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CNTs embedded in breathable PU-membranes provide a comfortable heating

INTRODUCTION

The main objective of the investigations was to realize an electrically induced heating of breathable polymer surfaces that is suitable for the application in personal protective equipment (PPE) as well as outdoor clothing. Based on polyurethane (PU) as polymer matrix, thin electrically heatable polymer sheets were developed using multi-walled carbon nanotubes as electrically conductive fillers. An optimal processing of the MWCNT in the viscous polymer masses was found by means of a three roll mill. The particle alignment, the percolation, the electrically and heating properties of the membranes as well as the influence of the fillers to the breathability were investigated.

MAIN STEPS MANUFACTURING HEATING LAMINATES WITH HIGH BREATHABILITY

1. INCORPORATION OF CNTS IN THE POLYMER FORMULATION

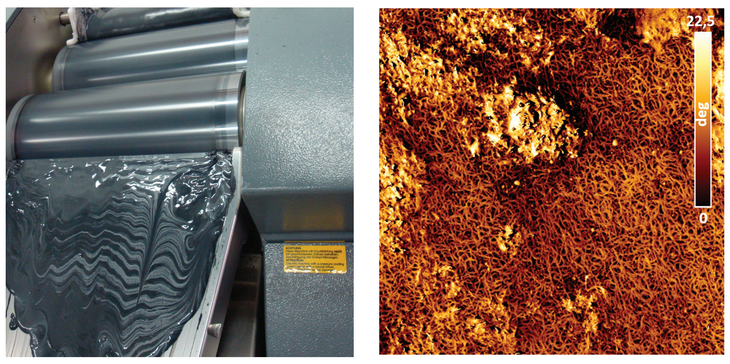


Fig. 1: three roll mill (left), AFM phase image (8x8µm) of water-born PU-foil with dispersing agent, 4%CNT (right)

- dispersing of MWCNTs by calandering using a three roll mill in waterborne PU dispersions
- highest conductivity was measured at the gap mode
- transition to the force mode causes a decrease in conductivity

2. PROCESS THE COATING MASS TO FORM THIN LAYERS

Fig. 2: blade coating facilities in technical scale

- reverse coating from roll to roll
- coating width: up to 65 cm
- drying with three different temperature zones

3. APPLICATION OF ELECTRODE

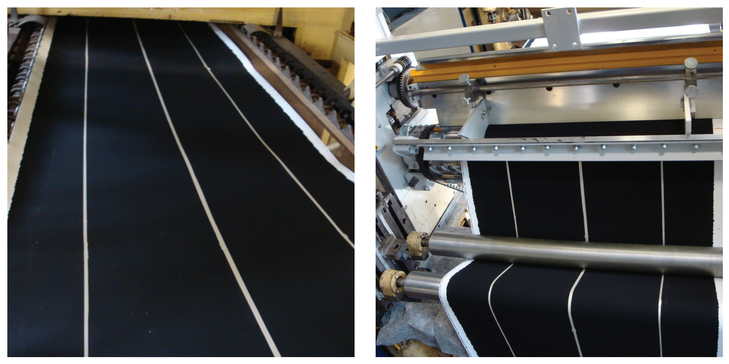


Fig. 3: applicated surface conducts on R2R material

- application of silver containing adhesive by means of screen printing
- usable distance is between 5 to 20 cm
- the higher the distance between the surface conducts, the lower the performance

