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A Review on-Nanocomposite Coating on Textile Fabrics

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Abstract:

There has been an increasing consideration in nanotechnology during the present decade due to its enormous potential in applying and creating novel materials for enhanced properties and applications. Numerous studies were undertaken in improving the textiles and clothing properties and performances by applying nanocomposites. Microscopy technique which is a fundamental tool in nanotechnology has been widely employed for the investigation of particle size, size distribution and the homogeneity of nanocomposite coatings. This technique can also be used to investigate the properties of surface, thickness of applied nano layer and 3D morphology of the surfaces. Current microscopy methods contain a vast majority of analysis that can be applied to characterize nanocomposite coatings on the textiles. These analyses include scanning electron microscope (SEM), transmission electron microscope TEM), atomic force microscope, laser scanning confocal microscope. In this chapter, approaches to develop nanocomposite coating on textile materials are summarized and microscopy methods and analysis conducted by researchers to identify and determine the surface properties of nanocomposite coatings on the textile fibres are discussed. Nanotechnology has been involved in textile performances improvement and/or new functions for several years and has been caught enormous attention in the textile field. Nanomaterials are ultrafine materials in at least one dimension to the size of nanometer order (below 100nm).

Keywords- *Nanocomposites, Properties, Techniques, Compounds, Fabrics, Scanning,Coating.*

Introduction:

A nanocomposite coating is a material composed of in two phases, separated from one another by interface region. The material must contain the nanometer scale in at least one dimension in which the major component is called matrix. Making clothing and fabric with nanoparticles or nanofibers allows the improvement of fabric properties without a significant increase in weight, thickness, or stiffness. For example, incorporating nano-whiskers into fabric used to make pants produces a lightweight water- and stain-repellent material.The proposed method provided Poly the potential applications in smart displays for traffic warning signals, taking into account the challenge of large-scale fabrication of Poly.Blois obtained multifunctional luminescent textiles by applying for the first-time new iridium supported silica (Ir*SiO_2) compounds in the form of coating. Treated textiles displayed very promising self-marking properties together with antibacterial activity. The strong interaction between Ir complexes and silica nanoparticles enabled easy detection under UV light, both when used as coating for textiles and after release in the environment. The homogeneous distribution of such luminescent coating can be usefully exploited as a wear diagnostic tool.The synergetic mechanism of both metal-nonmetal co-doping and dye sensitization on the photocatalytic activities of TiO_2 nanoparticles under visible light irradiation was investigated. The superior photocatalytic activity of the dye-sensitized PET-Ag-N-TiO_2 composite photocatalyst was primarily due to the quick separation of photo-generated electron-hole pairs and efficient interfacial charge transfer. This not only generated more holes, but also inhibited the recombination of electron-hole pairs by the transfer of electrons to the dyed PET substrate and Ag nanoparticles. In comparison to the PET filaments coated with TiO_2 nanoparticles, the PET filaments coated with Ag-N co-doped and dye-sensitized TiO_2 nanoparticles exhibited greatly enhanced light absorption capacity, efficient separation of electron-hole pairs, and substantial photocatalytic activity in degradation of MO dye under visible-light irradiation. The proposed photocatalytic composite structure can be taken as a novel approach to design textile materials based composite photocatalysts for the photo-degradation of organic pollutants.Through a facile coating and sintering process, hybrid polymer-mediated films were made that exhibited low surface resistances of up to 10^{-4} W/sq. Furthermore, the surface resistance of the hybrid films appeared to decrease due to the interconnected network formed by the AgNPs. The results indicated that these films are promising as nano-conductors in electronic devices. Silver-based electrodes show demonstrated potential not only in biosensor ECG systems for monitoring cardiac activity, but also in functional biological applications. However, exploring the large-scale production of these films is dependent on commercial viability and uptake. The use of dry electrodes for ECG devices is an exciting application for wearable technology featuring nanohybrid films.

