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Electrical and Electronic Properties of Fibers

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----------**ABSTRACT**----------
This paper offers the latest trends into developing technology to boost wear ability of e-textiles and smart clothing by rereading cutting-edge research and development. Training to act in accordance with rulesof electronic textiles is spoken, and electronic textiles are initiated from the textile and clothing viewpoint as well as the electrical andviewpoint. Studies are made of fabric made by electrical resistances of conductive yarns. Some investigationexamining flexibility and wash ability of e-textiles is introduced. Relative insignificance toward mechanical properties and the absence of traditional test methods are considered the most tricky for sustainable development of e-textiles.
Key words:Conductive fabric; polyaniline; in situ polymerization; nylon 6; serviceability,electrochromism, supercapacitors

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I. Introduction

The term electro-textiles,mentions to a blend of microchip technology and textile manufacturing resultant fabrics having electrical properties. Electronic textiles are located in the latent area of juncture among textiles, electronics, and info science. Electronic textiles have been referred to as smart textiles or intelligent textiles, and wearable computers depending on the tactic.

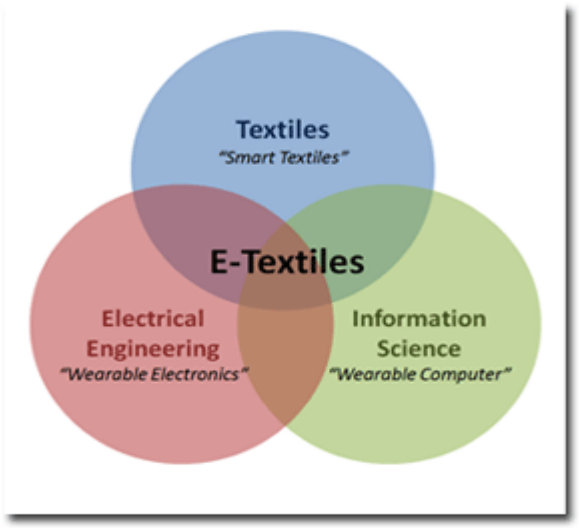


Figure 1: Multidiscipline of E-textiles

Viewed from electrical point, conductivity is the most significant factor. Electrical resistance low enough to authorize a flow of electric energy, such as for power or data broadcast, is serious. Metalor optical fibers, carbon, are characteristicallyknown conductors. Progressive technologies are required to produce process able fibers and yarns from these materials. From the textile viewpoint, properties of traditional wearable textiles need to be combined with the electronic properties. E-textiles should be stretchable,flexible and washable while retaining good electrical conductivity.

This paper recapitulates the current accomplishments of e-textiles in its electrical properties. Electrical resistances of conductive yarns and subsequent fabrics are studied. A few research approaches examining mechanical properties of electronic textiles are presented. Flexibility and washability are studied as two of the indispensable mechanical properties of e-textiles. Tests in testing methods and calibration are lectured.

II. Electrical Properties

Yarns that are good conductors are either pure metal yarns or syntheses of metals and textiles. Metals are greater in strength and fineness, and textiles are chosen for soothe. To produce a fruitful conductive yarn, the top mixture of conductive and materials which are not able to conduct is critical. As a thread takes on a bigger portion of conductive mechanisms, it loses the characteristic textile properties such as drapability or flexibility and becomes more conductive.The accomplishmenthas ranged from 0.24 ohms per meter (Ω/m) to 5,000 Ω/m.

Design Of Conductive Yarns

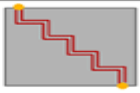
	Verstraeten	Dhawan	Cottet	Post	Watson
Conductive Part (# of Strand)	Copper (1)	Copper (28)	Copper (1)	Steel (spun 20%)	Steel (4)
	d=148 µm	d=70 µm	d=40 µm	Not Known	d= 35 µm
Non-conductive Part (# of Strand)	Steel (3)	-	Polyester	Polyester (80%)	Polyester (1)
	d=12 µm ×275		150.3 denier	4.5 denier	600 denier
Structure (Location of conductive material is described in darker colors)					
Twist Density (tpm)	Z100	Not Known	Not Known	Not Known	S350 & Z350
Resistance (Ω/m)	1.2	0.2441	15.7 – 17.2	~5,000	180

References
1. Verstraeten, S., J. Pavlinec, and P. Speleers, "Electrically Conductive Yarn Comprising Metal Fibers," U.S. Patent No. 6,957,525 (2005), assigned to N.V. Bekaert S.A.
2. Dhawan, A., T.K. Ghosh, and A.M. Seyam, "Fiber-based Electrical and Optical Devices and Systems," Textile Progress monograrph series, Manchester: The Textile Institute, 2004.
3. Cottet, D., et al., "Electrical characterization of textile transmission lines," IEEE Transactions on Advanced Packaging 26 (2), 2003: 182-190.
4. Post, R., et al., "E-broidery: Design and Fabrication of Textile-based Computing," IBM Systems Journal, 39 (3/4) 2000: 840-860.
5. Watson, D.L., "Electrically Conductive Yarn," U.S. Patent No. 5,927,060 (1999), assigned to N.V. Bekaert S.A.

Table 1

The method of integration of these yarns to generate the conductive path on the fabric substrate is critical to decide overall electrical resistance.Flourishing integration create a dependable conductive path on the fabric surface, while also protecting the path against frequent dimensional change or abrasion for long-standing conductivity.

