REVIEW ARTICLE

Development of antistatic finish in textiles

Usha Sayed*, Kanchan Sharma
Department of Fibres and Textile Processing Technology,
Institute of Chemical Technology, Nathalal Parekh Marg, Matunga, Mumbai-400019, India

ABSTRACT: Static electricity is a common problem in the world of polymers, which themselves act as electrical insulators. Static electricity causes the surfaces to pick-up dust or to stick to each other. A more dangerous consequence is its sudden discharge which, for example, can lead to a dust explosion. This paper suggests the remedies such as the addition of an antistatic agent to the base polymer. This lowers surface resistivity to such a level that the static charge can easily get dissipated.

KEY WORDS: Antistats, Plasma, Nano finish, Synthetic fibre.

INTRODUCTION

The primary role of an antistatic agent is to prevent generation of electricity within the different textile materials. Static electricity is generally developed either due to extra electron or due to deficiency of electron, these inequalities can be generated by separation or friction of two materials or through induction processes particularly due to contact with ionized air. These inequalities are either due to separation or by friction of two material or through induction processes, and is particularly due to contact with ionize air. Static electricity can be generated during processing; transportation and handling are also in the final end use of the textile material. Once the charge is generated, dissipation of the charge is dependent on the nature of the materials involved and the surrounding conditions [1].

This phenomenon affects the polymer, mainly due to the fact that they have very high volume resistivities (p_v) in the range 10^{14}- 10^{18} Ω-cm and are therefore good insulators. Depending on the materials involved as well as the ambient conditions such as relative humidity, the induced charge generation can reach up to 30,000-40,000 volts.

The accumulated electrostatic voltage can be discharged via an arc or spark by contact with another material possessing sufficiently different potential. There are many causes connected with the problem of static electricity. Electrostatic discharge in the polymer industry is very common and hence the role of electrostatic agents is very important [2].

- In production: clinging effects during sheet extrusion or during fibre spinning can occur.
- In the packaging industry: problems with the loading of bags with dry materials, particularly powders, damage of packaged goods due to electrostatic discharge.
- Transportation: problems with feeding liquids or powders through plastic tubes or funnels, as well as liquids in plastic bags or bottles
- Accumulation of dust on plastic articles, which is not only a nuisance, but also a problem during the storage of end-use articles and causes electrostatic discharge [2].

In order to overcome these problems the most practical solution is to lower the surface resistivity of the plastic to a value below 10^{14} Ω/sq. by using an antistatic additive, conductive fillers, plasma, flame or corona treatment, conductive coatings or metal deposition [3].

ANTISTATIC TEXTILE:

Antistatic finishes are generally applied when the antistatic nature of the substrate is to be maintained for a longer time, antistatic can be applied to the textile material either by coating, finishing or as an addition in the polymer dope itself. Antistatic agents are added to the bulk of the polymer forming a pathway for the charges to flow from the polymer surface to ground.

External antistatic agents are applied externally from solutions to the textile surface through a variety of methods including padding baths, spraying, plasma grafting, vapor deposition, coating, finishing etc. External antistatic agents have hydrophobic and hydrophilic functionalities in their molecular structure. The hydrophilic part orients itself towards the air and promotes the absorption of moisture, resulting in better ion mobility and dissipation [4].

NON-DURABLE FINISHES:

Non-durable antistatic agents are used to treat textile substrates that will not undergo repeated or any laundering in their lifetime. These include products like conveyor belts and driving cords.

More common non-durable antistatic finishes are anionic in nature and include compounds like esters of phosphoric acid, alkyl phosphates, ethoxylated secondary alcohols, glycerol mono- and distearate, sodium alkyl sulfonates, neutralized alcohol phosphate, sorbitan monolaurate and sorbitan monooleate etc [5].

The important industrial processing methods of applying amine antistats include extrusion, calendaring, immersion, dipping, compounding, blow molding, sheet extrusion, spraying, surface printing etc. It also includes non-ionic compounds, these are mostly ethoxylated fatty esters, alcohols and alkylamines. The ethoxy groups provide good hydrogen bonding.