Preparative Methods

Sol-Gel Method:

The sol-gel method is suitable to obtain high quality films up to micron thickness and is a complementary of the physical deposition techniques. However, there are limits of sol-gel application to coating on the metallic subtracts. This method exhibits several drawbacks involving crackability and thickness limits. Sometimes also the thermal treatment may be critical. Tensile stresses develop during drying and can lead to crack formation if the film is thicker than a critical value.In case of inorganic matrix, the second phase can be added to sol-gel for inorganic nanofillers, such as the I/I coatings. In the case of organic matrix, a well-known approach to generate inorganic nanophases within an organic matrix is to utilize sol-gel chemistry. Inorganic sol-gel precursors such as silicon, titanium, aluminium, and zirconium metal alkoxides are employed in the formulation of nanocomposite coatings. A wide range of oligomers as well as low molecular weight organic compounds are often reported to be used as organic phase precursors. Under controlled conditions, silanes and organic molecules can form coatings containing silica nanoparticles or nanophases. In the presence of a coupling agent, the organic and inorganic phases can be covalently linked. Silica nanofiber formation in a system containing TEOS, methacryloxypropyl-trimethoxysilane (MAPTMS), a urethane acrylate resin, and an acrylatephenyl phosphine oxide oligomer (APPO) has been reported.

The nanofibers were shown to improve the mechanical properties of the organic matrix. By this sol-gel process, Facio and Mosquera also successfully fabricated the nanocomposite coatings containing (i) a mixture of monomeric and oligomeric ethoxysilanes, (ii) a hydroxyl-terminated polydimethylsiloxane, (iii) colloidal silica particles, and (iv) a surfactant (n-octylamine). In addition, the sol-gel method could be used in combination with the electrodeposition for incorporation of inorganic nanofillers into the organic matrix or into inorganic matrix.

Cold Spray Method:

Unlike the traditional thermal spray (gas-flame, plasma, and detonation spraying), cold spraying allows fabrication of coatings at the lower temperatures than melting points of the sprayed materials. Cold spray technique was conducted at low temperatures, so this method avoids the deterioration phenomenon of the materials such as oxidation and decomposition as well as phase transition during the process. The obtained coatings have low porosity (<1%) and low oxygen concentration. In addition, the coatings have high strength (>280 MPa) and strong adhesion (>70 MPa).

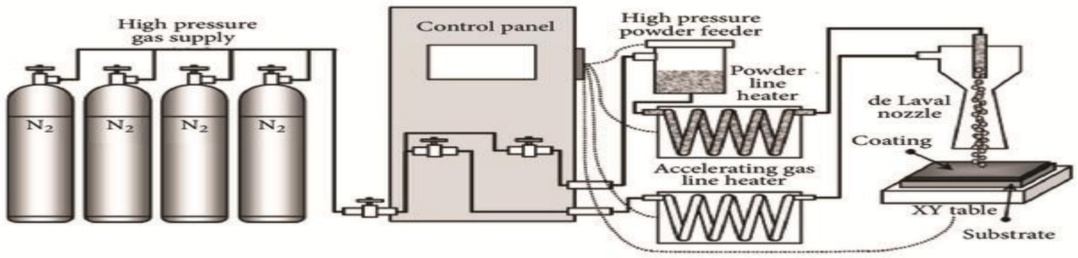

Figure-Cold spray technique

This method is used to produce the nanocomposite coating, which has metallic matrix, such as Cu, Al, Co, or alloy matrix, and its nanofillers are nitrite, carbide, boride, diamond, CNT and others. To fabricate the nanocomposite powders for this cold spray method, the mechanical alloying (MA) should be used with metallic matrix powders and other nanoparticles.

Chemical Vapour Deposition (CVD) Method:

This method usually used for the fabricating of the I/I nanocomposite coatings, which include the inorganic matrix and inorganic nanofillers. In order to improve the quality of coating, the aerosol-assisted CVD method can be used.On the other hand, the O/I nanocomposite coatings were also successfully fabricated by usingChemical Vapour Deposition CVD method with platinum (II) hexafluoroacetylacetonate as precursors.