Comparison Between Integration Methods

	Dhawan	Linz	Post	Rattfält
Conductive Yarn	Copper filaments	Silver coated polyamide	Steel spun	Steel filaments
	d=70 µm /28	11.7 tex/17 ×2	40 tex	275 tex ×2
Original Yarn Resistance (Ω/m)	0.2441	500	~100	15
Fabric Substrate	Polyester plain weave	Stretch knit	Not Known	-
Integration Structure	Woven	Two sewn paths	E-broidered path	Knitted
Measurement Traces and Points			-	
Measurement Remarks	Welded at yarn intersections	Sewn three times in zigzag shape	Steel + polyester spun covering yarn	Measured on human skin
Final Trace Resistance (Ω/m)	0.25-0.50	~25	Not Known	~4,000,000

References
1. Dhawan, A., T.K. Ghosh, and A.M. Seyam, "Fiber-based Electrical and Optical Devices and Systems," Textile Progress monograph series, Manchester, U.K.: The Textile Institute, 2004.
2. Linz, T., et al. "Fully Integrated EKG Shirt based on Embroidered Electrical Interconnections with Conductive Yarn and Miniaturized Flexible Electronics," International Workshop on Wearable and Implantable Body Sensor Networks, Proceedings, Boston, 2006.
3. Post, R., et al., "E-broidery: Design and Fabrication of Textile-based Computing," IBM Systems Journal, 39 (3/4) 2000: 840-860.
4. Rattfält, L., et al., "Electrical characteristics of conductive yarns and textile electrodes for medical applications," Medical and Biological Engineering and Computing 45 (12) 2007: 1251-1257.

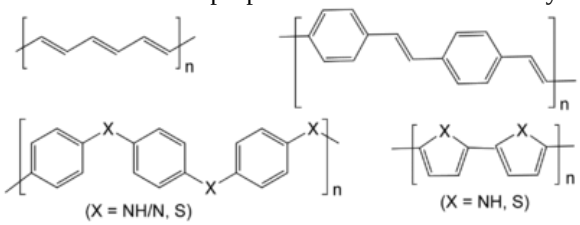
Table 2

By making astute interconnections and interruptions between various conductive paths, it was possible to let electrical current flow through aelected path; welded interconnection points largely upgraded the total conductivity in a woven construction. Multiple sewn threads resulted in improved electrical properties; two head-to-head paths of sewn tracks where each path is sewn three times attained much lower resistance. For electrical broidery, it was recommended that conductive covering threads with lower resistance and better mechanical properties could be used to complement the conductivity of implied conductive threads.

SUMMARY

MOLECULAR PROPERTIES

Conductive polymers or, more accurately, **intrinsically conducting polymers** (ICPs) are organic polymers that conductelectricity.The biggest benefit of conductive polymers is their process ability, mainly by dispersion. Conductive polymers are generally not thermoplastics, that meansthey are not thermally comfortable. They are organic materials just like insulating polymers. They do offer high electrical conductivity but do not show similar mechanical properties to other commercially available polymers.Diffusion alters the electrical properties.



Conductive polymers are equipped by many methods. Most conductive polymers are generated by oxidative coupling of monocyclic precursor. Such reactions dehydrogenation:

$$n\ H–[X]–H \rightarrow H–[X]_n–H + 2(n–1)\ H^+ + 2(n–1)\ e^-$$

The short solubility of the majorityof polymers presents challenges. Some scientists have addressed this through the configuration of nanostructures and surfactant stable conducting polymer dispersions in water. These include polyaniline nanofibers and PEDOT:PSS. These supplies have low molecular weights.

A **conductive textile** is a fabric which has askill to conduct electricity. Conductive textiles can be made with metal strands woven into the building of the textile. There is also an attention in semiconducting textiles, made by infusing usual textiles with carbon or metal based powders.

Conductive fibers consist of a non conductive or less conductive substrate, which is then either coated or entrenched with electrically conductive elements, oftensilver,carbon, copper,titaniumgold. Substrates characteristically include polyester, cotton, stainlessnylon, and steel to high performance fibers such as aramids. Straddling the worlds of textiles and wires, conductive fibers are sold either by weight or length.

Because of the speedy growth in the kinds of conductive fibers and the uses of these fibers, a trade association has been formed to increase awareness, utilization, and possibly standardizelanguage. The association is Conductive Fiber Manufacturers Council.

Mechanical Properties

To develop practical wearable systems, mechanical property of electronic textiles are critical. However, there has been very slight research that methodically evaluates the bodily behavior of e-textiles. Furthermore, the fact that each research project uses its own assessment method, different from a traditional textile testing method, results in empirical conclusion in wreckage and makes it tricky to understand the mechanical behavior as textiles.

Flexibility

Flexibility can be understood as the resistance to enduring deformation under stress such asbending or folding. Flexibility of yarns can be enhanced through textile process such as spinning or twisting as the overall geometry

of the yarn is a former factor to those of individual fibers. Yarn flexibility is generally affected by an individual fiber's uniqueness, such as fineness or Young's modulusand, flatness and their geometry.

The hanging heart loop method was customized for textile cables of copper wiresand aluminum metalized polyester shielding, nylon fibers. Because this electronic textile was much stiffer than any predictable textiles, load helping textiles bend was applied and Bus Stiffness was calculated from the slope of the load vs. displacement curve. Bus stiffness measurement of the textile cable was reported to be three times larger than the same textile band without any conductive constituent.

$$\text{Bus Stiffness } (K_b) = \frac{\text{Force } (g)}{\text{Displacement } (inch)}$$

Equation 1

Sewability was also measured as an index for bending individuality of conductive threads. *The Curl Test* was invented to observe the outstanding curling and moderate the sewability of conductive threads for the reason that a conventional sewing thread did not show residual curls at all. It was known empirically that good number conductive threads were not entitled for machine sewing because of their short ofmechanical properties. They could not hold outto the mechanical stresses that machine sewing causes through the needle. Fine wires, however thin or flexible it may be, would break under the tension in the needle, or jam the mechanism in the bobbin.