4. LAMINATION WITH TEXTILE

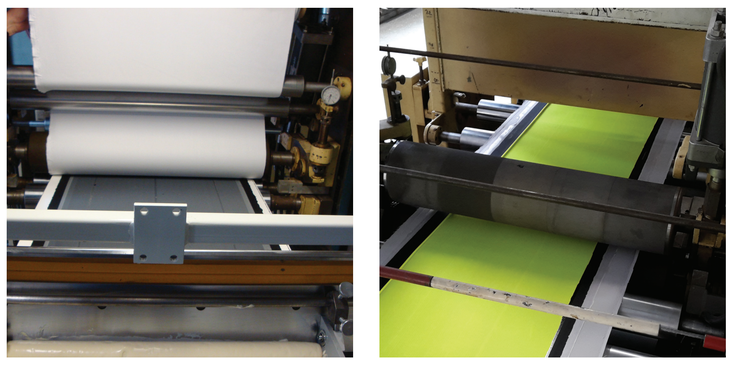
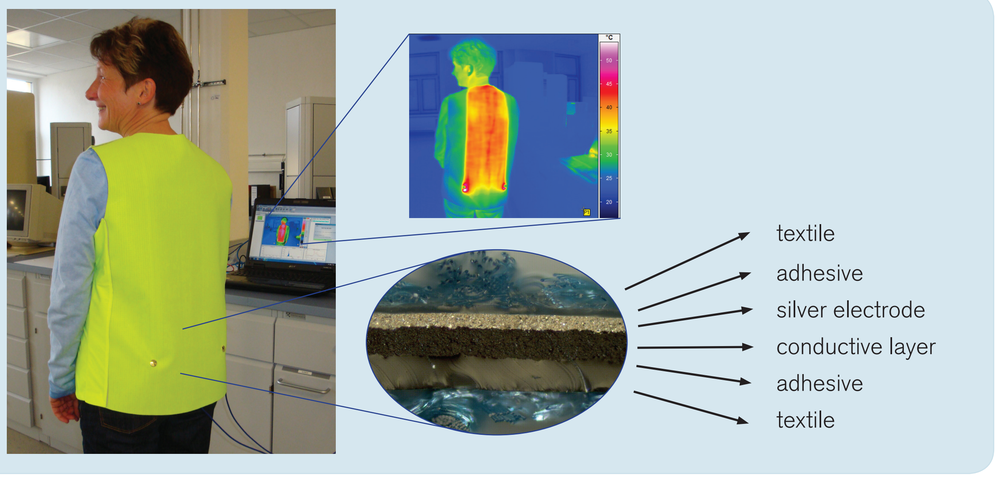


Fig. 4: application of adhesive coat and textile lamination

- application of an adhesive coat and subsequently lamination of the textile
- after drying and curing the compound can be delaminated from the transfer paper



PROPERTIES OF THE PU-MEMBRANES

BREATHABILITY (TEST METHOD: DIN EN ISO 15496)

CNT-content [%]	Thickness [µm]	MVTR [g/m²d]	Ret [m²Pa/W]
0	25	12,800	5,5
0	50	6,850	11,0
4	**25**	12,190	5,9
4	**30**	12,660	5,6
4	**45**	9,220	8,0
4	**50**	8,460	8,7
4	**55**	8,430	8,8
5.6	50	6,470	11,6

- measuring the Moisture Vapour Transfer (MVTR) and Resistance to Evaporating Heat Transfer (Ret)
- the higher the MVTR-value the lower the Ret-value
- MVTR depends strongly on the film thickness (hydrophilic PU system)
- solvent-based system shows a high breathability, whereas the breathability of the waterborne system is rather low
- CNT content does not perceptibly lower the MVTR

HEATING PERFORMANCE

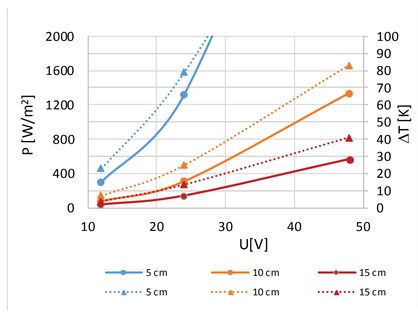


Fig. 5: Effect of the contacting distance on the performance and temperature changes of the PU membrane, P – solid lines, ΔT-dotted lines

- distance between the contact lines strongly effects the performance and temperature change
- homogeneous warming of the surface is possible

CONCLUSION

Within the scope of the work a breathable membrane was developed as well as a surface contact. The conducted membranes have a high conductivity and are highly flexible. The investigations showed no major impact of the CNT content to the breathability because of the low CNT content (<5 %). The reached properties enables the membrane for the application in Personal Protective Equipment (PPE). Therefore, further investigations regarding the lamination with textiles and the behaviour in washing procedures are reasonable.

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