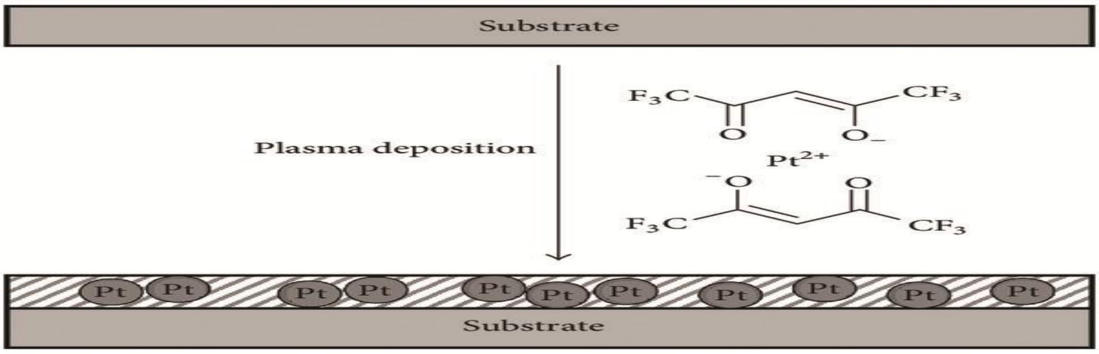

Figure- Chemical Vapour Deposition CVD method

This process allows producing a layer of nanocomposite on the organic substrate by a single step which displays both ionic and electric conductivities. The distinct advantages of this method are related to its high-quality films and its facility for any kind of complex subtracts with a good reproductivity.

Plasma Vapour Deposition (PVD) Method:

This method is used generally for producing of the I/I nanocomposite coating, which includes the inorganic matrices and inorganic nanoparticles. For these type of coatings Plasma Vapour Deposition is the main method includes the following: laser ablation, thermal evaporation, ion beam deposition, ion implantation, laser-assisted deposition, and atom beam cos puttering technique. In case of O/I nanocomposite coatings, it has been successfully fabricated the nanocomposite coating with organic matrix, by using the aerosol-assisted plasma deposition.

Thermal Spray (TS) Method:

This method is often used to make nanocomposite coatings with a matrix of metal or alloy. The spray material is a nanosized alloy powder formed by ball milling and dispersed in a suspension solution using suspensions (Thermally Sprayed and Suspension Plasma Spray Process) to conduct plasma thermal spraying.

PolymerizationCoating(PC) Method:

This method was used to fabricate the nanocomposite coatings with organic matrices, which were conducting polymer or other monomers with initiators. The nanofillers were metals or metal oxides. The polymerization takes place by using electric power (electrodeposition), oxidizing agents, or photon (photopolymerized). The similar methods are emulsion polymerization or latex emulsions for organic matrices.

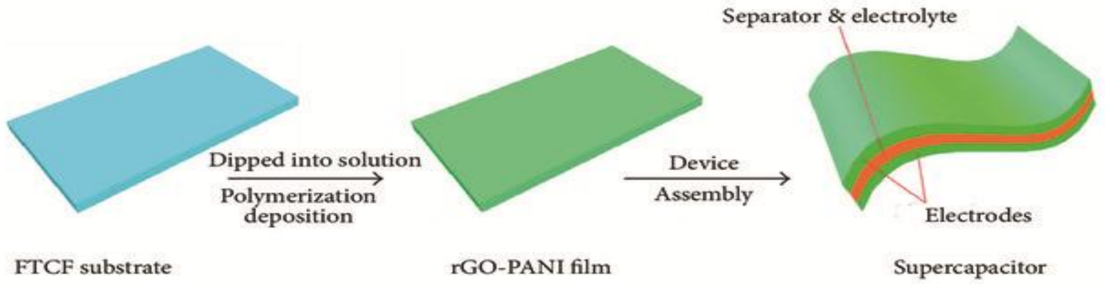

Figure- Preparation of nanocomposite coating by situ polymerization method

Electro-Less Deposition (ELD) Method:

This method is usually applied for producing the nanocomposite coatings with Niken matrix and nanofillers are carbide, nitrite, boride, or PTFE. In order to improve the hardness, anticorrosion, and anti-wear of coating, the thermal posttreatment at 500–700°C should be applied.

Electro Deposition (ED) Method:

This method could be used for the fabrication of nanocomposite coatings, which contain organic nanofillers (such as PEO, PTFE) or inorganic matrices or organic matrices.In the case of organic matrices, the electrochemical codeposition of nanocomposites has been reported by many researchers. In this paper we discussed, the various nanostructured organic-inorganic coatings using electrophoretic deposition. The author summarized various organic matrices, such as polyelectrolytes, poly(ethylene imine), which were electrochemically codeposited with metal ions as well as with ceramic nanoparticles. The electrochemical codeposition of carbon nanotubes/conducting polymers has also been reported. Other studies involved the electrochemical codeposition of oxide and metal nanoparticles, such as Ni (as matrix) and Al_2O_3 (as nanofiller). It is also observed that as a dominant organic matrix, used for the electrodeposition of nanocomposite coatings.In the case of inorganic matrices, the electrodeposition of nanocomposite coatings can be performed by using the direct current (DC), pulsed current (PC), and pulsed reverse current (PRC) methods. Among these 3 methods, the PC method provides more control on structure and properties of the coatings through this methodwe obtained coatings had better tribological and corrosion properties than ones made by DC method. On the other hand, compared with other methods, the electrodeposition technique was much easier in terms of manufacturing processes and lower cost.