Washability

Washability is a very only one of its kind characteristic of electronic textiles unless the wearable system is not reusable. Washability is related to chemical resistance against moisture and detergents as well as physical resistance against mechanical stresses and elevated temperature. Known as the most efficient performer, copper itself is ineligible for washability because it is corroded quickly by moisture. Challenges concerningwashability have a grave end result: most smart clothing have been urbanized as a concept and exists only in laboratories.

A series of durability tests on stitches of conductive yarns was experimented by following the existing guiding principle: a washing test for textiles and accelerated ageing tests for conventional electronics. In both washing and accelerated ageing tests, electrical association by stitches has been shown to be more long-lasting when there is not aorganized hole. The conductive stitches were long-lasting enough to withstand conventional washing devoid of any prepared hole, but they did not hold out toaccelerated ageing tests.

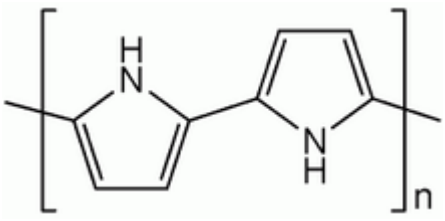
Most research pertaining to washability was testing metal-plated fabrics, possibly because plated fabrics are notorious for a lack of conductivity reliability. More or less, conductive fabrics lost their conductivity after repeated laundering *(See Table 3)*. The increase in resistance could be attributed to fibrerupture and scrape of the conductive plating. Dry cleaning was found to be a safer way to clean electronic textiles than machine washing.

Comparison Of Washability

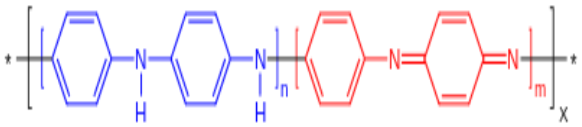
	Cho	Cho	Slade	Slade
Material	Cu/Ni plated polyester	Cu/Ni plated polyester	Ni/Cu/Ag plated yarn	Ni/Cu/Ag plated yarn
Structure	Ripstop	Mesh	Woven Ribbons	Woven Ribbons
Washing Type	Machine wash	Machine wash	Machine wash	Dry cleaning
Initial Resistance (Ω/cm^2)	0.035	0.097	~ 0.0040	~ 0.0032
Resistance after 10 cycles (Ω/cm^2)	0.062	5.063	~ 0.0037	~ 0.0042
Resistance after 50 cycles (Ω/cm^2)	N/A	N/A	~ 0.0090	~ 0.0057

References
1. Cho, J., et al., "Design and Evaluation of Textile-based Signal Transmission Lines and Keypads for Smart Wear," 12th International Conference on Interaction Platforms and Techniques, Proceedings: 1078-1085, Beijing, 2007.
2. Slade, J., et al., "Washing Electrotextiles," Materials Research Society Fall Session Symposium D3.1, Boston, 2002.

Conductive fibers were obtained using two experimental processes. In melt spinning process, polyaniline ,graphite and polypyrrole were used in order to obtain conductive polypropylene (PP) based fibers with unambiguous electrical and mechanical properties. Polyaniline was treated using dodecylbenzene sulfonic acid to improve the solubility and the dispersalof .Polyaniline in xylene.Polyaniline coating on PET yarns were performed by absorption of yarns through polyaniline solution. The electrical resistance of conductive yarns were investigated. These yarns are supposed to be used to create intelligent clothing, corrosion protection or conductive fabrics for electromagnetic shielding applications.

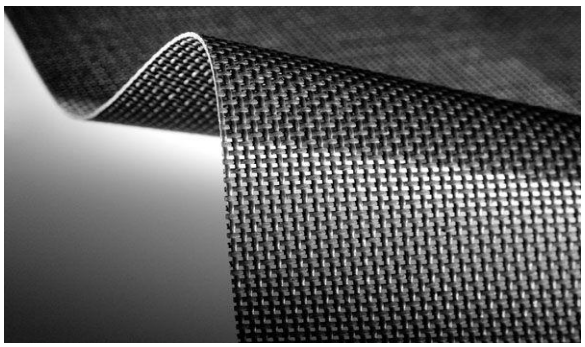


The resistance figures of the cotton fabric coated with PAni and PPy were found to be 350 and 512 Ω, correspondingly. The standard electromagnetic shielding efficiency and average absorption values of the cotton fabrics coated with PAni were found to be 3.8 dB and 48%, correspondingly, and these values for the cotton fabrics covered with PPy were 6 dB and 50%, respectively.



Molecular foundation of electrical conductivity

The conductivity of these kind of polymers is the result of quite a few processes. For example,the valence electrons are bound in sp^3 hybridized covalent bonds in traditional polymers such as polyethylenes,These kind of sigma bonding electrons have low mobility and do not contribute to the electrical conductivity of the fabric. However, in conjugated materials, the situation is entirelydissimilar. Conducting polymers have backbones of neighboring sp^2 hybridized carbon centers. One valence electron on each center resides in a p_z orbital, which is orthogonal to the rest of the three sigma-bonds. All the p_z orbitals coalesce with each other to a molecule wide delocalized set of orbitals. The electrons in such delocalized orbitals have elevated mobility when the material is "doped" by oxidation, which eliminates some of these delocalized electrons. Thus, the conjugated p-orbitals form a one-dimensional electronic band, and the electrons inside this band become mobile when it is moderately emptied. The band structures of conductive polymers can with no trouble be calculated with a tight binding model. In principle, these same materials can be doped through reduction, which adds electrons to an if notunoccupied band. In practice, most organic conductors are doped oxidatively to provide p-type materials. The redox doping of organic conductors is corresponding to the doping of silicon semiconductors, whereby a small portionof silicon atoms are replaced by electron rich, *example*, phosphorus, or electron-poor, *e.g.*, boron, atoms to generaten-type and p-type semiconductors, correspondingly.



