (i.e. 40 °C), *F*- Fabric temperature, *R*- Room temperature.

The electromagnetic (EM) shielding effectiveness (SE) of the samples was measured according to ASTM D4935 -10 standard for the planar materials. Surface resistance and volume resistance of the samples have been measured by using concentric electrodes (applied pressure 2.3kPa) under a 100V direct current (DC) power supply, according to standard ATSM D257 -07. This standard is intended for insulating samples and it was chosen due to the wide sample set containing insulating, semi-conductive and conductive samples allowing a comparison of the results.

## 3. RESULTS AND DISCUSSION

### 3.1. Surface morphology of sol-gel coated fabric

The surface of coated and uncoated fabric samples was observed using SEM. **Figure 1** shows the surface morphologies of sol-gel coated fabrics with different silane coating. It is apparent from the micrographs that a thin film was formed on the coated fabric surface and the film formation is significantly depending on the type of silane used for the sol-gel coating. In fact, each fiber is covered with a continuous layer of sols, these layer formation on the fiber surface confirmed that the copper coated fabric has been protected through sol-gel coating techniques.



(a) (b)

**Figure 1** Impact of silanization on the copper coated milife fabric;
(a) before sol-gel coating, (b) after sol-gel coating (PhTES)

From the figure, it can be seen that the sol-gel coating made significant changes in the surface by creating the roughness, also the surface roughness depends on the type of silane used. In this study, sols prepared with phenyl and ortho based silane creates more roughness than the sols prepared with octyl alone, which is due to the chemical groups presented in the silane and its structure. However, octyl having the flexible long alkyl chain groups provided the significantly less roughness. Meanwhile, phenyl has benzene groups which make more roughness on the network, therefore, it produces more roughness as well as it reduces the physical properties of coated materials. **Table 2** shows the roughness characteristic of the fabric before and after coating. In overall, numerical values showed the drastic changes in the peak height (Rp), depth valley (Rv) and the addition of both parameters (Rz). As a result, the highest numerical value indicates the more roughness, and thus significant changes in the surface roughness.

**Table 2** Surface roughness characteristics of milife fabrics

| Sample | Type of fabric | Max. Peak height (Rp) (µm) | Max. Valley depth (Rv) (µm) | Max. Depth (Rz) Rz=Rp+Rv (µm) |
|---|---|---|---|---|
| **Control** | Milife | 0.92 | 0.44 | 1.36 |
| | Milife (CU-coated) | 1.22 | 1.18 | 2.4 |
| **Octyl** | Milife | 1.1 | 1.65 | 2.75 |
| | Milife (CU-coated) | 0.65 | 1.62 | 2.27 |
| **Phenyl** | Milife | 1.45 | 1.68 | 3.13 |
| | Milife (CU-coated) | 3.21 | 2.54 | 5.75 |
| **Ortho** | Milife | 0.65 | 1.28 | 1.93 |
| | Milife (CU-coated) | 3.8 | 4.21 | 8.01 |

### 3.2. Electromagnetic shielding effectiveness

**Figures 2 to 5** shows the dependence of the EM SE in dB on the whole measured frequency range for all the samples. **Figures 2 and 4** shows the SE of milife samples coated with copper. It is found that the control sample exhibits a certain SE performance and the values gradually decrease with the increasing frequency. The SE of milife samples containing copper coated with phenyltriethoxysilane silane roughly doubles that of control samples, and its downward trend with increasing frequency slows down. Oppositely, with increasing frequency, SE has a downward trend for both the octyltriethoxysilane-coated milife samples containing copper and the tetraehoxysilane-coated milife samples, SE of the former gets around 0 dB at 1.5 GHz. In **Figures 3 and 5**, the reflection of milife samples coated with copper have closer values at the beginning. Only the reflection of samples treated with octyl silane gets increased with increasing frequency.

