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Metal-containing coatings on textiles – concepts and properties

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ABSTRACT*:* Metal-containing coatings on fabrics are presented using two concepts that involve the application of metal fibers or platelet-shaped pigments. Metallic properties, such as electrical conductivity or antimicrobial effectiveness, can be successfully transferred to the textile material. In addition to the introduction of metallic properties, the coating also significantly changes the look and feel of the treated fabric. The use of platelet pigments in particular leads to an attractive appearance, which can also be aptly described as a "metallic coating".

KEYWORDS: Metal pigments, coatings, Electro-smog, shielding, Antimicrobial.

1. INTRODUCTION

The purpose of metal-containing coatings on textiles is, in principle, to transfer metal properties to fabric. The possible areas of application for such metal-coated functional textiles are diverse and can often be directly assigned to the newly transferred properties. Electrically conductive textiles can be used as antistatic materials or in components of intelligent clothing [1,2]. Reflective properties (metallic lustre) can be used to create an attractive metallic appearance. The combination of good reflectivity with electrical conductivity can result in a shielding property against electromagnetic waves in the radio wave, microwave and infrared light range, enabling products with applications in electro-smog reduction and heat reflection [3]. Shielding from cell phone radiation could be considered, for example. The increased reflection of heat radiation from metallized textiles should allow applications in the area of thermal protection, e.g. in work clothing or as home textiles such as blinds or curtains.
Another property that is often transferred to tissues through metallization is the antimicrobial effectiveness against bacteria, fungi and algae. The antimicrobial property of metals is also described as an oligodynamic effect and varies significantly depending on the type of metal. Sometimes the metals are classified in the oligodynamic series with increasing effectiveness [4].
Silver, copper and their compounds are particularly noteworthy for producing antimicrobial properties on textiles. This will have outstanding position due to the high antimicrobial effectiveness combined with low human toxicity [5-7]. Antimicrobial textiles are often used in the supportive therapy of diseases. An example of this is the use of silver-plated special textiles in the treatment of neurodermatitis, whereby the textile counteracts secondary infections on neurodermatitis-damaged skin [8]. Other applications can be found in supportive prevention of diabetic feet or in antimicrobial wound care systems [9, 10]. This article is intended to introduce textile coatings with metal components; essentially, two concepts are compared that are suitable for producing metallized fabrics. The first concept using metal threads consists of combining conventional pigments made of graphite and copper together with metal threads in a silicone coating. The second concept using platelet pigments includes platelet-shaped metal pigments fixed with a polyurethane binder.

II. LITERATURE SURVEY

Electro-smog, often referred to as electromagnetic pollution or EMF (Electromagnetic Fields) pollution, is a growing concern in our technologically advanced world. Electro-smog originates from various sources, including power lines, wireless communication devices (cell phones, Wi-Fi routers), and electrical appliances. It encompasses different types of electromagnetic radiation, such as Extremely Low Frequency (ELF) radiation from power lines and radiofrequency (RF) radiation from wireless devices.

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Numerous studies have explored the potential health effects of electro-smog exposure. While some research has suggested possible links between long-term exposure to EMFs and adverse health outcomes, the evidence remains inconclusive. Health concerns often revolve around increased cancer risk, reproductive problems, and neurological effects. Organizations like the World Health Organization (WHO) have classified RF electromagnetic fields as "possibly carcinogenic to humans". Various measures can be taken to reduce exposure to electro-smog, such as using electrically conductive material that can effectively conduct and ground the electromagnetic waves. Electro-smog is a complex and evolving area of research that touches on various aspects of modern life, from technology usage to public health concerns. While some studies suggest potential risks associated with exposure to electromagnetic radiation, further research is needed to establish conclusive evidence and provide clear guidelines for minimizing these risks. Public awareness and responsible technology usage are crucial in addressing the challenges associated with electro-smog.

III. MATERIAL AND METHODS

For the first concept, graphite and copper pigments are combined with stainless steel fibers in a silicone coating applied to polyamide fabric along with Elastosil, crosslinker from Wacker Chemie as a sealer and crosslinker between the fabric and proposed silicone-metal complex coating. Reference samples are prepared to contain only silicone coating. For the second concept, platelet-shaped metal pigments from Eckardt viz silver-plated copper, copper and aluminium are being used [11]. Applications can made with polyurethane binders on polyester or cotton fabric.
Microscopic examinations of the coating surface are carried out using a reflected light microscope from Keyence and a scanning electron microscope from Hitachi (TM-3000). In order to achieve sufficient material contrast with the electron microscope, the samples are not sputtered before the SEM examinations. In parallel to the electron micrographs, additional EDX measurements for element analysis are carried out using an EDX unit from Bruker. The antimicrobial properties are tested against E.coli bacteria. The reduction in bacterial viability is determined by the reduction of methyl thiazolyl-diphenyl tetrazolium-bromide (MTT) [12, 13]. For reference, the same measurements are carried out with non-coated fabric or without any finishing. The conductivity of treated material is determined using a four-point conductivity measuring device. A transmitter-receiver setup is used to estimate the shielding ability against radio waves (transmitter: 446MHz, power 500mW // receiver: Aaronia, model Spectran, measuring range 10MHz to 8 GHz) [14].

