Journal of Environmental and Applied Bioresearch
Published online February 20, 2015 (http://www.scienceresearchlibrary.com)

ISSN: 2319 8745
Vol. 03, No. 1, pp. 25-32

Review Article **Open Access**

Polymer metal oxide composites on textile applications

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Received: January 02, 2015 / Accepted: February 18, 2015

Abstract

Composite materials are often used for different purposes in military applications. The composite materials provide interesting results especially through their strength, corrosion resistance, low specific weight and other properties. The composite materials have various structures and any defect in these materials is more complicated. Nanotechnology is booming in an unprecedented way in creating its impact in various applications. Metal oxide nanoparticles (MONPs) such as TiO_2 and MgO are currently used as potential catalysts for the decontamination of chemical and biological warfare (CBW) agents. Various textile substrates, chemical agents, polymerisation techniques and functional applications in defence area are reviewed in this article.

Keywords: Composites, polymers, metal oxides, nanotechnology, defence, fabrics.

Introduction

Textile fibers such as Kevlar, Nomex and Nylon find applications in protective garments for military personnel. High strength, antiballistic and flame retardancy are some of the vital properties that make the fiber suitable for defence and other high-tech applications. Specialty chemicals and coatings enhance the performance of protective fabrics. Non-woven materials such as spun-bonded and melt-blown fabrics are mainly used for the manufacture of protective wears like barrier protection and fire-retardant fabrics. The advantages of using these fabrics, as against the conventional fabrics, lie in their low cost, improved barrier properties, impermeability to particulate matter, adequate strength and comfort properties. There is a growing interest in the use of fine fibers such as micro and nanofibers for specialty applications. The protective clothing made up of fine fibers and their composites give high performance, functionality, comfort, longer life span, less weight and size.

The Defence Research and Development Organization (DRDO) sector has identified certain research areas under Technologies for soldier support. They include Sensors for weapons and Electro-mechanical triggering, Miniaturized Air burst Fuze, Recoil mitigation techniques, Miniature monocular ICCD camera for weapon and helmet, Miniaturised Diode laser based LRF (Little Rock Air Force Base), Fire proof Fabric, micro-porous coated fabric for breathability, multi layered and silver impregnated fabric for Nuclear Biological Chemical protection and Fabrics with low reflectance value with that of surrounding (UV, Visible, IR). Perusal of literature reveals that nanocomposites have been used in textile substrates (cotton, silk, wool, nylon, polyester, lycra, viscose) for soldier support applications.

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i) Textile substrates studied

Cotton

Polypyrrole was prepared using cyclic voltammetry method and coated on cotton to make the fabric electrically conductive in the range of 0.2-15 S/cm (Bhadani et al., 1997). Conductive polymer-coated fabrics were prepared by admicellar polymerisation method using polypyrrole, polyaniline and polythiophene on cotton. Polypyrrole-coated fabric showed resistivity around 10^6 Ohm (Lekpittaya et al., 2004). Antistatic cotton fabrics were developed for applications such as antistatic carpets, filters, hygienic hospital apparels and these fabrics showed improved electrical conduction about 3-8 orders of magnitude (Seshadri et al., 2005). Cotton coated with polypyrrole by vapour and liquid phases showed increase in heat resistance property (Hossein et al., 2005). Polypyrrole was deposited electrochemically on cotton fabrics with water soluble adhesive and the conductivity, surface structure of the resultant polymer showed template dendrite growth (Subianto et al., 2005). Polypyrrole on the surface of cellulose fibers decreased the electrical resistance of bulky polypyrrole/cellulose compounds with degradation of cellulose fibers (Benventi et al., 2006). Conducting cellulose was prepared using polypyrrole and the resulted polypyrrole-cellulose conducting composite showed good light and washing fastness (Dall Acqua et al., 2006). Conductive cotton yarns prepared by vapour polymerisation have the optimum specific resistance of $1.53\Omega g/cm^2$ (Kaynak et al., 2008). Cotton coated with polypyrrole showed a conductivity of 6.4×10^{-4} S/cm (Amirhossein Esfandiari et al., 2008). Electrically conductive fabric prepared by deposition of thin films of doped polypyrrole on the surface of cotton by in-situ oxidative chemical polymerisation finds application as technical textiles with antistatic (low electrical resistance) heat generation, hygroscopic, antibacterial and high temperature resistance properties(Varesano et al., 2009). The structural, electrical and electromagnetic properties of cotton fabric coated with polyaniline and polypyrrole was investigated. The resistance value of cotton fabrics coated with polyaniline and polypyrrole was 350Ω and 512Ω respectively. Fabric coated with conductive polymers had excellent UV protection properties(Onar et al., 2009). Electrochemically coated cotton fabric with polypyrrole produced thicker films of globular microstructure with conductivity in the range 1.9×10^{-2} – 3.3×10^{-1} S/cm(Babu et al., 2009). Electrochemical polymerisation of cotton yarn was studied by using Box-Behnken design of experiments in conjunction with response surface methodology of analysis (SyamalMaiti et al., 2012).