DURABLE ANTISTATIC FINISHES:

Conventional durable antistatic finishes are obtained by forming a functional polymer network on the surface of the

**Corresponding Author:* *ushatxt@gmail.com*
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substrate. The polymer network has hydrophilic groups that assist in the dissipation of any charge. The polymers can be formed prior to application on fabrics or they can be formed on the surface of the substrate itself [6].

MIGRATING & NON-MIGRATING ANTISTATIC ADDITIVES:

Excellent antistatic properties with strong ultrasonic welding performance and high moisture permeability can be obtained using antistatic additives. Potential applications include packaging for pharmaceutical and cosmetic products, electrical components, food and drink as well as pallet packaging [10].

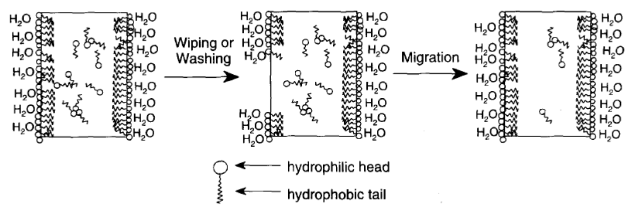

Figure 1Migration of internal antistatic additives in a polymeric matrix

Non-permanent antistatic agents are typically based on hygroscopic compounds with a low molecular weight, such as glycols, sulphonates or amides. They are more-or-less incompatible with the base polymer and therefore migrate to the surface once the final product is formed. The result is the formation of a thin surface layer, which, with sufficient air moisture, absorbs water to become conductive. The speed of migration to the surface will depend on the chemical structure of the molecules. Fig-1The antistatic effect is not permanent, as the content of the antistatic agent in the polymer will decline after time. Permanent antistatic agents are usually based on polymers [11]. during processing they form a co-continuous network within the polymer which they need to render antistatic. Consequently it is functional almost immediately and without activation time and the network formed allows negligible migration to take place. This brings with it two major benefits namely:

- The antistatic effect remains over time, if the agent is not consumed.
- The effect limits itself to the intended, specific layer of the package. The agent does not have a negative effect on the packaging content. Even if the material is used for decoration the adhesion properties of the surface is not effected [12].

Common permanent antistatic agents are based on polyamide or polyesters and are therefore incompatible with polyolefin, which may have a negative effect on processing but, the newly-developed permanent antistatic agent based on an ethylene ionomer chemistry such as Entira™ ASMK400 from DuPont eliminates this problem [13].

APPLICATION OF PLASMA ON POLYESTER:

To improve antistatic behavior of polyester fabric low temperature plasma technique can also be used. As we know Plasma treatment has been used in the aerospace, semiconductor, and electronic industries for years in cleaning, etching and surface treatment for various materials [14, 15].

Using this technique modification of some polymeric surface can be done. New properties can be incorporated in the polymer only after altering the atomic layer of the polymer. Low temperature plasma technique is regarded as an environmentally friendly process because no chemicals are involved or released in the treatment. LTP only does etching and oxidation on the surface of textile material, hence surface properties are modified along with those which associates with the surface characteristics [16,17]. Short time exposure to plasma could greatly reduce the charge density of the fabric. For the further improvement in the antistatic behavior of polyester fabric treatment with Poly vinyl alcohol can be done after application of low temperature plasma.

ANTISTATIC NANO FINISHES:

Synthetic fibers such as Nylon and polyester absorb less water because of which these are prone to static charge accumulation. It has been reported that nano sized TiO2, ZnO whiskers, nano antimony-doped tin oxide (ATO) and silane nanosol can also be used to impart antistatic properties to synthetic fibers. TiO2, ZnO and TiO2 nanoparticles are electrically conductive in nature and can be used to dissipate the static charge in these fibers [18].