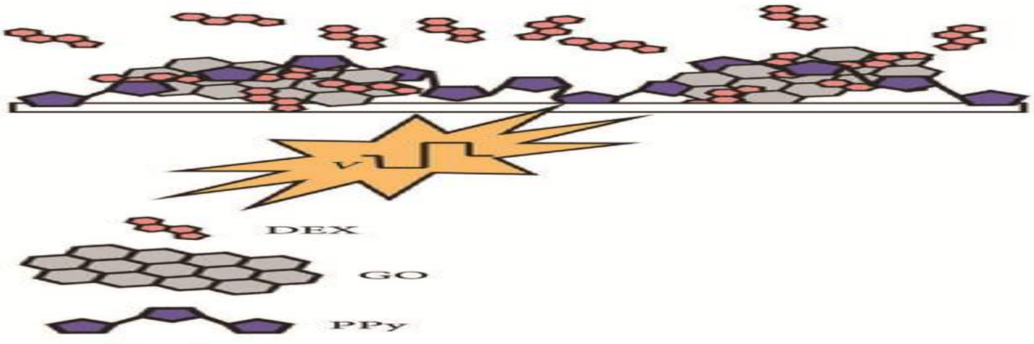

Figure-DEX release from the GO/PPy nanocomposite in response to electrical stimulation

The main advantages of this technique are related to the uniform distribution of particles, the ability of continuous processing and the reduction of waste materials. Compared to conventional coatings, nanocomposite coatings exhibit higher hardness and heat resistance due to the presence of nanoparticles in the grain boundaries, which can prevent the dislocations movement and recrystallization at high temperature. As a strong and tough metal, Nickel has been widely used as an electrodeposited metal matrix, in combining with nanofillers such as boron nitride and Al_2O_3 nanoparticles. Some authors reported that the changing duty cycle and frequency during pulsed electrodeposition can also produce nanocomposite coatings.

Solution Dispersion:

This method is mainly applied for the preparation of polymer nanocomposite coatings, reinforced with nanofillers such as metal oxides, nanoclay, and carbon nanotube (CNT). In this method, beside the use of traditional magnetic/mechanical stirring methods, the ultrasound-assisted (sonication) stirring was used for better dispersion of nanofillers into polymer matrices.

Sprayand Spin Coating (SSC) Methods:

These methods are widely used for the preparation of polymer nanocomposite coatings. In the case of spray coating, by using the atomizer, the nanocomposite coatings had better properties. The atomizer could also be used for thermal spray method, for example, atomized spray plasma deposition. In the case of spin coatings, it provides uniform thin films to flat substrates. The substrate is rotated at high speed in order to spread the coating materials by centrifugal force. This method is suitable for the preparation of thin-film nanocomposite coatings.

Dip Coating (DC) Method:

This technique is widely used in industry; the dip coating technique consists in soaking a substrate in a solution of nanocomposite and pulled up at a constant and controlled speed. The substrates are then covered with nanocomposite as it is removed from the solution. Due to the imposed pulled up rate, the amount of nanocomposite on the substrate surface is also controlled.There are two pulled out rates of the substrate, which have direct effect on the thickness of the film. At low pulled up rates, there is the capillary regime where the rate of evaporation of the solvent is greater than that of the shrinkage of the plate. This means that the shorter the shrinking speed, the thicker the film. At high pulled up rates, the trend is reversed. In this so-called drainage regime, it is the combination of the adhesion of the solution to the substrate and the gravity that forces the drainage of the solution. This causes thickening of the films as the shrinkage rate increases.The advantage of this technique is that the preparation of a flat surface is therefore suitable for all forms of coated substrates. The fact that the solution can be reused until evaporation or depletion of the solute also makes this technique particularly convenient, especially for industrial applications.