Silk

Silk substrates in various forms such as spun silk tops, non-woven web, yarn and fabric were coated with electrically conducting doped polypyrrole by in-situ oxidative polymerisation and characterised by optical, SEM, FT-IR, DSC and TG analyses. The coated silk material showed excellent electrical properties. After exposition to atmospheric oxygen for 2 years, a residual conductivity of 10-20% was noted (Boschi et al., 2008).

Wool

Wool yarns were coated with polypyrrole by chemical synthesis. The changes in tensile strength, moisture absorption, and electrical properties of the coated yarns were studied. The results showed higher tenacity and higher breaking strain (Kaynak et al., 2002). Wool fiber coated with polypyrrole showed good electrical, thermal and fastness properties(Varesano et al.,2005). Polypyrrole coated wool yarns showed specific electrical resistance of 2.96Ω (Najar et al., 2007). In-situ polypyrrole synthesis on wool by preliminary oxidative treatment (shrink-proofing, bleaching or depigmentation) improved the conductivity of the resulting conductive composite (Varesano et al., 2009).

Nylon

Polymerisation of pyrrole on nylon was tested(Kuhn et al., 1997). Polypyrrole on nylon-6 woven fabric resulted into polypyrrole-nylon-6 composite with high electrical conductivity. The electromagnetic interference (EMI) shielding efficiency was in the range of 5-40 dB that depended on sequence of the conductive fabric (Kim et al., 2003). The feasibility of controlling polymer flammability properties of nylon-6 clay-nanocomposite was studied. The fire retardant properties of the materials, organic-inorganic nanocomposites were observed. The nanocomposite enhanced the performance of the reinforcement of the charred layer (Gilman et al., 1997). Temperature changes in conducting polypyrrole/p-toluene-2-sulphonic acid coated nylon by microwave method in the range of 8-9 GHz and 15-16 GHz frequency was noted that a temperature difference of around 4˚C in the conducting fabric relative to ambient temperature as 48% absorption and 26.5±4% reflection(Kaynak et al., 2009). Effect of methyl red dye, bulk/nano TiO_2 on antistatic and antiflammable properties of nylon was tested. The coated material showed improved antistatic and antiflammable properties (Vinothini et al., 2009). Polyletrafluoroethylene and their composites coated aramid fiber showed increased friction coefficient (Wang et al., 2009).

Polyester

Polypyrrole coated polyester was prepared for gas sensing capabilities. The change in conductivity was reversible and the magnitude of the change decreased with time (Kincal et al., 1998). Polypyrrole doped with naphthalene sulphonic acid was coated on polyester woven fabric. Electromagnetic interference shielding efficiency (SE) and DC conductivity were found to be good. The measurement frequency was ranged from 50 MHz to 1.5 GHz (Hong et al., 2001). Polypyrrole and silver-palladium metal compound coated on polyester woven and non-woven fabrics showed EMI shielding efficiency in the range 8-80 dB measured at vacuum-evaporation and was found to be excellent radio frequency and microwave absorber indicating potential materials for military applications(Lee et al.,2002). Polypyrrole was chemically and electrochemically coated on polyester woven fabric. The EMI and SE were in the range of 36 dB over wide frequency range up to 1.5 GHz (Kim et al., 2002). The surface resistance of polypyrrole coated polyester fabrics were studied with coating thickness and the resistance decreased from 10^6 to $10^3\Omega$ with increase in pyrrole concentration (Lin et al., 2005). Polypyrrole coatings were applied on polyester fabric and the dielectric characteristic in the frequency range of 1-18 GHz was studied. The reflection contribution of electromagnetic shielding increased with polymerisation time (Hakansson et al., 2006). The chemical polymerisation of pyrrole and the polypyrrole coating on polyester showed microscopic of the fiber cross sections (Ferrero et al., 2006). The shielding effectiveness of polyester reinforced thermoplastic composites was compared with various measurement techniques (Chen et al., 2007). Polyprrrole coated woven and non-woven polyester fabric in the frequency range 100-1000 MHz was measured (Avloni et al., 2007). Presence of nanodispersed montmorillonite clay in polymeric matrices produced a substantial improvement in flame retardancy. Polylactide and thermoplastic polyurethane and their combination with conventional flame retardants were compared (Kimura et al., 2005). Polyester-polypyrrole composites incorporating different anionic dopants such as indigo carmine, p-toluene-2-sulphonic acid were heated at 60, 80, 105, 125 and 150˚C. Heating at 125˚C for 900 seconds showed a decrease of 29% resistance in polyester/p-toluene-2-sulphonic acid (Kaynak et al., 2008). The electro-polymerisation of polypyrrole/$pw_{12}O_{40}^{3-}$ and its coating on polyester showed improved coating properties (Molina et al., 2008). Thermal and flame resistance study on polyester non-wovens with polypyrrole has resulted in the reduction of temperature at thermo-oxidative degradation of polyester (Varesano et al., 2008). Aniline was polymerised by cyclic voltammetry and potentiostatic methods on polyester. The potentiodynamic synthesis of doping level was higher than potentiostatic synthesis (Molina et al., 2009). The effect of yarn count, pick, and density, type of mordant and layers of fabrics on the electromagnetic shielding properties of polyester was measured in the frequency range 100 MHz - 3 GHz. The number of apertures and thread density did not have significant effect on electromagnetic effectiveness for metallic sheets (Das et al., 2009). Polyester-polypyrrole composite fibers were prepared by chemical polymerisation and characterized by surface resistivity, density, diameter, FT-IR, TGA, optical microscope and SEM techniques (Aydin et al., 2010). The stability of polyester covered with polypyrrole/anthraquinone sulphonic acid was tested in different pH using cyclic voltammetry. The measurement showed a gradual loss of electro activity as the pH increased (Molina et al., 2010). A Composite was prepared by coating polypyrrole or poly (3,4-ethylenedioxythiophene on polyester by chemical and electrochemical oxidation. The resistivity of the composite was low 0.3 Ω cm gave rise to about 36 dB of EMI SE over the wide range of frequency up to 1.5 GHz (Kim et al., 2003).