Modifying textiles by numerous nano-sized particles (TiO2, silica, iron oxide, zinc oxide, etc.) is one approach for enhancing and/or imparting new functionalities to various types of fibres and forms of textile materials, i.e. improved thermal stability and flame-retardancy [19,20] water repellent properties [21,22] easy to clean properties [23-25]. These protective properties, e.g. UV and EMR shielding [26,27], antimicrobial activity [27,28] etc. Various methods are being employed in order to create multifunctional nano-textiles and are generally classified into three groups as described below: [29].

(i) Inclusion of nanoparticles within the fibres,
(ii) Chemical grafting of nanoparticles onto the surface of fibre, and
(iii) Functional nano coating of textiles' surfaces.

In order to prepare nano coated textile materials, there are certain distinct methodologies including coating by the dispersion of well-defined Nano-oxides [20,26,28], functionalization by inorganic sol gel coating [19, 22, 29, 31], the layer by layer deposition method [32-33] and embedding the nanoparticles on the fibres' surfaces by crosslinking agents such as water-based polysiloxane emulsion [34] and (poly) carboxylic acid [21,35]. These developed technologies should offer desirable levels of material functionality and furthermore, should meet environmental and economic demands.

From amongst a number of nanoparticles of various sizes, shapes, and structures, inorganic TiO_2 has received increased interest over recent years for the functionalizing of textile materials because of its excellent optical properties, good thermal stability, long-term lifetime, lack of toxicity, and relatively low-cost, as proved in [24, 26, 28, 30]. Moreover, nano-sized TiO_2 particles show high photocatalytic activity when applied onto the surfaces of different materials, because they have a relatively large surface area per unit mass and volume, which facilitates diffusion of the surface, and generates charge-carriers under light irradiation [25]. These so-called self-cleaning or easy-cleaning textile materials provide promising applications for medical and protective purposes, domestic textiles, technical textiles, interior decorative coverings, the furnishings of public buildings, filters, etc.

In addition, due to its capability of absorbing UV and transmitting visible light, TiO2 is already being employed as a UV-filtering substance in sunscreen cosmetics, as well as for the production of sun protective clothing against the sun. [27,36].

LABORATORY TESTING OF ANTISTATIC FINISH:

Temperature and relative humidity are the important parameters to be kept in control for the evaluation of antistatic finish, relative humidity affects the antistatic property of the fabric since the resistivity of the fibre depends on its moisture content. The higher the relative humidity, the higher the moisture content and the lower the resistivity.

Mostly electrostatic test methods can be divided in three main categories:

- measuring the cling time
- the electrical resistance or the electrostatic voltage or charge
- often as half-life time

Quantitative results can be obtained with AATCC Test Method 115: 'Electrostatic clinging of fabrics: Fabric to metal test', also known as the 'cling' test. A fabric that has been electrically charged in a repeatable manner by rubbing is placed next to a grounded inclined metal plate. Any residual electrical charge causes the fabric to cling to the plate. The time required for the fabric to be released from the plate is measured. Shorter the cling time, better the antistatic properties.

However, fabric-to-metal cling times are not directly related to fabric-to-body cling times [37].

AATCC Test Method 76: 'Electrical resistivity of fabrics' is used to measure the surface resistivity of fabrics (units are ohm/square). The voltage drop across a ring electrode system is used to determine the fabric's resistivity. A resistivity value of 1011 ohm/square or lower is considered to be indicative of a fabric with negligible static propensity. [38]

Table 1 shows a common assignment of surface resistivity values to practical usage of the finished textiles at 65% relative humidity (corresponding to DIN 54 345-1: 'determination of electrical resistance').

A charge generation test for carpets is given in AATCC Test Method 134: 'Electrostatic propensity of carpets'. The body voltage of a person wearing shoes with standard neoprene or leather soles is measured as they walk across a carpet. The maximum voltage after 30–60 s is recorded. Again, the lower the voltage, the better the antistatic properties [40].

Properties that are measured include surface resistance, static decay and dust pick-up after generating static electricity on the finished piece. The latter was measured by rubbing the testing object against a cotton cloth before bringing it in contact with Bonita Flakes (fish flakes).