Even thoughcharacteristically "doping" conductive polymers involves oxidizing or reducing the material, conductive organic polymers connected with a protic solvent may also be "self-doped."

Undoped conjugated polymers states are semiconductors or insulators. In such compounds, the energy difference can be > 2 eV, which is too immense for thermally activated conduction. Consequently, undoped conjugated polymers, such as polyacetylenes, polythiophenes only have a short electrical conductivity of approximately 10^{-10} to 10^{-8} S/cm. Even at a very near to the ground level of doping (< 1%), electrical conductivity increases more than a few orders of magnitude up to values of approximately 0.1 S/cm. Succeeding doping of the conducting polymers will effect in a saturation of the conductivity at values approximately 0.1–10 kS/cm for dissimilar polymers. Highest values reported up to now are for the conductivity of stretch oriented polyacetylene with established values of about 80 kS/cm. Although the pi-electrons in polyactetylene are delocalized along the chain, immaculatepolyacetylene is not a metal. Polyacetylene has sporadic single and double bonds which encompass lengths of 1.44 and 1.36 Å, correspondingly. Upon doping, the bond alteration is diminished in conductivity increases. Non-doping increases in conductivity can even be attained in a field effect transistor (organic FET or OFET) and by irradiation. Some resources also show signs ofnegative differential resistance and voltage-controlled "switching" analogous to that seen in inorganic amorphous semiconductors.

In spite ofconcentrated research, the relationship sandwiched between morphology, chain structure and conductivity is still poorly understood.Generally, it is assumed that conductivity should be superior for the higher degree of crystallinity and better alignment of the chains, still this could not be confirmed for polyaniline and was only recently confirmed for PEDOT, which are largely amorphous.

Textiles are ubiquitous. Not only do they protect but they also have aesthetic appeal and cultural importance. Recent technological advances have permitted the conventional functionality of textiles to be extended. Advances in materials nanoscience have supplemented intelligence to textiles and created smart apparel which can sense and react to environmental circumstances or stimuli from, for example, thermal,mechanical, electrical,chemical or magnetic sources. Such textiles find uses in plentiful applications ranging from armed and security to tailored healthcare, hygiene and entertainment.

Smart textiles possibly will be deemed passive or active. A passive smart material monitors the wearer's physiology or the external environment such as a shirt with integrated thermistors to log body temperature over time. If actuators are integrated the textile material becomes anvigorous smart material as it may respond to a particular stimulus such as in the temperature aware shirt may automatically roll up the sleeves when the body temperature becomes elevated.The fundamental components in many of the smart textile are sensors and actuators. Interconnections, power supply and control units are also needed to complete the system. These components have got to all be integrated into textiles while still retaining the usual tactile flexible and comfortable properties which an individual expects from a textile. Materials such as metals, optical fibres and conductive polymers may be incorporated into the textile arrangement, thus supplying electrical conductivity, sensing capability and data broadcast capability to the material.The investigational determination of both the thermal and electrical conductivity of single fibrespresents a test. Fibres are characterized by having one very

long dimension and the other two very small. This makes the purpose of their mechanical and physical properties far from trivial. In particular, purpose of their transverse properties, i.e. in the direction of the fibre diameter, can be difficult. In the at hand document we report on recently developed yet readily attainable methodologies by which such important physical measurements may be made.

II. MEASUREMENT PROTOCOL

In more basic scheme resistivity or conductivity can be measured by probe method which can be two probe or four probe .however both the method two probe and four probe is used to measure electrical resistance or conductance of material given in the figure. In the former method a uniform current density is applied across the specimen which is in between two electrodes located on parallel faces and measure the potential drop across the latter electrodes.

NOTE THAT

Laser fibre is used to measure the diameter of fibre. The technique can be rapid and systematic .The body of the liquid becomes charged when we apply sufficiently high voltage to a liquid droplet, as the electrostatic repulsion counteracts the surface tension and droplet which gets stretched, at a critical point a stream of liquid erupts from the surface. Eruption point of drop is known as the Taylor cone. As the molecular cohesion of the liquid is sufficiently high, stbreakup does not occur (if it does, droplets are electro-sprayed) in steam due to which charged liquid jet is formed. As the jet dries in flight, as the charge migrates to the surface of the fibre mode of current flow changes from ohmicto connective. The jet gets elongated by a whipping process caused by electrostatic that is electrostatic repulsion initiated at small bends in the fibre, till it gets finally deposited on the grounded collector. The elongation and thinning of the fibre results due to it from this bending instability which leads to to the formation of uniform fibreswith nanometer nanometer-scale
diameters as shown in the figure. The theoretical description of the electrospinning process is complex and has been examined for many years. Seminal work was conducted by Taylor and more recently by Reznik and Hohman.