IV. RESULTS AND DISCUSSION

A. CONCEPT NO.1 – METAL THREADS

With this concept, copper pigments and metal fibers made of stainless steel are fixed to fabric through a silicone coating. The copper pigments show the formation of larger agglomerates, which are enclosed in the silicone matrix. Higher concentrations of metal fibers cause the fibers to protrude from the coating and form an irregular surface, the feel of which could also be described as “flock-effect”.

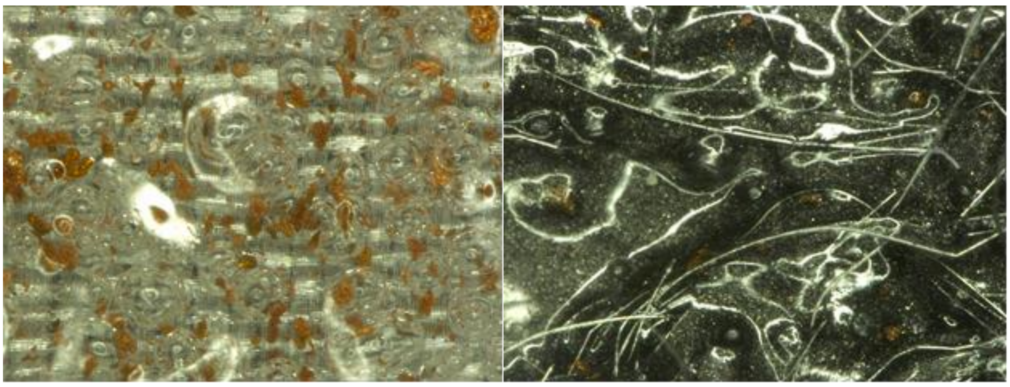

Figure 1: optical microscope image of the silicone coating with 10% copper content on polyamide fabric (left) and with 10% graphite, copper and steel fibers on polyamide fabric (right)

Using a scanning electron microscope and EDX, it can be confirmed that the metal fibers are embedded in the silicone coating and another part protrudes from the coating. Some of these protruding fibers are themselves covered by a silicone layer. However, in other places the stainless steel fibers are free of a silicone coating. These areas stand out in Figure 2 due to their higher contrast and brightness. EDX provides additional evidence here, with which the elemental composition of the sample surface can be reproduced and the metals iron, chromium and nickel are attributed to the stainless steel fibers. However, the copper pigments embedded in the silicone matrix cannot be detected on the sample surface using EDX and should therefore be completely enclosed in the silicone coating.

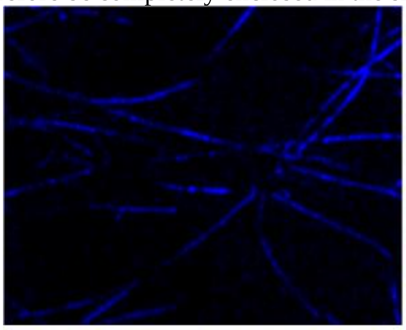

Figure 2a

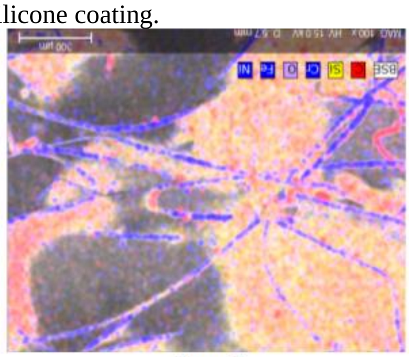

Figure 2b

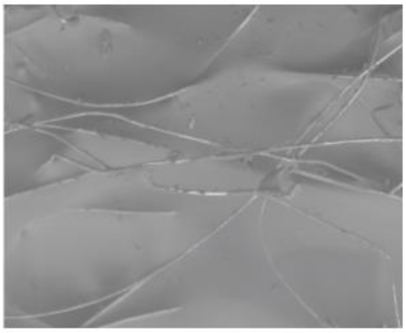

Figure 2c

Figure 2: Electron microscopic image of a silicone coating with embedded steel fibers (a & b) and, in comparison, the elemental composition on the sample surface determined with EDX (c).