Table 1 Surface resistivity and practical use of antistatic finished textiles [39]

Surface resistivity range (Ω)[a]	Assessment
$1 \times 10^6 - 1 \times 10^8$	Very good
$1 \times 10^8 - 1 \times 10^9$	good
$1 \times 10^9 - 1 \times 10^{10}$	Satisfactory
$1 \times 10^{10} - 5 \times 10^{10}$	Limit of sufficiency[b]
$s > 5 \times 10^{10}$	Insufficient

[a] Normal climate with 65 % relative air humidity.
[b] Need for more control and detailed specification

Table 2 Field intensity half-life time and practical use of antistatic finished textiles [39]

Field intensity half-life time (s)[a]	Assessment
0–0.3	Very good
2-Jan	Good
3-Feb	Satisfactory
3-Feb	Sufficient[b]
> 3	Insufficient[c]

[a] Normal climate with 65 % relative air humidity.
[b] Need for more control and detailed specification.
[c] Absolute times for change of charge are an additional helpful criterion for the selection of antistats.

Fig 2 The amount of antistatic agent used for these tests varies in between 10 - 30 wt. % In polyethylenes, the desired low surface resistance and required low static decay time could be achieved with additive levels between 15 and 20 wt% (measured at 50% RH)[41].

The newly developed ethylene ionomer chemistry is in conjunction with a variety of polymers, ranging from polyethylene (PE) and polypropylene (PP) to ethylene-copolymers (EMA and EVA) to engineering polymers (ABS and polyamide). Polymer processing methods employed included blown film, extrusion blow moulding, injection moulding and roll mill mixing [42].

The additive even when applied to the thin outer layer of polymer gives the performance of the complete surface during testing. The new permanent antistatic agent maintains most of its performance down to humidity levels of approximately 30%RH [43].

Properties	Test method	Units
Density	ISO 1183-1987	Kg/m^2
Melt flow Rate	ISO 1133-1997	g/10min
Melting point	DSC	C
Vicat softening point	ISO 306-1994	C
Tensile strength @ break	ISO 527-2-1993 type 1BA bars, 2mm thick	MPa
Tensile elongation @break	ISO 527-2-1993 type 1BA bars, 2mm thick	%

stiffness	ASTM D747	MPa
Hardness, Shore D	ISO868-1985	-
Surface resistivity At 23 C X30% RH At 23 C X50% RH	Ω/sq.	Ω/sq.

Figure 2 Test performed to check effect of additives as permanent antistatic agent

TROUBLESHOOTING FOR ANTISTATIC FINISHES AND PARTICULARITIES:

The performance of most antistatic finishes depends on the kind of fibre and sometimes also on the kind of fabric (anisotropic behaviour, for example, different in warp and weft directions). Although wool is a hydrophilic fibre, wool fabrics often are highly charged, caused by the strong friction between the wool scales.

For optimal performance uniform penetration for fabric is important while applying antistatic finish. The use of wetting agents in the finish formulation is recommended. Pad, spray and kiss-roll applications are preferred method of application. In exhaust method cationic antistats are suitable Spray and foam applications are enabled by the low add-on values (mostly about one or a few percent on weight of fibre). With identical add-on, padding leads to lesser affects than does foam application [44].

This is probably caused by the higher concentrations of antistatic agents on the fibre surface by the foam application. On the other hand, the durability of the padded finish might be greater.

Some of the potential side effects of the use of antistatic finishes include wear comfort (no clinging and a pleasant skin contact caused by hydrophilicity), soil release properties, increased soiling with dry soil, yellowing after exposure to heat and impaired crock fastness of textiles dyed or printed with disperse dyes. The permanence of antistatic finishing effects to repeated washings, even at only 40°C, is limited, as the mechanical stress of the washing process decreases the antistatic performance significantly. So the washing and the abrasion resistances of antistatic finishes are crucial [45].

