



## INFLUENCE OF ZINC OXIDE ON THE ELECTRICAL CONDUCTIVITY OF PRINTED ANTIMICROBIAL FABRICS

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**Abstract:** Linen fabrics are printed on a screen printing semi-automatic machine S-300. The printing is done with a modified alginate pasta with addition of *Pinus sylvestris* L. alcohol extract and Zinc oxide. The antimicrobial activity of printed linen fabrics against *Escherichia coli*, *Staphylococcus aureus* and *Candida albicans* are examined. Antimicrobial activity against *S. aureus* is observed in samples printed with alginate pasta modified with *Pinus sylvestris* L. Electrical conductivity is measured using a HAMEG LCR bridge in the frequency range from 24 Hz to 125 kHz at room temperature. The main result of this study is that the addition of zinc oxide to the alginate paste of printed linen fabrics shows an increase in the electrical conductivity as well as antimicrobial activity against *S. aureus*.

**Keywords:** Antimicrobial linen fabrics, Electrical conductivity, Dielectric properties, Fabrics, Herbal extract of *Pinus sylvestris* L, Zinc oxide.

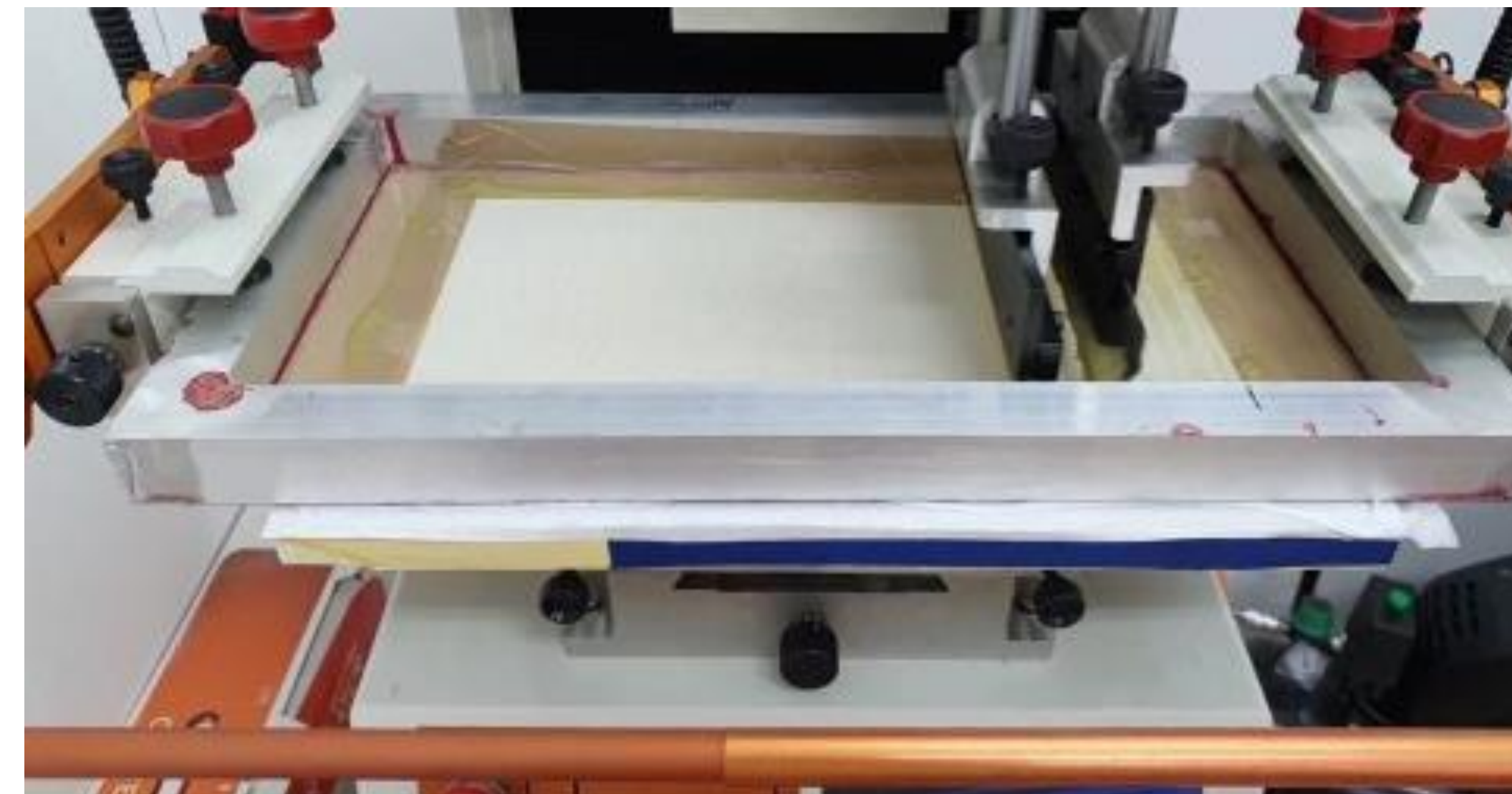


Figure 1. Printing process.



Figure 2. Experimental setup for a measuring of the dielectric properties of fabrics.