Antimicrobial properties against E.coli could not be demonstrated for this sample type. Due to the copper component present, it should be expected to have an antimicrobial effect. However, the copper pigments are entrapped in the silicone matrix, which means they are not accessible to micro-organisms.

The samples show a clear difference depending on the layer composition with regard to electrical conductivity and the ability to attenuate radio waves (Figure 3). The measuring arrangement used shows a reduction in radio waves of around 10% to 15% due to uncoated polyamide fabric and the silicone-coated polyamide fabric, respectively. In the measurement setup used, such values are common for textiles and nonwovens without electrically conductive components [14]. The addition of conductive pigments made of graphite or copper or a mixture of these leads to a significant reduction in radio wave transmission. However, a higher reduction can only be achieved with the proportionate addition of stainless steel fibers, as is found, for example, for nonwovens with antistatic properties (e.g. Needlona ExCharge - products with stainless steel fibers from BWF) [14]. The introduction of steel fibers seems to be necessary for the higher shielding effect, as they contact the conductive centers to form a coherent network or grid.

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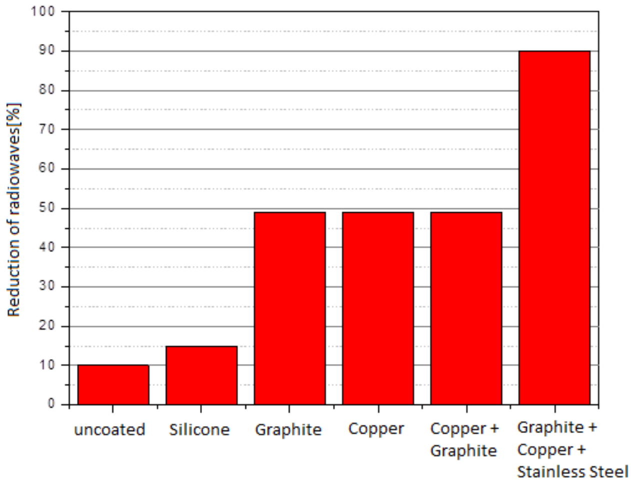

Figure 3: Reduction of electromagnetic radiation in the radio wave range through uncoated polyamide fabric and a comparison of polyamide fabric with various modified silicone coatings. The loading level with the various additives amounts to a total of 10%.

B. CONCEPT NO.2 – PLATELET PIGMENTS

Metallic platelet pigments can be applied to cotton and polyester fabrics using polyurethane binders. The appearance of the fabrics coated in this way is strongly influenced by the metallic properties of the applied pigments. At higher pigment concentrations (>5%), one can speak of an attractive "metallic look" (Figure 4), the colour nuance of which is determined by the embedded metal. The use of copper platelets results in a strong copper-red colour, while the silver-plated copper platelets only result in a light red tone.

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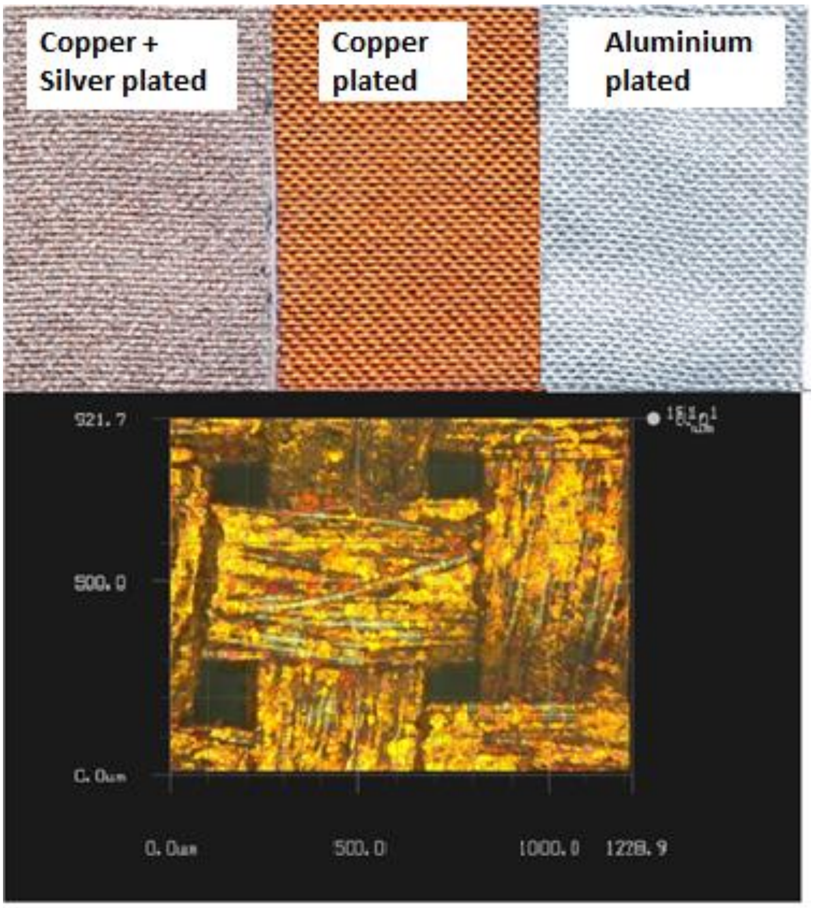