DEVICES USED TO MEASURE STATIC CHARGE GENERATION AND DISSIPATION OF CHARGES:

To access testing is being done under controlled environmental condition such as humidity and temperature. Some devices are as follows which are used to measure static charge generation and dissipation of charges. Tribo Electric Tester (Fig-3) is used to measure static charge and dissipation on polymeric two-dimensional surfaces using simple repeated contact and separation, Tribocharge Tester (Fig-4) device is used to measure static charge and dissipation on two-dimensional surfaces using repeated rubbing cycles and the Contact and Rubbing Testers (Fig-5) is a device used to measure static charge and dissipation on yarn surface) [46].

CONCLUSION:

The literature has revealed that development in conducting polymeric materials such as polyaniline, polypyrole and polythiophene has been evolving due to their durability, weight and cost advantages. Durable antistatic chemicals and the fabrics containing conductive materials can be replaced by conducting polymers, functional materials like conductive nanomaterials, carbon nanotubes, graphene etc. [47], these are some new developments in the field of antistatic finishing of textiles. New technique like ecofriendly plasma treatment at low temperature is being given to polyester to modify the polymeric surface to impart new functional properties to the polymer and it involves no chemicals and also no chemical is released. It is also interesting to have electrically conducted nanoparticles on synthetic fibres to impart good antistatic behavior and much of the recent research is in this direction [48].

Finally, there has been an increase in facilities capable of manufacturing bicomponent and indeed tricomponent fibres. This not only increases the possibility of having splittable fibres and thereby instantly creating a lot more surface area, but also gives greater potential for creating multicomponent fibres which could potentially have conductive components incorporated into the fibre. Such fibres would find use in applications for either generating or suppressing static electrification.

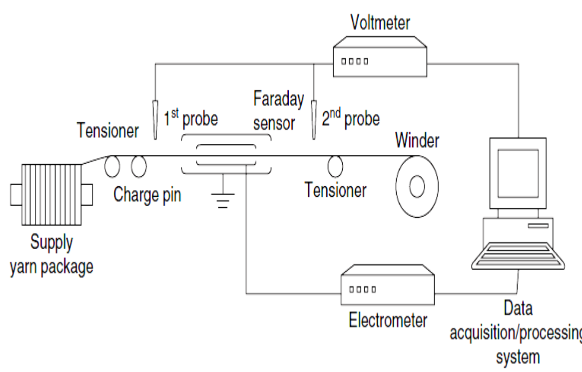

Figure 3 Triboelectric Tester

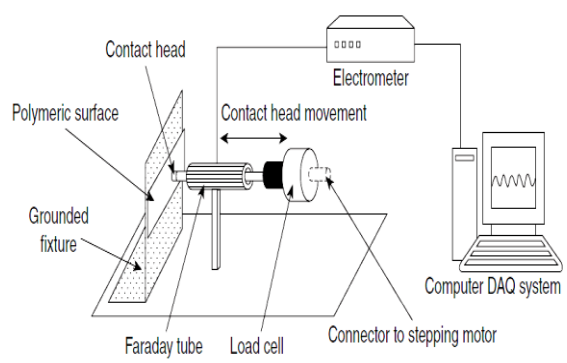

Figure 4 Tribocharge Tester

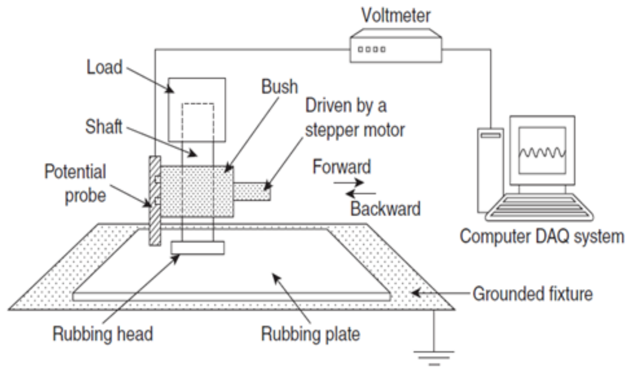

Figure 5 contact and Rubbing Testers

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