Int. J. Electrochem. Sci., Vol. 6, 2011 5736 to measure the DC conductivity of well defined single fibres formed by a variety of methods has been indicated in this paper briefly . The experiment is actually important and requires stylish high resolution imaging equipment. Physical determination of the corresponding current vs voltage response curve is straightforward once the physical determination of is set measuring electrodes by connection between fibre and injecting materila. The field is still in its early years and the examples chosen are typical of the results obtained from the literature.The topic of single fibre conductivity measurement has only begun over the last few years. In the literature more amount of work is set at the level of the analysis of current vs potential response curves. dc analysis is all well and good in this method, but more complexity in the experimental procedure adopted and data analysis employed is clearly needed. To the analysis both of single fibres as well as arrays of the latter when included into garments one obvious extension is to be employed at well eshtablished technique of complex impedance spectroscopy. The electrical impedance of the fibre is measured as a function of frequency over a wide range of value of the latter, and the electrical characteristics of the material characterized interms of a suitable electrical equivalent circuit in this experiment which we have measured. Indeed the technique could be envisaged as forming the basics for investigating the properties and potential of conductive textiles for the electrical transmission of data. Thus the bringing to completion of this type of development and extension in experimental methodology will assist to usher the era of truly smart fabrics and wearable computers .

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Electrostatic Properties and Characterization of Textile

Materials Affected by Ion Flux According to experiment it is known that unintended consequences of electrostatic discharge which causes serious problems in a many of situations which can damage products in electronic assembly and can also impair the quality of products which creates problem create problems of workers like' health and safety, and many others . Textile materials like textiles, fabrics, upholstery fabrics etc are widely used and are also known for their ability to accumulate electric charge. So as to avoid the mentioned undesirable effects textile material must be developed so that they would have acceptable electrostatic properties. Textile materials tends to be like an capacitor which accumalates charge where the dielectric material is composed of fibers and air gaps . The air gap present infibers and textiles can also be modelled as a mixed-type capacitor dielectric layer which specifies the electrical properties for textile materials. Consequently, there is a broad range of electrical properties for fabrics or textile products which totally depends on the

topography, compactness, thermal such as heat and chemical treatment of the final product but with this also depends on atmospheric conditions where the textile products is used or can be used or where the electrical properties are measured. Consumers of textile materials are aiming to have desired electrical properties of fibres with acceptable electrostatic properties. So those properties must be measured and examined.

Most materials which are actually used for textile products are electric insulators and the main measured electric parameter is the surface resistance that varies extremely, in the range of 1013 Ω to 106 Ω . As it is well-known and also has high surface resistance materials can be electrostatically charged. Thus electriccharge which is acumalated has the quality to generate and regain an electrostatic field of significant magnitude. This electric field can be detected as a surface voltage that can be measured by detecting surface voltage. Thus the surface voltage and voltage dynamics can also reflect the main electrostatic properties which are examined in textile material. so methods which are widely used for measuring electrostatic properties of the textile materials are presented in the European standards, which describe the test methods for acurately measuring surface resistivity and electrical resistance through a material and electric charge decay system and is applied in textile materials research and laboratories . Measurements of electrostatic properties can also described in Chinese standards and can be ysed for testing testing static properties and static voltage semi-decay of textile materials andstatic electricity testing of textiles . A closer examination of test methods shows that measurement of electrostatic parameters of textile material are based on methods, which in some cases do not provide sufficient information about tested products. The method described below has certain advantages because the sample is affected by ion flux and that makes it possible to measure the integral surface voltage and the amount of charge simultaneously that contribute additional information on textiles. The method may be adapted also for measurement of surface voltage distribution. Therefore, in this article we discuss a technique of direct measurement of electrostatic parameters and also we discuss the possibility of applying it to investigate electrostatic properties of textile materials.

III. Measuring method and instrumentation

The measuring method described below takes the textile materials electrical properties into consideration. The method is based on the investigation of the sample surface electrical parameters when a sample is affected by ion flux generated by a corona charging device [11 – 13]. The applied instrumentation is able to measure the time dependences of the accumulated amount of electric charge of the sample and the surface voltage when the sample is affected by ion flux or not. There are two different measuring processes. Process 1: when the sample is affected by ion flux an amount of electric charge Q is measured and in the time interval when the deposition of ions is stopped, the surface voltage V is measured; the amount of electric charge and surface voltage are measured one after another periodically, and the charging process of the examined sample is investigated. Process 2: after a time interval when the sample was affected by ion flux and was electrically charged, the surface voltage V dependence on time t is measured. In the latter case measuring periodically the surface voltage of the examined sample when the corona charging device is switched off, the electric discharge process is investigated. The experiment may be carried out affecting the sample to positive or negative ions generated in humid air at atmospheric pressure by a corona charging device.

The charging process is used to evaluate the physical properties of the samples. When the charging process is carried out, i. e. when the time dependence of the amount of electric charge Q and the surface voltage V are measured simultaneously, the surface voltage dependence on deposited electric charge (V-Q) is obtained. Theoretically, the dependence of the surface voltage of an ideal dielectric layer on the amount of electric charge accumulated on its surface must be linear, which is not the case in the real situation. The (V-Q) dependence also depends on positive or negative electric charge deposited on the sample surface. From the linear part of the (V-Q) dependence, the capacitance C of the investigated sample can be calculated ($C = \Delta Q / \Delta V$, see Fig 3), the maximum deposited electric charge Qmax when the surface voltage reaches the limiting value can be found and finally the accumulated electric charge energy WQ can be calculated ($WQ = C \cdot Vmax2 / 2$). The measurement process more detailed is described .

The discharging process is used to evaluate the antistatic performance of the samples.When the discharging process is carried out, the surface voltage dependence on time (V-t) is obtained . To evaluate the discharge rate of the tested material, the period of time during which the surface voltage is reduced by half is determined from the V-t dependence (Fig. 4). The shorter the semi-decay time tmed , the better the antistatic ability of the samples composition. Here are a few parameters of the measuring instrumentation. The maximum corona charging devices voltage Vcv is about 9.0 kV, the maximum value of current generated by the corona charging device is 100 μA. The measuring interval of the electric charge meter is from 10–4 C to 10–10 C (the relative

error of measurement is ±5 %). The surface voltage measuring interval is from 30 V to 3500 V (the absolute measurement error is ±7.5 V). In the described instrumentation, the dimensions of a test sample are 51 mm × 46 mm and the measurement aperture area – 40 mm × 30 mm. The test sample must be evenly placed on the substrate surface.