Figure 4: Polyester fabric with different types of platelet pigments, along with an optical micrograph of the sample with copper pigment.

The scanning electron microscope shows a good contrast between the bright metal particles and the darker fabric tissue. With this method, the metal particles cause the emission of a higher number of back-scattered electrons and therefore appear brighter than the textile fibers consisting of the elemental oxygen (O) and carbon (C) (Figure 5). Additional information about the metal pigment distribution is provided by the EDX, which shows the distribution of the elements carbon (for the polyester fiber) and copper (for the pigment). However, the distinction from the element oxygen is less useful, as some copper pigments have partial oxygen content. This oxygen content on the copper pigments could be interpreted by partial oxidation of the pigment surface. Overall, both microscopic methods used show that the degree of coverage of the textile fabric increases with the concentration of platelet pigments. However, the platelet pigments used here do not achieve complete coverage of the textile surfaces even when using the highest pigment concentration of 20% (Figures 4 and 5). To achieve the metallic look, it is not necessary to completely cover the fabric with the pigments.

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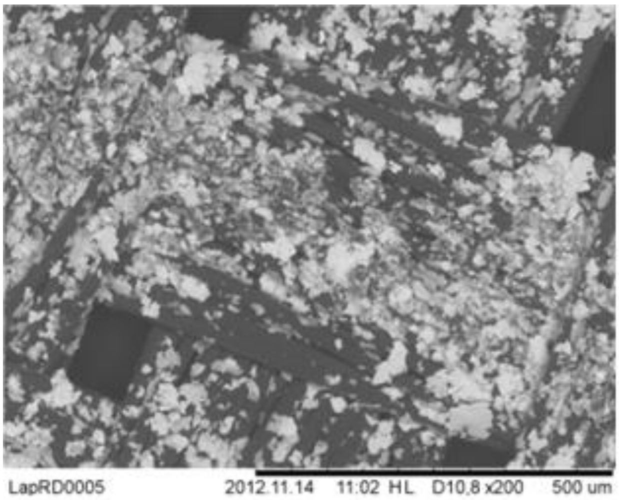