### RESULTS AND DISCUSSION

#### Dielectric Spectroscopy

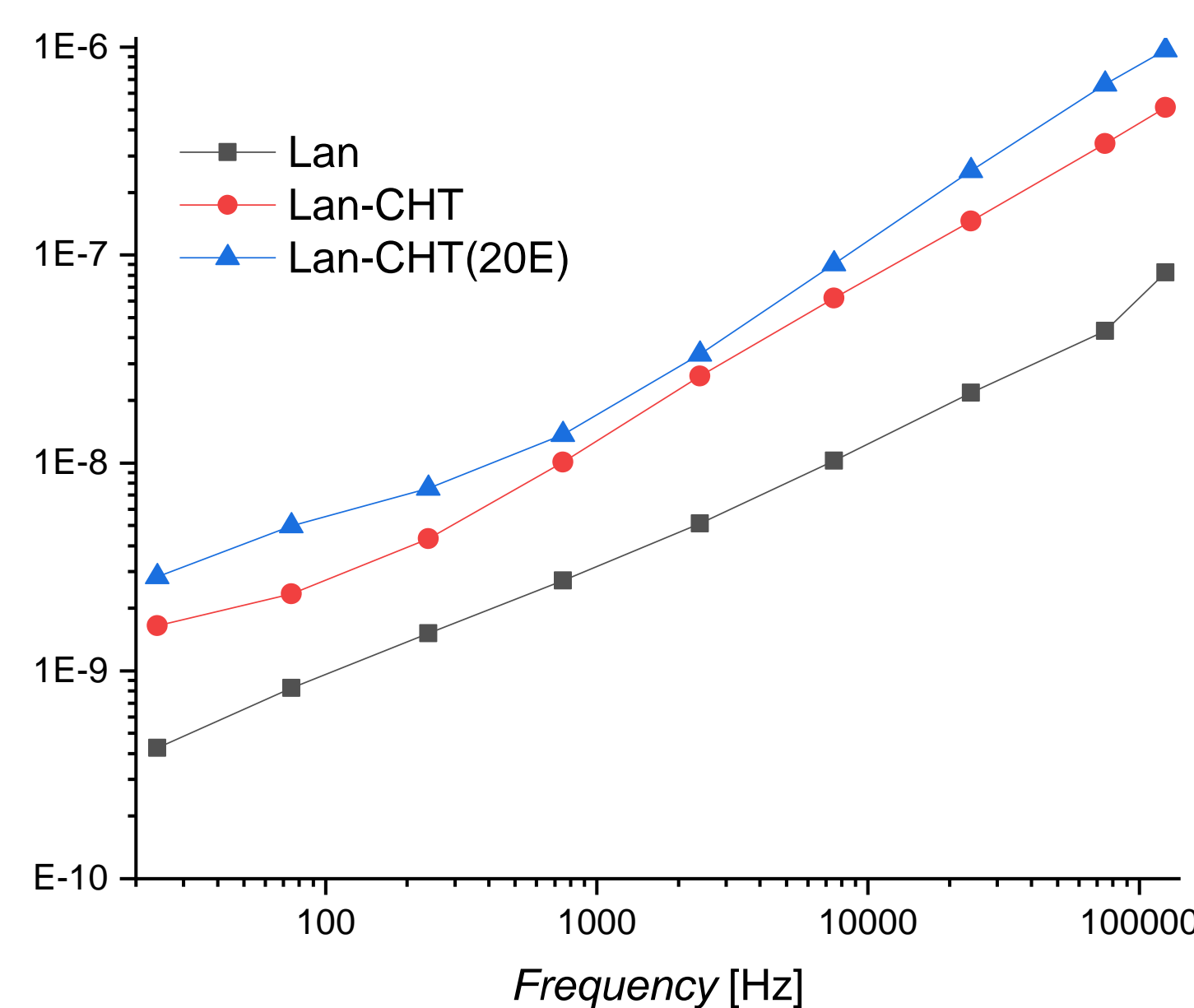


Figure 3. Specific conductance versus frequency in frequency range from 20 Hz to 125 kHz for pure linen sample (Lan), linen sample modified by CHT-NV (Lan-CHT) and linen samples modified by CHT-NV and extract *Pinus sylvestris* L.