Layer-by-layer (LBL) Method:

Layer-by-layer (LBL) technique is another method for fabricating a thin layer film and is based on the concept of self-assembled nano layers. LBL process causes to enable modifying multi-composite molecular assemblies with a control on the molecular structure and a high degree of control over the thickness. There is more attraction using electrostatic self-assembled (ESA) because of the simplicity and efficiency. In LBL method, polyelectrolytes with opposite charge were alternately deposited on the fabric surface with wash steps in between. For increasing the thickness, cycles of adsorption can be repeated. LBL technique incorporated to nanomaterials was used for applying a thin nanocompposite on the fabric surface and wide range of functionalities have been imparted to fabric with LBL method.

Other Methods:

There are also several other methods for the elaboration of nanocomposite coatings but they are less popular such as the following: self-assembly (O/I coatings); layer-by-layer assembly (O/O coatings); localized laser heating, solid-state displacement reactions, ball impact deposition (for I/I coatings, resp.); and atomic layer deposition (for I/O coatings).

Characterisation:

1. Scanning Electron Microscope (SEM):

Microscopic analyses are essential in nanotechnology. Electron microscopes are one of the most common analysis instruments that use the interaction of emission ray of electrons with the sample atoms to provide magnified image. There are several types of electron microscopes according to the type of electrons that has been using for producing image. Hereon SEM and TEM are two main types of electron microscopes. Electron microscopes are precise instruments and play an important role in nanoscale systems. Electron microscopy can be employed in nanostructure imaging, composition, determine physical properties measurements and even building and manipulating nanostructures.

2. Transmission Electron Microscope (TEM):

TEM is an important technique in textile used in a wide range of applications. It has the ability to provide detailedinformation about the ultrastructre and it is applied to investigate the internal structure. For example, TEM was used to study the details of the Microcrystalline cellulose (MCC). TEM provides information on the particle nucleation, core–shell structure of the particles, crystalline nature, film thickness, particle shape, nanofiber diameter, distribution of nanoparticle through nanofiber and structure of coating. In many literatures, the shape, distribution, and particle size of nanomaterials were investigated using TEM images.

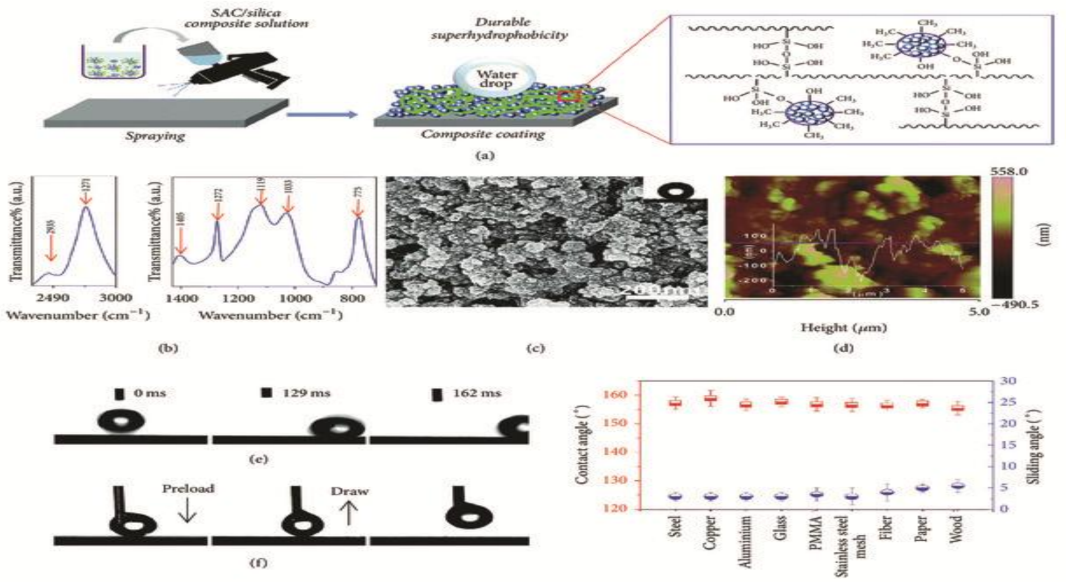

Figure: VariousCharacterisation methods of nanocomposites

Properties:

1. Effect of Nanofillers on the Microstructure and Morphology of Coatings
2. Effect of Nanofillers on the Mechanical Properties of Coatings
3. Effect of Nanofillers on Thermal Property of Coating
4. Effect of Nanofillers on the Anticorrosive and Anti-wear Properties of Coatings
5. Effect of Nanoparticles in Nonwetting Nanocomposite Coatings

Applications:

Medical Uses: Fabrics are engineered so that they can be used for drug delivery and wound healing. Silver nanoparticles possess antimicrobial properties. Therefore, silver nanoparticles are extensively used in products related to dressings for burns and scald. Nano-engineered fabrics are also used to screen heart rate, body temperature, and breathing rhythm.

Military Uses: Production of fabrics that are lightweight but show a high degree of resistance to extreme temperatures, durable, antibacterial activity, improved camouflage, water-resistant, and embedded with multipurpose nanosensors. The textiles also possess high anti-ballistic flame-retardant and RF-shielding properties. Such characteristics are ideal for military usage.

Antiwrinkle cotton fabric: For cotton fabrics, wrinkle resistance can be developed by using the nano-engineered cross-linking agents during the fabric finishing process. Besides the wrinkle resistance, such finishing is also capable of eliminating toxic gases, while preserving the preferred comfort properties of cotton.

Odor-free fabric: Application of silver nanoparticles on fabrics prevent the nasty odor caused due to the microbial activity. Many companies use fabrics coated with silver nanoparticles to develop odor-free clothing, such as stockings, socks, and undergarments. Korean-based Hyosung develops nylon fibers containing silver nanoparticles that reduce 99.9% growth of several harmful bacteria.

Water-resistant fabric: Silica nanoparticles create a water-resistant coating when inserted into the fabric or sprayed onto the fabric surface.

Ultraviolet-protective fabric: When inserted into fabrics, nanoparticles of zinc oxide or titanium dioxide protect the skin from sun damage. These nanoparticles have the ability to scatter the ultraviolet light present in the sun's rays, reducing the risk of skin diseases linked to UV exposure.

General Uses:

1. The coating is in the form of an aqueous suspension of nanoparticles based on silicon.
2. It penetrates deeply into the fibre structure and binds to them, creating a thin layer repelling water, fatty substances, dirt anti-bacteria, fungus and germs which significantly facilitates cleaning.
3. The durability of the temporary coating after a proper application is about 5 washing cycles.
4. The air permeability of the coated surface remains unchanged.
5. The product is compatible with all types of fabrics (natural, synthetic and semi-synthetic).
6. Permanent coating does not cause discolouration.
7. Guarantees the safety of use and does not burden the natural environment.
8. The product contains nano-silver, which maintains the sanitary cleanliness of the surfaces to be cleaned, reduces the growth of microbes, bacteria, fungi and mould,protects against unpleasant odours.
9. Can be used on soft furniture as a waterproof coating thatprovides the stain resistance.
10. Produced in Eco-friendly processes and biodegradable product.

Conclusions:

We tried to trace here an overview of the nanocomposite coatings in both basic fundamental and last recent developments in design, preparation, and applications of the nanocomposite coatings. With a rapid growth rate of the nanotechnology and related fields, nanocomposites coatings today become smatter, cheaper, and more functional. The domains of application of nanocomposite coatings are thus expected to be larger in the future, dealing with drug delivery systems, anticorrosion barrier coatings, antibacterial coatings, self-scratch repair, fire retardant coatings, reflective coatings, and screen effect coatings.The nanocomposite coating today not only serves as a protection for the materials but also plays other roles due to the presence of multifunctional nanofillers. Tow most popular examples can be cited, and they are antibacterial coatings and smart coatings which are used for sustainable energy fields. In the first case, the nanofillers based silver nanoparticles and their related products are very promising in the next decades. In the future, we will face many risks and challenges, especially energy problems, and the research on the sustainable energy conversion is expected to explode, in terms of both theory and experiment, and the nanocomposite coating will not stand out of this trend, for example, self-cleaning or “easy-to-clean” coatings, coated on building, protective substrates and on glass, can help save energy and water in facility cleaning while insulant nanocomposite coatings help to save the energy loss saving billions of dollars for maintaining homes in winter, especially in North America where the winter is cool and long.

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