Lycra

Polypyrrole coated lycra fibers was prepared by chemical vapour deposition method and the electrochemical behaviour of fibers was investigated. The resistance changed with applied strain, damage level of the conductive fibers (Xue et al., 2004). In the fabrication of polypyrrole coated textile substrate composed of 83% Tactel and 17% Lycra by vapour phase polymerisation, the polymerisation temperature had great effect on the sensitivity and strain sensing reproducibility (Li et al., 2005).

Other fibres

Polypropylene and viscose substrates were modified by in-situ synthesis. The influence of sp (pyrrole-functionalized silane) by the washing fastness of polypyrrole and conductivity of textile fabric was studied. Higher concentration of sp has led to improved fastness of conductive layer (WmPP-0.2sp/25py=3×10^{-5} S/square; WmPP-1sp/25py=8×10^{-5} S/square) (Micusik et al., 2007).

ii) Chemicals used

Polypyrrole: Polypyrrole is the first polyacetylene-derivative to show high conductivity, whose properties can be tuned through chemical synthesis and composite processing. Polypyrrole is used for testing the blood lithium levels of patients being treated for bipolar disorder. Polypyrrole is also being investigated in low temperature fuel cell technology to increase the catalyst dispersion in the carbon support layers and to sensitise cathode electrocatalysts. Metal electrocatalysts (Pt, Co, etc.) when coordinated with the nitrogen in the pyrrole monomers show enhanced oxygen reduction activity.

Polyaniline

Amongst the family of conducting polymers and organic semiconductors, polyaniline is unique due to its ease of synthesis, environmental stability and simple doping/dedoping chemistry. Because of its rich chemistry, polyaniline is one of the most studied conducting polymers of the past few decades. In the doped Emeraldine salt form, polyaniline is electrically conductive; this makes it suitable for the manufacture of electrically conducting yarns, antistatic coatings, electromagnetic shielding and flexible electrodes. Polyaniline is typically produced in the form of long-chain polymer aggregates, surfactant (or dopant) stabilised nanoparticle dispersions, or stabiliser-free nanofiber dispersions. Polyaniline is an ideal option for acid/base chemical vapour sensors. The different colours, charges and conformations of the multiple oxidation states also make the material highly promising for applications such as actuators, supercapacitors and electrochromics. Attractive fields for current and potential utilization of polyaniline is in antistatics, charge dissipation or electrostatic dispersive (ESD) coatings and blends, electromagnetic interference shielding (EMI), anti-corrosive coatings, hole injection layers, transparent conductors, ITO replacements, actuators, chemical vapour and solution based sensors, electrochromic coatings (for colour change windows, mirrors etc.), toxic metal recovery, catalysis, fuel cells and active electronic components such as for non-volatile memory. The most notable property is electrical conductivity resulting from the delocalisation of electrons along the polymer backbone.

Poly(3,4-ethylenedioxythiopene)

Poly(3,4 ethylenedioxythiophene) also called as PEDOT has advantages in optical transparency in its conducting state, high stability and moderate band gap and low redox potential. A large disadvantage is poor solubility which is partly circumvented in the PEDOT. Coatings with PEDOT possess high stability over different charge and discharge cycles and can be electro generated directly on a conductive support (Pt, Au, glassy carbon, indium tin oxide) in organic solvents or in aqueous solution.