2.2. Surface voltage distribution visualization technique

The method when the investigated material is affected by ion flux is also applicable for textile materials surface voltage distribution visualization. The voltage distribution on the whole surface of the investigated textile material is measured fixing it on a mechanically rotating cylinder. A step-by-step ring scanning mode for surface voltage measuring is applied and the measured data are collected and visualized on a computer.

The main technical parameters of surface voltage distribution measuring instrumentation are the following. The diameter of the conductive cylinder made of aluminum alloy is 120 mm. The scanning surface is 250 mm × 210 mm. The length of one scanned line is 250 mm, the scanning step is about 1.25 mm and so the full surface is scanned in 168 lines. The time required for one line scanning is about 1.0 s and the full surface is scanned in 3.5 min. The corona charging device voltage Vcv can be selected from 4 kV to 9 kV. The maximum value of a current density generated by a corona charging device is 30 μA/cm2. The surface voltage is measured with a contact-free precision surface voltage meter (by TREK, INK. company) Trek model 400 with a vibrating reed probe sensor. The voltage measuring range of this surface voltage meter is up to ±2000 V, the measurement accuracy is 0.05 % and the resolution power is about 2 mm at a gap of about 2 mm (standard probe 400P-E). The diameter and the speed of rotation of the cylinder, the distance between the corona charging device and the surface voltage meter probe are chosen so as to ensure acceptably small decrease of the surface voltage after switching off ion flux. In the described instrumentation the surface voltage is usually measured at 0.14 s after the measuring place leaves the corona treatment zone.

III. EXPERIMENTAL RESULTS

Selected research textile materials and preparation of samples To verify the described method for measuring electrostatic properties of textile materials affected by ions two types of textile materials were selected. The first group was textile materials based on one type of natural or manmade yarns and the second group consisted of textile materials based on natural or man-made yarn assemblies. The experiments were carried out with the following textile materials. Cotton is a natural fiber that readily absorbs oxygen and is flammable. To reduce flammability the cotton fiber is chemically treated, which changes its physical and electrostatic properties. Sometimes cotton is also blended with linen in order to improve the fiber properties. Linen is a natural fiber that can absorb and lose water quickly, so the measured results depend on the environment humidity. Wool is one kind of natural animal fiber that consists of particular proteins.

Wool is flame resistant and has excellent moisture absorption properties. It is known that its electrostatic properties are different from those of other natural fibers. Viscose is a manufactured by transformation of natural polymers and does not build up static electricity. Viscose is produced of wood cellulose in a combination of natural and man made components. Acetate is a man-made cellulosic fiber. It has optimal moisture absorption and a quite high electrical resistance. Acetate is used on its own or with other natural or synthetic fibers. Acrylic is a man-made organic fiber made from a synthetic polymer composed of at least 85 % by weight of acrylonitrile units. The acrylic fabric has the ability to attract and convey moisture. Polyester is a synthetic polymer whose monomers are linked together by ester bonds. There are many types of polyester, but the term polyester commonly refers to a material made from polyethylene terephthalate. Polyester is highly flammable and tends to accumulate electric charge for a long time. Most synthetic fabrics have a natural ability to accumulate electric charge for a long time, because they are made from polymers. In addition to previously described fibers there are many other kinds of naturals and organic synthetic polymers suitable for textile materials fabrication, such us triacetate, polyamide, elastane and other. There are also man-made inorganic fibers, such us metal, glass, carbon that can also be used for textile materials and fabrics [15]. Their use can essentially change the physical and electrical properties of the final products. In practical applications, electrostatic properties of textile materials must be controlled. Sample preparation. The investigated textiles were selected according to the short information on the data sheet provided by the manufacturer. The textiles treatment methods were not available for the authors; therefore, the following results obtained have only an indicative character. Textile test samples may appear in a variety of forms: they may be of different thickness, surface density and type of weaving; be of different composition, treatment method, softer or harder, and so on. But for the electrostatic properties measurement process it is important to know the moisture content of the fabric, because the moisture content substantially changes the measured data.

Therefore, the measurements must be carried out in a controlled environment where the ambient temperature and the relative humidity must be specified. In order to cover the difference in relative humidity and moisture content of the fabric the test samples must be at least for a couple of hours in the specified environment conditions.

3.2. Comparative analysis of selected research materials

The experimental data reported here have been obtained when a small sample (51 mm × 46 mm) of textile material was affected with ion flux and electrostatic integral parameters were measured. The corona charging device voltage was Vcv = 7.5 kV and the time interval of the sample charging process – 5 ms. The measurement of surface voltage starts 35 ms after the sample charging process is finished and are measured at a 12 ms time frame. The measurement process was repeated every 200 ms. The measurements were carried out with seven different previously mentioned textile materials and were compared by limiting value Vmax, maximum surface voltage semi-decay time tmed [s], deposited electric charge Qmax [mC·m–2], sample capacitance C[nF·m–2], accumulated electric charge energy WQ [mJ·m–2]. The textile materials samples were affected by negative (–) and positive (+) ion flux. All samples were subjected to the same conditions (see Table 1). Additionally in the Table 1 surface density [g·m–2] and thickness [mm] of the investigated textile materials are presented.