Figure 5a

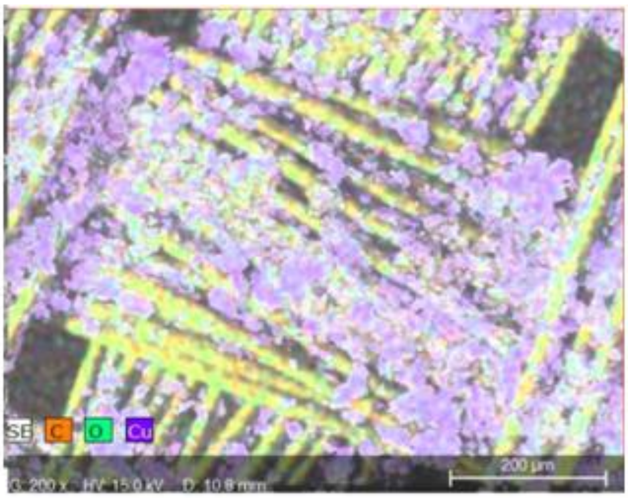

Figure 5b

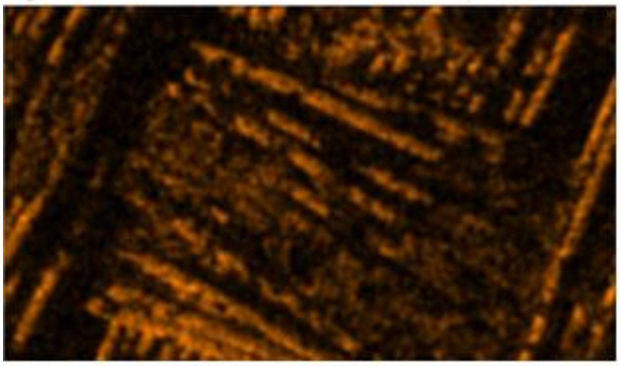
Figure 5c

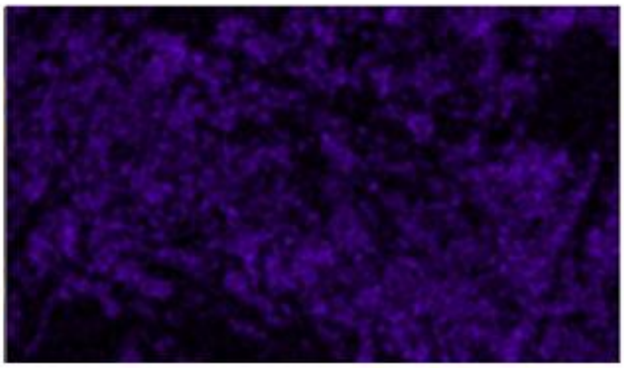
Figure 5d

Figure 5: Electron microscopic image of copper and graphite platelet pigments on polyester fabric (5a), EDX analysis of the pigment plated polyester fabric (5b) and in comparison, the elemental composition on the sample surface determined for graphite (5c) and copper(5d) with EDX.

The antimicrobial effectiveness of these coated fabrics is determined by the type of platelet pigment used and its concentration (Figure 6). The effectiveness is determined as a reduction in the viability of the bacterium E. coli compared to uncoated reference fabrics. The effectiveness of the copper-containing pigments is already achieved with a low pigment concentration. As expected, a further reduction in bacterial viability can be observed for increasing the pigment concentrations. What is unexpected, however, is that for almost all similarly produced coatings, the use of pure copper pigments results in a higher antibacterial effectiveness compared to preparations with silver-plated copper pigments. This is particularly notable since silver materials are usually considered (even when arranged within the oligodynamic series) to be the more potent antibacterial agent compared to copper. In contrast, the antibacterial effect of the aluminium-containing samples is, as expected, low and only appears weak at high concentrations of aluminium pigment.

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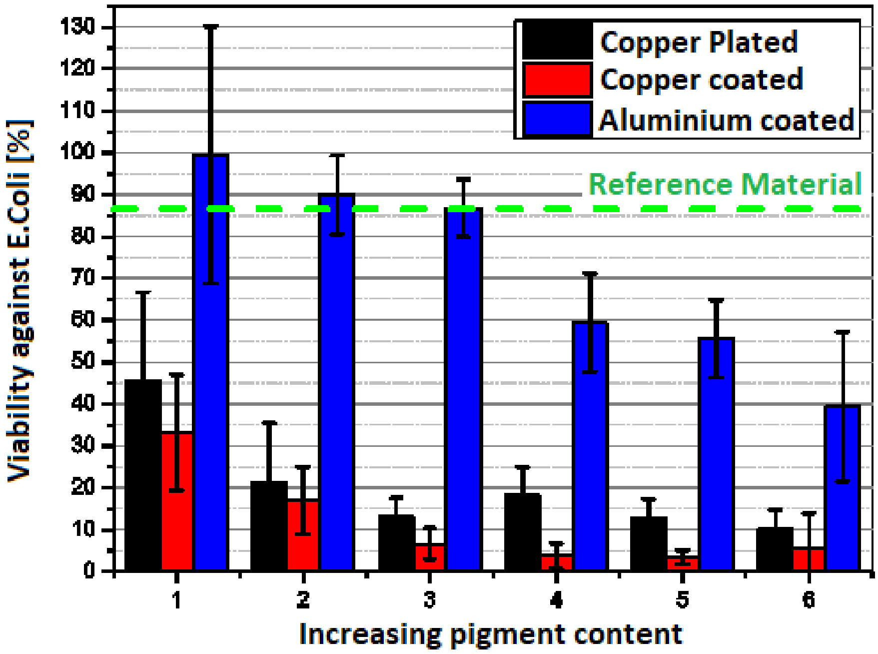

Figure 6: Antimicrobial effectiveness of platelet pigments on cotton. The remaining viability of E. coli after contact with the samples with increasing proportion of pigment up to a maximum proportion of 20 wt% is shown. Untreated cotton was used as a reference material - remaining viability 88% +/- 4%. The blank sample without tissue sample shows a viability of 98% +/- 32.

V. CONCLUSION

Using two preparation methods, the properties and possibilities of metal-containing coatings on textiles are shown. The transfer of various metal-typical properties to conventional textiles can be impressively demonstrated in further experiments.

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