Polyamide

Polyamides are commonly used in textiles, automotives, carpet and sportswear due to their extreme durability and strength. Aramid is made from two different monomers which continuously alternate to form the polymer and is an aromatic polyamide. These materials are completely insulating, and generate static electricity, cause dangerous sparks that can damage electronics in manufacturing plants and in consumer products. This has resulted in an interest in incorporation of conductive fillers such as carbon black, metals and conducting polymers. The most common conducting fillers are silver and carbon black. Both of these materials have processing deficiencies, while silver is also prohibitively expensive for applications such as antistatic.

Thermoplastic composite: Thermoplastic composites are composites that use a thermoplastic polymer as a matrix. These composites can be reinforced with glass, carbon, aramid or metal fibres. A thermoplastic polymer is a long chain polymer that can be either amorphous in structure or semi-crystalline. These polymers are long chain, medium to high molecular weight materials, whose general properties are those of toughness, resistance to chemical attack and recyclability. For instance, an advanced thermoplastic composite component can be chopped to pellet-size and injection-moulded to yield long-fiber reinforced mouldings, which can in turn be recycled at the end of their life. Another advantage of thermoplastic composites is their superior impact and damage resistance properties. Over 90% of polymers used in composites are thermosets, with thermoplastic composites still a niche market, mainly due to the difficulties in processing.

Polylactide (PLA) is thermoplastic aliphatic polyester derived from renewable resources, such as corn starch, tapioca products or sugarcanes. It can biodegrade under certain conditions, such as the presence of oxygen, and is difficult to recycle. Polylactic acid can be processed like most thermoplastics into fiber (for example using conventional melt spinning processes) and film. PLA is currently used in a number of biomedical applications, such as sutures, stents, dialysis media and drug delivery devices. The total degradation time of PLA is a few years. It is also being evaluated as a material for tissue engineering.

Dopant

A dopant is a trace impurity element that is inserted into a substance (in very low concentrations) in order to alter the electrical properties or the optical properties of the substance. In the case of crystalline substances, the atoms of the dopant very commonly take the place of elements that were in the crystal lattice of the material. There are two types of dopant materials (i) inorganic dopants and (ii) organic dopants. The inorganic materials such as metal oxides used for the doping process is termed as inorganic dopants. ZnO is a white powder that is insoluble in water, which is widely used as an additive in numerous materials and products including plastics, ceramics, glass, cement, lubricants, paints, ointments, adhesives, sealants, pigments, foods (source of Zn nutrient), batteries, ferrites, fire retardants, and first aid tapes. Titanium dioxide (TiO_2), also known as titanium (IV) oxide or titania, is the naturally occurring oxide of titanium and well-known minerals rutile, anatase and brookite, additionally as two high pressure forms, a monoclinic baddelyte-like form and an orthorhombic α-PbO_2-like form. The most common form is rutile, the metastable anatase and brookite phases both convert to rutile upon heating. Rutile, anatase and brookite all contain six coordinated titanium. Titanium dioxide, particularly in the anatase form, is a photo catalyst under ultraviolet light. Titanium dioxide can also oxidise oxygen or organic materials directly and thus added to paints, cements, windows, tiles, or other products for its sterilising, deodourising and anti-fouling properties and are used as a hydrolysis catalyst. It is also used in dye-sensitised solar cells, which are a type of chemical solar cell (also known as a Graetzel cell). Organic dopants such as *p*-toluene-2-sulphonic acid, naphthalene sulphonic acid, anthraquinone sulphonic acid are commonly employed.

iii) Polymerisation techniques employed

Chemical polymerisation: Monomer (pyrrole, thiophene, aniline etc) reacts with chemical oxidising agent (ammonium peroxydisulphate, ferric chloride etc) in a suitable solvent (acetonitrile, n-butanol, methanol, etc) to produce a polymer is called chemical polymerisation (Varesano et al., 2008).

Electrochemical polymerization

Monomer subjected to electrochemical potential application to initiate polymerisation in a suitable electrolyte (p-toluene sulphonic acid or sodium salt of anthraquione-2-sulphonic acid in acetonitrile medium, etc) to produce a polymer is called electrochemical polymerisation (Hong et al., 2001).

Chemical vapour deposition (CVD)

It is a chemical process used to produce high-purity, high-performance solid materials. In a typical CVD process, the wafer (substrate) is exposed to one or more volatile precursors, which react and/or decompose on the substrate surface to produce the desired deposit. Microfabrication processes widely use CVD to deposit materials in various forms including monocrystalline, polycrystalline, amorphous and epitaxial. The materials include silicon, carbon fiber, carbon nanofibers, filaments, carbon nanotubes, SiO_2, silicon-germanium, tungsten, silicon carbide, silicon nitride, silicon oxynitride and titanium nitride (Li et al., 2005).