The data measured under the described conditions and presented in Table 1 suggest the following conclusions. The smallest surface voltage (about 90 V) is acquired by linen, the highest (about 2000 V) – by polyester coated with polytetrafluoroethylene. There is a group of textile materials that has good electrostatic performance because the surface voltage semi-decay time is about 1 s or less. The group is composed of linen, viscose, cotton and wool. The smallest surface voltage semi-decay time is for linen (about 0.1 s). The other group is composed of acetate, polyester and polyester coated with polytetrafluoroethylene, which have a significantly worse performance than the first group. The surface voltage semi-decay time of polyester coated with polytetrafluoroethylene is as large, as 60 s. The longer the semi-decay time tmed, the worse the antistatic ability of the textile material. The calculated value of a sample capacitance when the sample is affected by ion flux may differ from results obtained with other capacitance measuring methods, because the capacitance value depends on sample leakage current, electric field strength, electric charge polarization, measurement equipment frequency range and compression pressure, sample thickness and surface density, weather conditions and other. The numbers in parentheses in Table 1 were obtained by differential capacitance measurement of some investigated samples at mechanical pressure of 1.2 kPa and at frequency of 600 kHz without action of any external electric field. We can see some differences and similarities. Table 1. Calculated parameters of selected textile materials when the voltage of corona charging device was Vcv = 7.5 kV, ambient temperature 23 °C and relative humidity 50 %

Textile materials Vmax / V tmed / s Qmax/mC·m–2 C/nF·m–2 □ WQ□ /mJ·m2 Surface density, g·m–2 According to our research, performed with the measuring equipment produced in accordance with the standards described in [4, 5] linen is characterized by a certain surface and volume resistance, therefore the calculated capacitance when the sample is affected by ion flux is much larger than the measured differential capacitance at described conditions. In the case of viscose, capacitance values coincide quite well, because the surface and volume resistance is larger (about 104 times) than linen and the thickness variation at compression pressure is only 0.1 μm·kPa–1. Polyester coated with polytetrafluoroethylene has the surface and volume resistance about 1015 Ω and the thickness variation at compression pressure is about 2 μm·kPa–1, therefore the calculated capacitance when the sample is affected by ion flux is less than the measured differential capacitance. Also we can see that the largest accumulated electric charge energy is in polyester.

3.3. Surface voltage distribution of an upholstery fabric

The experimental data reported below are obtained when a sample of textile material (the sample dimensions are 250 mm × 210 mm) was affected locally by ion flux and a surface voltage distribution was measured as described in section 2.2. This measuring method takes the surface voltage of a small area spatially limited by voltage meter sensor dimensions. Such measuring method makes it possible to visualize the surface voltage distribution. An example of the measured surface voltage distribution is shown. The sample was an upholstery fabric produced by "Audėjas" company, article name Fausta-1, composed by 66 % of cotton and 34 % of polyester. A and c, the brighter shade corresponds to cotton yarn and the darker shade correspond to polyester yarn. This is a weft double knit fabric in which a Jacquard type mechanism is used. The experiment was performed at ambient temperature 23 °C and relative humidity 24 %, the corona charging device voltage +5.0 kV. The surface voltage was measured at 0.14 s after the ion flux treatment. In the Fig. 6, b, we can see zones with different surface voltages that vary from a very small value (about 50 V) up to about 600 V. The surfacevoltage value depends on the resulting arrangement of the fabric near the surface potential measuring

probe. In the zone A (Fig. 6, a), the aluminum cylinder conductive substrate is covered by a polyestercotton woven layer, which is coated by a layer of cotton using the Jacquard mechanism. In this zone surface voltage varies from 450 V up to 550 V. In the zone B, where the aluminum cylinder conductive substrate is only covered with a polyester-cotton plain woven layer, surface voltage varies from 150 V to 350 V.
The cotton and the polyester maximum surface voltages Vmax are more or less similar, but in the investigated upholstery fabric there are zones corresponding to two different cotton and polyester yarn weaving method, surface voltage values become different. To explain the results obtained, a deep examination of the physical phenomena of the measured structure is needed, but that is not the aim of this article. The presented example highlights the method of surface voltage distribution measurement that is well suited for quantitative analysis of textile materials' surface voltage and makes it possible to localize zones where electric charge is accumulated. A contact-free method and the measurement technique for electrostatic properties characterization of textile materials when they are affected by ion flux is suitable for testing of textile materials. This method takes it possible to measure main electrostatic parameters of textile materials, i. e. the maximum surface voltage, the semi-decay time, the deposited electric charge and a surface voltage distribution. The last mentioned parameter is a new parameter introduced to describe the electrical properties of textile materials. The performed experiments with different kinds of textile materials clearly show that the obtained data are inherent characteristics reflecting the electrostatic properties of textile materials. There are many factors that can affect the measured data: the composition of the fibers and yarns, the weaving mode, the compactness of the fabric, the production equipment and the process of treatment of the finally produced textile material, the atmospheric conditions (temperature, pressure and humidity), and the state of stress, the surface defects and many others. For deep understanding of the effects that take place in the investigated sample, the relationships between the properties of the investigated sample and the given measuring data and the factors that can affect the measured data must be known. We believe that the results will be useful for interpretation of experimental data and characterization of textile materials and allow manufacturers or designers to find a way to compare different materials as well as to use the method as a quality control test.