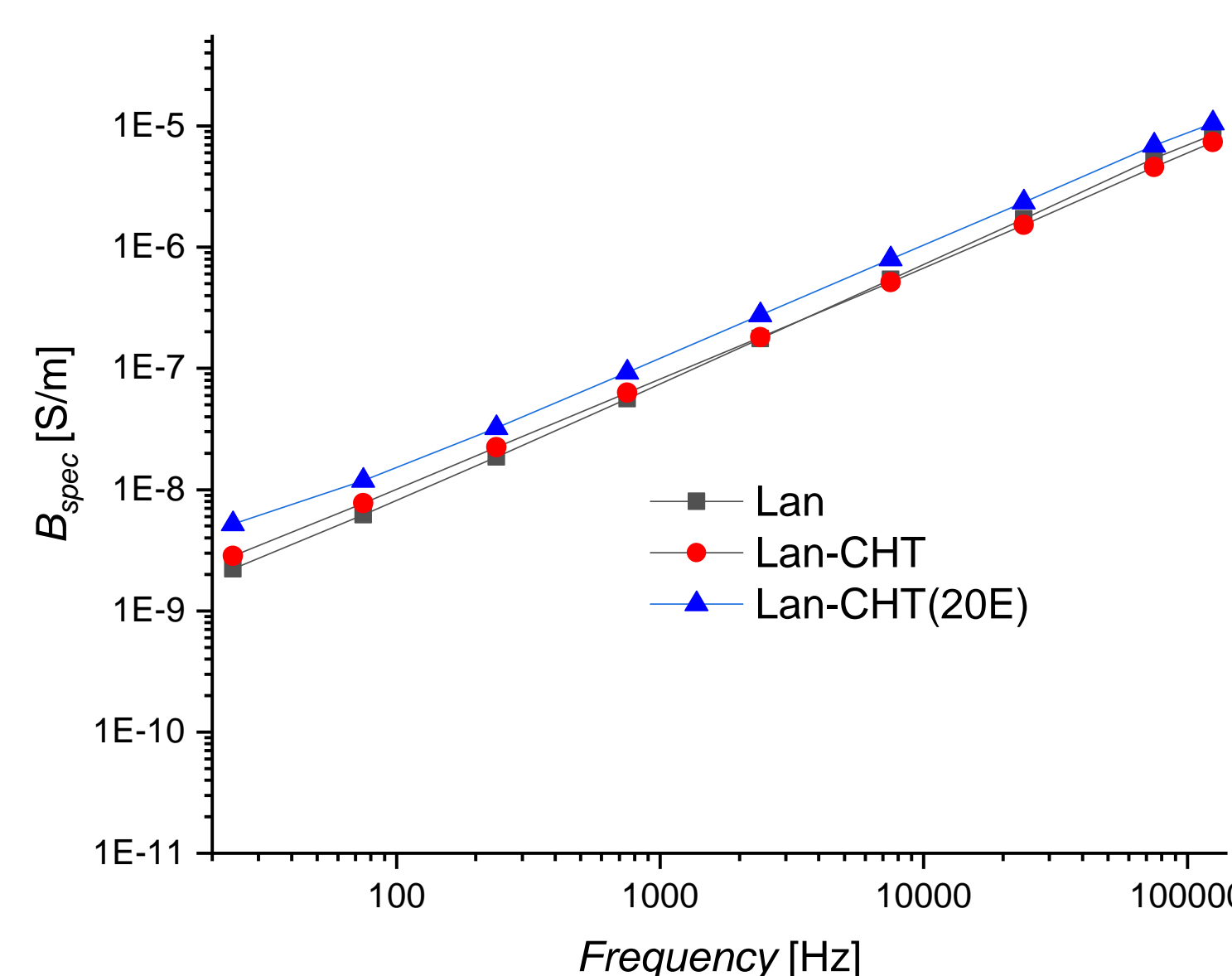


Figure 4. Specific susceptance versus frequency in frequency range from 20 Hz to 125 kHz for pure linen sample (Lan), linen sample modified by CHT-NV (Lan-CHT) and linen samples modified by CHT-NV and extract *Pinus sylvestris* L.