In-situ polymerization

Monomers are cationically polymerised in-situ on the surface of material (fabric, yarn or fibres), provided with relatively strong chemical oxidants like ammonium peroxydisulphate, ferric ions, permanganate or dichromate anions, or hydrogen peroxide. These oxidants are able to oxidise the monomers, leading to chemically active cation radicals of the monomers used. The cation radicals thus formed react with monomer molecules, yielding oligomers or insoluble polymers. This chemical polymerisation can also occur in the bulk of the solution instead of on the surface of material, and the resulting polymers precipitate as insoluble solids. The distribution of the resulting conducting polymer between the precipitated and in-situ coated depends on many variables and varies within a broad range. For efficient coating, it is necessary to shift this distribution toward the surface of material and the bulk polymerisation should be diminished as far as possible. This can be usually achieved by choosing the reaction conditions like the concentration of solution components, the concentration ratio of oxidant to monomer, reaction temperature and an appropriate treatment of the surface of the material to be coated. Although a bulk polymerisation cannot be suppressed completely, a reasonably high yield of in-situ coating on material surface can be achieved by adjustment of the reaction conditions (SyamalMaiti et al., 2012).

iv) Applications of nanotechnology in textiles

Electromagnetic interference (EMI) and Shielding Effectiveness (SE)

EMI is a disturbance that affects an electrical circuit due to either electromagnetic induction or electromagnetic radiation emitted from an external source. The disturbance may interrupt, obstruct, or otherwise degrade or limit the effective performance of the circuit. The source may be any object, artificial or natural, that carries rapidly changing electrical currents. EMI can be intentionally used for radio jamming, as in some forms of electronic warfare, or can occur unintentionally, as a result of spurious emissions for example through intermodulation products, and the like. It frequently affects the reception of AM radio in urban areas, mobile phone, FM radio and television reception. SE is a parameter used for shielding evaluation, which is defined as the ratio between the field strength, at a given distance from the source, without the shield interposed and the field strength with the shield interposed. It shows the shielding effectiveness when using only ferrite, only copper and the combination of them. To meet different SE requirement in different situations, different material or combination can be chosen (Perumalraj et al., 2010).

Military application (stealth technology)

Stealth technology, also termed as low observable technology, is a sub-discipline of military tactics and passive electronic counter measures, which cover a range of techniques used with personnel, aircraft, ships, submarines and missiles to make them less visible to radar, infrared, sonar and other detection methods. Stealth technology has its fundamental principle, the prevention of detection by the enemy, and applies to aircraft, naval vessels and armoured vehicles. Stealth technology does not simply mean the evasion by aircraft of radar through the reduction of radar signature, but encompasses the reduction of an aircraft's visibility in other spectra, most notably acoustic, visual and infra-red (Kuhn et al., 1997).

Strain sensing

Strain sensors made from pieso-electric materials may be used in biomechanical analysis to realise wearable kinesthetic interfaces able to detect posture improve movement performance and reduce injuries. Such devices may be used to teach athletes the correct way to perform movement skills by providing real-time feedback about limb orientation (Kim et al., 2003).

Gas sensing

A gas detector is a device which detects the presence of various gases within an area, usually as part of a safety system. This type of equipment is used to detect a gas leak and interface with a control system so a process can be automatically shut down. A gas detector can also sound an alarm to operators in the area where the leak is occurring, giving them the opportunity to leave the area. Gas detectors can be used to detect combustible, flammable and toxic gases and oxygen depletion. This type of device is used widely in industry and can be found in a variety of locations such as on oil rigs, to monitor manufacture processes, photovoltaic and fire-fighting (Kincal et al., 2001).

Fire retardant

Fire retardant fabrics are textiles that are naturally more resistant to fire than others through chemical treatment or manufactured fireproof fibers. The tests used specified in building codes, such as NFPA 701, are more correctly flame resistance tests, which test a fabric's ability to resist ignition with the flame size and duration in the test conditions. The result is a comparative test, which provides a measure of the material's resistance to propagating combustion caused by small scale ignition sources. In many cases, if exposed to a sufficiently large and sustained exposure fire, the fire retardant fabrics will burn vigorously. Fabrics will burn; some are naturally more resistant to fire than others. Those that are more flammable can have their fire resistance drastically improved by treatment with fire retardant chemicals. Flame resistance is the characteristic of a fabric that causes it not to burn in air. Flame resistance is often confused with flame retardant which is a term used to describe a chemical substance that imparts flame resistance on fabric. The most commonly used test method for measuring flame resistant fabrics is ASTM D6413. The test uses an enclosed cabinet in which 12-inch long specimens are suspended vertically over a controlled flame which is impinged on the bottom edge of the fabric for 1 seconds (Varesano et al., 2008).