Properties and applications
Due to their poor processability, conductive polymers have few large-scale applications. They have promise in antistatic materials and they have been incorporated into commercial displays and batteries, but there have had limitations due to the manufacturing costs, material inconsistencies, toxicity, poor solubility in solvents, and inability to directly melt process. Literature suggests they are also promising in organic solar cells, printing electronic circuits, organic light-emitting diodes, actuators, electrochromism, supercapacitors, chemical sensors and biosensors, flexible transparent displays, electromagnetic shielding and possibly replacement for the popular transparent conductor indium tin oxide. Another use is for microwave-absorbent coatings, particularly radar-absorptive coatings on stealth aircraft. Conducting polymers are rapidly gaining attraction in new applications with increasingly processable materials with better electrical and physical properties and lower costs. The new nanostructured forms of conducting polymers particularly, augment this field with their higher surface area and better dispersability.

With the availability of stable and reproducible dispersions, PEDOT and polyaniline have gained some large scale applications. While PEDOT (poly(3,4-ethylenedioxythiophene)) is mainly used in antistatic applications and as a transparent conductive layer in form of PEDOT:PSS dispersions (PSS=polystyrene sulfonic acid), polyaniline is widely used for printed circuit board manufacturing – in the final finish, for protecting copper from corrosion and preventing its solderability.

IV. Conclusion

There is no uncertainty that electronic textiles and smart apparel will upgrade quality of life inventively on a daily basis. The eventual goal of an e-textile is to look, feel, and behave like standard textiles while providing electronic functions. Compared to the apprehensions related to the electrical properties of e-textiles, mechanical properties have been largely abandoned so far. Besides flexibility and washability, there must be other significant mechanical properties such as breathability, drapability, or surface properties. More consideration must be made to mechanical properties in order to produce practicable e-textiles and commercialize them for smart clothing applications. One of the issues for sustainable development of e-textiles in the future is standardization. There have been no standard testing methods and specified requirements for e-textiles. Conventional test methods would be good bases, and alterations might be required after taking the physiognomies of e-textiles into consideration. Standards and necessities should be developed in a way that covers the multidisciplinary features of e-textiles as textiles, as electronics and as computers. More concerted works relating these three research fields are essential.

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REFERENCES

http://www.sciencedirect.com/science/article/pii/S0379677904002735

http://onlinelibrary.wiley.com/doi/10.1002/app.30652/abstract;jsessionid=0E29829338617DF9493D0E94905265DF.f03t04?userIsAuthenticated=false&deniedAccessCustomisedMessage=

https://en.wikipedia.org/wiki/Polypyrrole

https://en.wikipedia.org/wiki/Conductive_polymer

http://www.textileworld.com/Articles/2010/June/Textile_News/E-Textiles_For_Wearability-Review_On_Electrical_And_Mechanical_Properties

Int. J. Electrochem. Sci., Vol. 6, 2011 5732

[1] Lüttgens, G. Collection of Accidents Caused by Static Electricity Journal of Electrostatics 16 (2 – 3) May, 1985: pp. 247 – 255.

[2] Alekseeva, L. V. Theoretical Aspects of Predicting the Electrostatic Properties of Textile Materials Fibre Chemistry 39 (3) 2007: pp. 225 – 226.

[3] BorisMahltig, TorstenTextor. Nanosols and Textiles.World Scientific, 2008: 224 p.

[4] LST EN 1149-1:2006. Protective clothing – Electrostatic properties – Part 1: Test method for measurement of surface resistivity.

[5] LST EN 1149-2:2006. Protective clothing – Electrostatic properties – Part 2: Test method for measurement of the electrical resistance through a material (vertical resistance).

[6] LST EN 1149-3:2006. Protective clothing – Electrostatic properties – Part 3: Test methods for measurement of charge decay.

[7] Stankutė, R., Grinevičiūtė, D., Gutauskas, M., Žebrauskas, S., Varnaitė, S. Evaluation of Electrostatic Properties of Fiber-forming Polymers Materials Science (Medžiagotyra) 16 (1) 2010: pp. 72 – 75.

[8] Chinese Textiles in Professional Standard FZ/T01042-1996 – The Testing of Static Properties and Static Voltage's Semidecay of Textile Materials.

[9] Chinese Mandatory National Standard BG/T12703-91 – Static Electricity's Testing of Textiles.

[10] Dascalescu, L., Plopeanu, M., Tabti, B., Antoniu, A., Dumitran, L.-M., Notingher, P-V. Corona Charging of Composite Non-Woven Media for Air Filtration Proc. ESA Annual Meeting on Electrostatics Paper D3 June 22 – 24, 2010: pp. 1 – 7.

[11] Lozovski, T., Montrimas, E., Maldžius, R. Investigations of Charging and Discharge in the Dark of Organic Electrographic Photoreceptors Synthetic Metals 109 (1 – 3) March, 2000: pp.195 – 198.

[12] Žilinskas, P. J., Montrimas, E., Lozovski, T. Measurement of Dielectric Layer Parameters by the Method of Periodic Charging of the Layer Surface Technical Physics 51 (10) Pleiades Pub. Inc. (USA) Springer Science, October 2006: pp. 1372 – 1378.

[13] Žilinskas, P. J., Lozovski, T., Jurkšus, J. Electrostatic Properties and Characterization of Specific Polymeric Materials for Building Purposes Materials Science (Medžiagotyra) 16 (1) 2010: pp. 57 – 62.

[14] Giacometti, J. A., Fedosov, S., Costa, M. M. Corona Charging of Polymers: Recent Advances on Constant Current Charging Brazilian Journal of Physics 29 (2) June, 1999: pp. 269 – 279. http://dx.doi.org/10.1590/S0103-97331999000200009

[15] Varnaitė, S. The Use of Conductive Yarns in Woven Fabric for Protection Against Electrostatic Field Materials Science (Medžiagotyra) 16 (2) 2010: pp. 133 – 137.