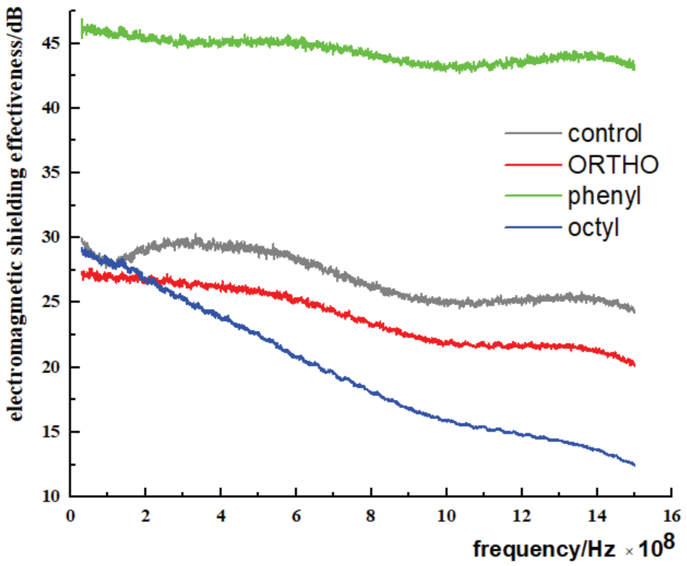


**Figure 2** EMI of Milife coated with copper (total electromagnetic shielding effectiveness)

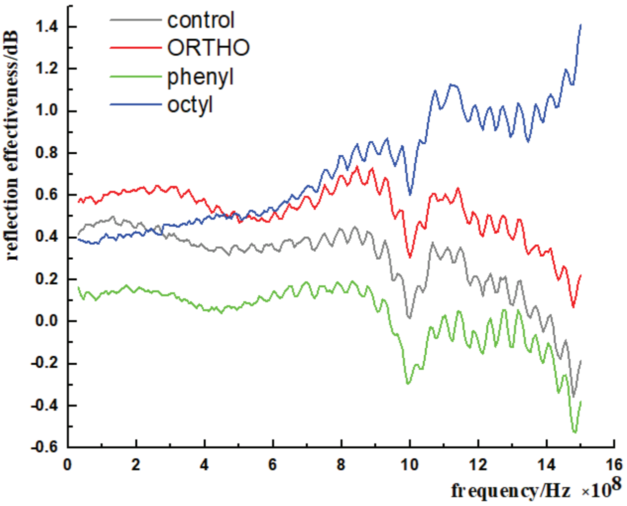


**Figure 3** EMI of Milife coated with copper (reflection shielding effectiveness)

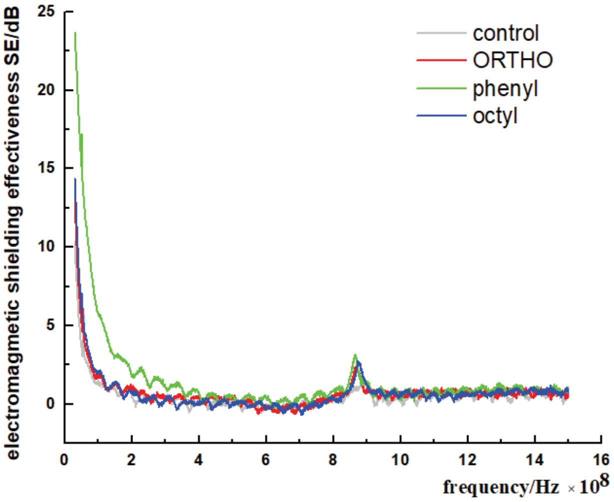


**Figure 4** EMI of Milife (total electromagnetic shielding effectiveness)

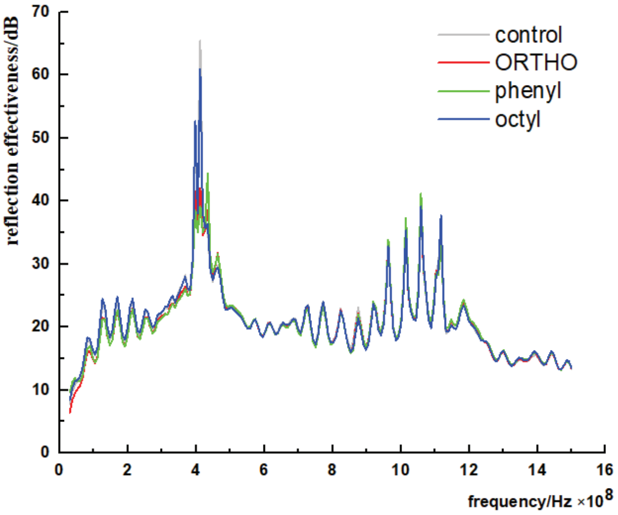


**Figure 5** EMI of Milife (reflection shielding effectiveness)

## 4. CONCLUSION

From this study, it can be concluded that the conductive copper layer of the milife fabric can be protected by silanization process. The results from surface morphology and surface proved the deposition of silane coating and the roughness factor of the different silane coating had an adverse effect on the copper coated milife fabrics. Electromagnetic shielding effectiveness (EMI) of phenyltriethoxy silane coated fabrics have the highest value of total shielding effectiveness ranging from 40 to 50 dB increases about 80 % of the values of copper coated milife compared to other two silane coatings.

## ACKNOWLEDGEMENTS

***This work was supported by the Ministry of Education, Youth and Sports of the Czech Republic and the European Union - European Structural and Investment Funds in the frames of Operational Programme Research, Development and Education - project Hybrid Materials for Hierarchical Structures (HyHi, Reg. No. CZ.02.1.01/0.0/0.0/16_019/0000843).***

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