Antistatic

The choice of a correct antistatic is crucial and is determined by a wide range of factors such as polymer type, processing conditions and end application. By careful selection of the correct blend of antistatic ingredients, a dynamic range of products can be developed. Masterbatches can be fast acting to reduce dust attraction in food packaging and display applications and can be formulated to give longer-term effects in demanding applications such as flooring. Combinations with antiblock and slip products for use in the film industry allow cost effective and high performance to be available for polyethylene and polypropylene film extruders (Vinothini et al., 2009).

Antibacterial

An antibacterial is a compound or substance that kills or slows down the growth of bacteria. The term is often used synonymously with the term antibiotic(s) with reference to antimicrobial compounds, including antifungal and other compounds. Many antibacterial compounds are classified on the basis of chemical / biosynthetic origin into natural, semi-synthetic and synthetic. Another classification system is based on biological activity: bactericidal agents kill bacteria, and bacteriostatic agents slow down or stall bacterial growth (Onar et al., 2009).

Wear resistance

Hard bearing materials are used where the embedding of abrasive particles and self-alignment are not required and where lubrication may be marginal. The inherent nature of thermal spray coatings seems to provide additional benefits over comparable wrought or cast materials due to the porosity acting as a lubricant reservoir and the composite nature of included oxides and amorphous phases increasing wear resistance. Some coatings show relatively low macrohardness compared to their relative wrought or cast materials, but very often show improved wear resistance (Wang et al., 2009).

Surface modification by Coating

The term coating is a covering that is applied to the surface of an object, usually referred to as the substrate. In many cases coatings are applied to improve surface properties of the substrate, such as appearance, adhesion, wetability, corrosion resistance, wear resistance and scratch resistance. In other cases, in particular in printing processes and semiconductor device fabrication (where the substrate is a wafer), the coating forms an essential part of the finished product. Coating and printing processes involve the application of a thin film of functional material to a substrate, such as paper, fabric, film, foil or sheet stock. Coatings may be applied as liquids, gases or solids. Coatings can be measured and tested for proper opacity and film thickness by using a drawdown card (Najar et al., 2007).

Electrical Conductivity / Resistivity

The electrical resistance of an electrical element is the opposition to the passage of an electric current through that element; the inverse quantity is electrical conductance, the ease at which an electric current passes (Lekpittaya et al., 2004).
Perusal of literature revels that textile fabrics such as cotton, wool, silk, polyester and nylon have been utilised for the deposition/ incorporation of polymer and its composites to import varies functional applications. The summary of such applications are listed below;

Substrate	Functional applications
Cotton	Electrically Conducting fiber
	Antistatic carpets, filters, antimicrobial heating pads
	Fastness performances to washing, light exposure and dry rubbing
	Electrical and physical properties
	Improving electrical property by novel covering methods
	Electromagnetic properties of coated fabric with UV-protection
	Military application and conductivity behavior of the fabric[(45)]
Wool	Conducting fiber
	Electrical and physical properties
	Electrical and thermal properties of the fabric
	Coating yarns with low electrical resistivity
Silk	Conducting fiber
	Improving electrical property by novel covering methods
	From apparel to technical uses
Polyester	Resistivity of conductive polymer
	Gas sensing capabilities
	EMI, SE, DC conductivity of fabric
	Dielectric characteristics of coated textile using frequency
	Flame retardancy
	conductivity and stability
	Coating property and electrical behaviour
	Strain sensor
Nylon	EMI and SE shielding
	Fire retardant
	Adsorption of microwave radiation in coated textiles

Conclusion

Use of textile fabrics in defence applications have been reviewed in this article. It is concluded that only few chemical agents have been applied on few fabrics for functional applications. Research work may be extended on the exploitation of new chemical agents as composite for defence applications.

References

Amirhossein Esfandiari., (2008). PPy covered cellulosic and protein fibers using novel Covering methods to improve the electrical property. Wor App Sci J. 3(3), 470-475.

Avloni, J., Ouyang, M., Florio, L., Henn, A. R.,(2007). sparavigna, A. Shielding effectiveness evaluation of metallized and polypyrrole-coated fabrics. J. Thermoplast. Compos.20, 241-254.

Aydin, Z., Karakisla, M., Sacak, M., (2010). Preparation and Characterization of Conducting Poly (ethylene terephthalate)/ Polypyrrole Composite Fibers. J. Thermoplast. Compos. 2, 683-698.

Babu,K.F., Senthilkumar, R.,Noel, M., AnbuKulandainathan,M.,(2009).Polypyrrole microstructure deposited by chemical and electrochemical methods on cotton fabrics. Synthetic Met.159 (13),1353-1358.

Benventi, D., Alila, S., Boufi, S., Chaussy, D., Nortier, P.(2006).Polymerization of pyrrole on cellulose fibers using a $FeCl_3$ impregnation-pyrrole polymerization sequence. Cellulose, 13, 725-734.