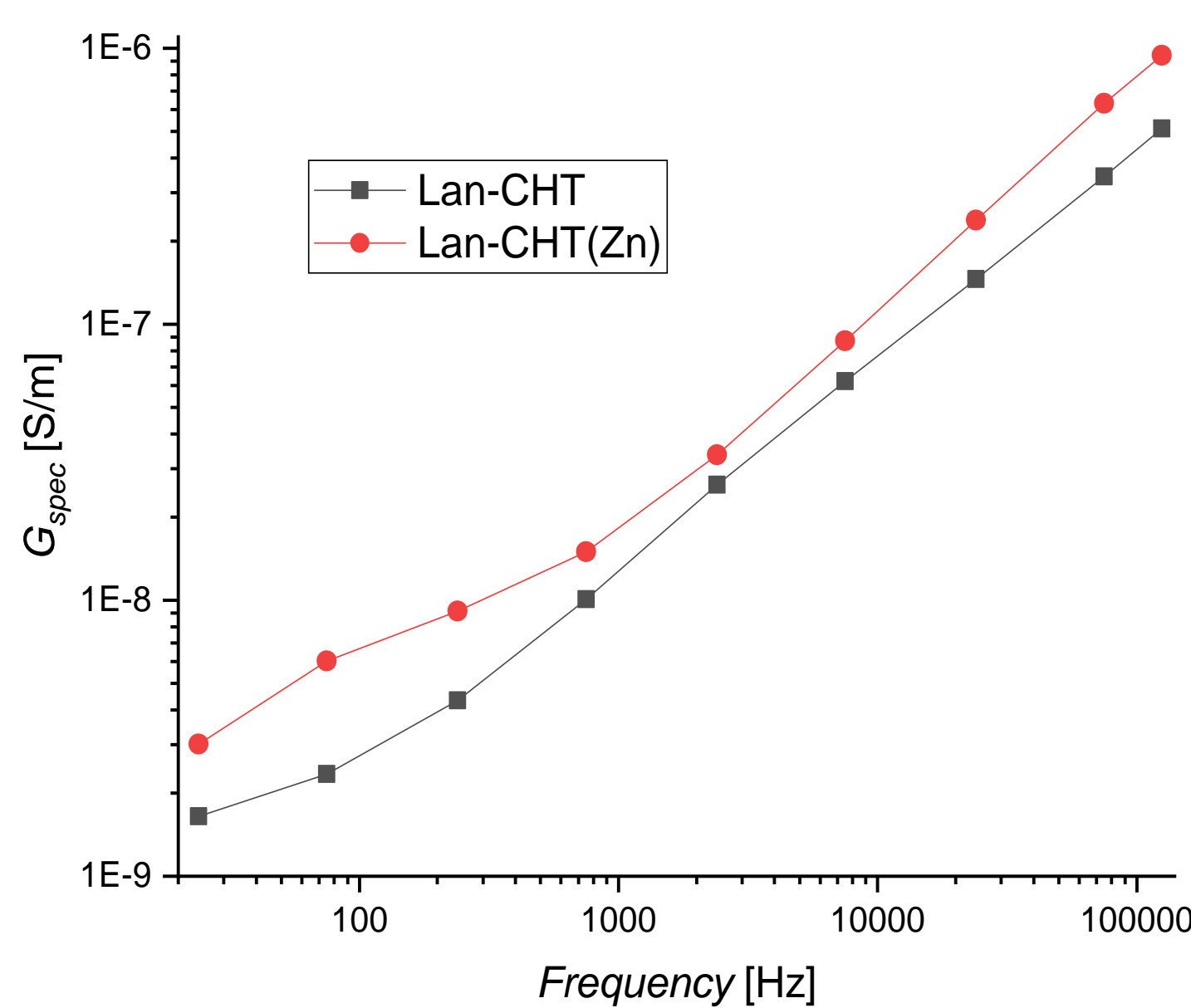


Figure 5. Specific conductance versus frequency in frequency range from 20 Hz to 125 kHz for linen sample modified by CHT (Lan-CHT) and linen samples modified by CHT and zinc oxide (Lan-CHT(Zn)).