Bhadani, S.N., MaduriKumari., Sen Gupta, S.K., Sahu, G.C.,(1997). Preparation of Conducting Fibers via the Electrochemical Polymerization of Pyrrole. Inc. J. Appl. Polym. Sci. 64, 1073-1077.

Boschi, A., Arosio, C., Cucchi, I., Bertini, F., Catellani, M., Freddi,G.,(2008).Properties and performance of polypyrrole(PPy)-coated silk fibers. Fiber. Polym. 9(6), 698-707.

Chen, H.C., Lee, K.C., Lin, J.H., Koch, M.,(2007). Comparison of electromagnetic shielding effectiveness properties of diverse conductive textiles via various measurement techniques. J. Mater. Process. Tech.192-193, 549-554.

Dall'Acqua, L., Tonin, C., Varesano, A., Canetti, M., Porzio, W., Catellani, M.,(2006). Vapour phase polymerization of pyrrole on cellulose-based textile substrates. Synthetic Met.15, 379-386.

Das, A., Kothari, V.K., Kothari, A., Kumar, A.,(2009). Effect of various parameters on electromagnetic shielding effectiveness of textile fabrics. Indian J. Fiber & Textile Res. 4, 144-148.

Ferrero, F., Napoli, L., Tonin, C., Varesano, A.,(2006). Pyrrole chemical polymerization on textiles: kinetics and operating conditions. Inc. J. Appl. Polym. Sci, 102, 4121-4126.

Gilman, J.W., Kashiwagi, T., Lichtenhan, J.D.,(1997). Nanocomposites: A revolutionary new flame retardant approach. SAMPE J. 33(4), 40-46.

Hakansson, E, Amiet, A., Kaynak, A.,(2006). Electromagnetic shielding properties of polypyrrole/polyester composites in the 1-18 GHz frequency range. Synthetic Met.156, 917-925.

Hong, Y.K., Lee, C.Y., Jeong, C.K ., Sim, J.H., Kim, K., Joo, J., Kim, M.S., Lee, J.Y., Jeong, S.H., Byun, S.W., (2001). Electromagnetic interference shielding characteristics of fabric complexes coated with conductive polypyrrole and thermally evaporated Ag. Curr. Appl. Phys. 1,439-442.

Hossein, H.S., Pairovi, A., (2005). Preparation of Conducting Fibers from Cellulose and Silk by Polypyrrole Coating. Iran polym.J. 14(11),934-940.

Kaynak, A., Hakansson, E., (2008). Short-term heating tests on doped polypyrrole-coated polyester fabrics. Synthetic Met.158, 350-354.

Kaynak, A., Hakansson, E., Amiet, A., (2009).The influence of polymerization time and dopant concentration on the absorption of microwave radiation in conducting polypyrrole coated textiles. Synthetic Met.159, 1373-1380.

Kaynak, A., Najar, S.S., Foitzik, R.C., (2008). Conducting nylon, cotton and wool yarns by continuous vapor polymerization of pyrrole. Synthetic Met.158, 1-5.

Kaynak, A., Wang, L., Hurren, C., Wang, X., (2002). Characterization of conductive polypyrrole coated wool yarns. Fiber. Polym. 3(1), 24-30.

Kim, H.K., Kim, M.S., Chun, S.Y., Park, Y.H., Jeon, B.S., Lee, J.Y., Hong, Y.K., Joo, J.,Kim, S.H.,(2003). Characteristics of electrically conducting polymer-coated textiles. Mol. Cryst. Liq. Cryst. 405, 161-169.

Kim, M.S., Kim, H.K., Byun, S.W., Jeong, S.H., Hong, Y.K., Joo, J.S., Song, K.T., Kim, J.K., Lee, C.J., Lee, J.Y.,(2002). PET fabric/polypyrrole composite with high electrical conductivity for EMI shielding. Synthetic Met.126, 233-239.

Kim, S.H., Jang, S.H., Byun, S.W., Lee, J.Y., Joo, J.S., Jeong, S.H., Park, M.J., (2003). Electrical properties and EMI shielding characteristics of polypyrrole–Nylon 6 composite fabrics. Inc. J. Appl. Polym. Sci.87, 1969-1974.

Kimura, K., Horikoshi, Y., (2005). Bio-based polymer. Fujitsu Sci. Tech. J.41, 173-180.

Kincal, D., Kumar, A., Child, A.D., Reynolds, J.R., (1998). Conductivity switching in polypyrrole-coated textile fabrics as gas sensors. Synthetic Met. 92, 53-56.

Kuhn, H.H., (1997). Adsorption at the liquid/solid interface: conductive textiles based on Polypyrrole. Textile Chemist and Colorist. 29(12), 17-20.

Lee, C.Y., Lee, D.E., Jeong, C.K., Hong, Y.K., Shim, J.H., Joo, J., Kim, M.S., Lee, J.Y., Jeong, S.H., Byun, S.W., Zang, D.S., Yang, H.G.,(2002). Electromagnetic interference shielding by using conductive polypyrrole and metal compound coated on fabrics. Polym. Adv.Technol.13, 577-583.

Lekpittaya, P., Yanumet, N., Grady, B.P., O'Rear, E.A.,(2004). Resistivity of Conductive Polymer-Coated Fabric. Inc. J. Appl. Polym. Sci. 92, 2629-2636.

Li, Y., Leung, M.Y., Tao, X.M., Cheng, X.Y., Tsang, J., Yuen, M.C.W., (2005). Polypyrrole-coated conductive fabrics as a candidate for strain sensors. J. Mater. Sci.40, 4093 -4095.

Lin, T., Wang, L., Wang, X., Kaynak, A., (2005). Polymerising pyrrole on polyester textiles and controlling the conductivity through coating thickness. Thin Solid Films. 479, 77-82.

Micusik, M., Nedelcev, T., Omastova, M., Krupa, I., Olejnikova, K., Fedorko, P., Chehimi, M.M., (2007). Conductive polymer-coated textiles: The role of fabric treatment by pyrrole-functionalized triethoxysilane. Synthetic Met.157, 914-923.

Molina, J., del Rio, A.I., Bonastre, J., Cases, F., (2008). Chemical and electrochemical polymerization of pyrrole on polyester textiles in presence of phosphotungstic acid. Eur. Polym. J.44, 2087-2098.

Molina, J., del Rio, A.I., Bonastre, J., Cases, F., (2009). Electrochemical polymerization of aniline on conducting textiles of polyester covered with polypyrrole/AQSA. Eur. Polym. J. 45(4),1302-1315.

Molina, J., Fernandez, J., Del Rio, A .I., Lapuente, R., Bonastre, J., Cases, F.,(2010). Stability of conducting polyester/polypyrrole fabrics in different pH solutions. Chemical and electrochemical characterization. Polymer Degradation and Stability. 95(12), 2574-2583.

Najar, S.S., Kaynak, A., Foitzik, R.C., (2007). Conductive wool yarns by continuous vapour phase polymerization of pyrrole. Synthetic Met.157, 1-4.

Onar, N., Aksit, A.C., Ebeoglugil, M.F., Birlik, I., Celik, E., Ozdemir, I., (2009). Structural, electrical, and electromagnetic properties of cotton fabrics coated with polyaniline and polypyrrole. Inc. J Appl. Polym. Sci.114, 2003-2010.

Perumalraj, R., Dasaradan, B.S., (2010). Electromagnetic shielding effectiveness of doubled copper-cotton yarn woven materials. Fibers Text East Eur.18, 3 (80), 74-80.

Seshadri, T.D., Bhat, V.N., (2005). Synthesis and properties of cotton fabrics modified with polypyrrole. Sen'IGakkaishi.61, 103-108.

Subianto, S., Will, G.D., Serge K., (2005). Electropolymerization of pyrrole on cotton fabrics. Int. J. Polym. Mater.54, 141-150.

SyamalMaiti., Dipayan Das., Kushal Sen.,(2012). Studies on electroconductive yarns prepared by In situ chemical and electrochemical polymerization of pyrrole. J. Appl. Polym. Sci.123, 455-462.

Varesano, A., Tonin, C., Ferrero, F., Stringhetta, M.,(2008). Thermal stability and flame resistance of polypyrrole-coated PET fibers. J. Therm. Anal. Calorim .94(2), 559-565.

Varesano, A., Aluigi, A., Florio, L., Fabris, R., (2009). Multifunctional cotton fabrics. Synthetic Met. 159(11), 1082-1089.

Varesano, A., Dall'Acqua, L., Tonin, C. A., (2005). study on the electrical conductivity decay of polypyrrole coated wool textiles. Polym. Degrad. Stabil. 89, 125-132.

Varesano, A., Tonin, C., (2009). Improving electrical performances of wool textiles: synthesis of conducting polypyrrole on the fiber surface. Text. Res. J. 78(12), 1110-1115.

Vinothini, C., Malathi, M., (2009). Application of nanotechnology in textile materials. Int. J. Nanotechnol.3(2), 83-87.

Wang, L.Q., Jia, X.M., Cui, L.I., Chen, G.C., (2009). Effect of Aramid fiber and ZnO nanoparticles on friction and wear of PTFE composites in dry and LN_2 conditions. Tribol. T.52, 59-65.

Xue, P., Tao, X.M., Kwok, K.W.Y., Leung, M.Y., Yu, T.X., (2004). Electromechanical Behavior of Fibers Coated with an Electrically Conductive Polymer. Text. Res. J. 74, 929-936.