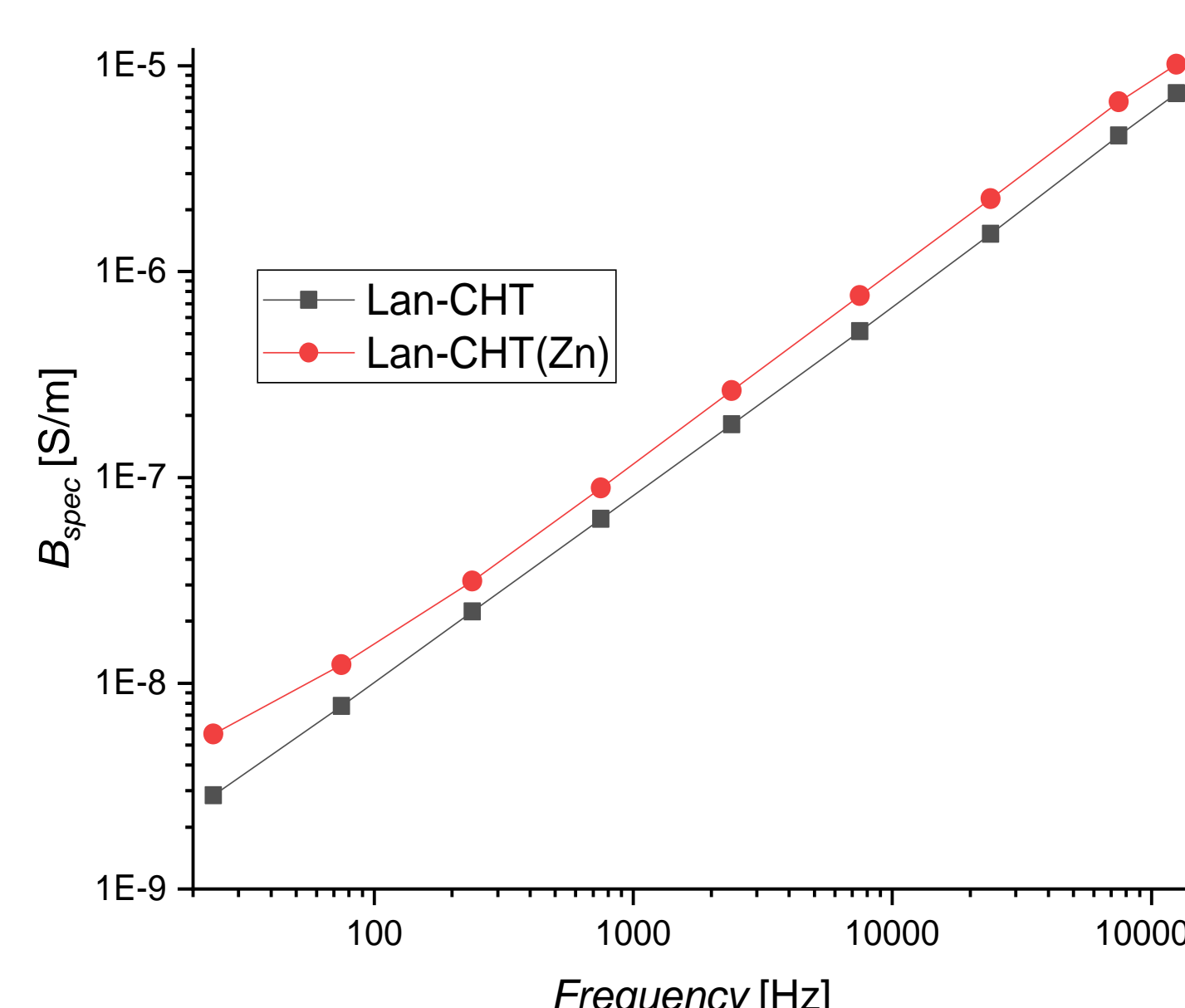


Figure 6. Specific susceptance versus frequency in frequency range from 20 Hz to 125 kHz for linen sample modified by CHT (Lan-CHT) and linen samples modified by CHT-NV and zinc oxide (Lan-CHT(Zn)).

#### Antimicrobial properties of modified fabrics

Sample	Tested microorganisms		
	<i>Staphylococcus aureus</i>	<i>Escherichia coli</i>	<i>Candida albicans</i>
Lan-CHT(Zn)	 Zi = 0,250 mm	 No activity	 No activity
Lan-CHT(20E)	 Contact inhibition	 Contact inhibition	 No activity
Lan-CHT(Zn+20E)	 Contact inhibition	 No activity	 No activity

Figure 7. Antimicrobial properties of fabrics modified with ZnO and plant extract of *Pinus sylvestris* L.

### CONCLUSIONS

From the results of the antimicrobial testing of printed linen fabrics, it can be seen that the best effect on *Staphylococcus aureus* was shown by fabric printed with alginate paste (CHT-NV) modified with ZnO with an inhibition zone of 0.25 mm, while fabrics printed with CHT-NV, *Pinus sylvestris* plant extract L. and ZnO exhibited antimicrobial activity in the form of contact inhibition. It was also observed that ZnO does not show any effect on the bacterium *Escherichia coli* and the yeast *Candida albicans*. Linen fabrics printed with CHT-NV paste, which contained 20% of *Pinus sylvestris* L. plant extract, showed antimicrobial activity against *E. coli*, which can be considered a very good activity given the low concentration of the extract in the paste.

Specific conductance versus frequency in frequency range from 20 Hz to 125 kHz for pure linen sample (Lan), linen sample modified by alginate paste CHT-NV (Lan-CHT) and linen samples modified by CHT-NV and extract *Pinus sylvestris* L., Figure 3. Specific conductance increases with increase in frequency in all frequency range, this increase is two orders of magnitude. After printing linen sample with CHT-NV one can see increase in conductivity one order of magnitude. Modification CHT-NV pasta with *Pinus sylvestris* L. alcohol extract leads to increase in conductivity up to 90% for sample modified with *Pinus sylvestris* L. alcohol extract. Figure 4 shows specific susceptance versus frequency in frequency range from 20 Hz to 125 kHz for pure linen sample (Lan), linen sample modified by CHT-NV (Lan-CHT) and linen samples modified by CHT-NV and extract. At frequency 125 kHz it is observed an increase in susceptance by CHT-NV pasta and extract modification for up to 43%. At lower frequency (24 Hz) this increase is 140%. An increase in the susceptance of four orders of magnitude with an increase in frequency was observed for all measured samples.

Figure 5 shows influence of the zinc oxide on the conductance of linen printed samples modified with CHT-NV. One can see an increase in conductivity by adding zinc oxide in all frequency range. At frequency 24 Hz an increase in conductance is about 83%, at 75 Hz an increase is 160%, while at 7,5 kHz an increase is 40%. At the highest frequency 125 kHz this increase in conductance is 85%. Figure 6 shows specific susceptance versus frequency for sample printed with pasta and sample printed with pasta modified by zinc oxide. Similar behavior has been observed for specific susceptance, i.e. susceptance increase by adding zinc oxide in all frequency range. At frequency 24 Hz an increase in susceptance is about 100%, while at 125 kHz an increase is 40%.

There is no significant difference between the value of the specific susceptance of linen printed samples modified with CHT-NV and extract by adding zinc oxide. It could be concluded that there are destructive interaction between zinc oxide and extract which leads to decrease in conductivity of the modified samples.