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강 태 진
지능형텍스타일시스템연구센터, 서울대학교 재료공학부

Smart Textiles in Modern Life

Tae Jin Kang
Director, Intelligent Textile System Research Center
Professor, School of Materials Science and Engineering
Seoul National University, Seoul 151-742, Korea

Introduction

A Smart Interactive Textile System (SITS) is a textile-system that provides an intelligent environment to the user by responding to and interacting with environmental stimuli. Certain reactions to these stimuli may include conducting, transferring or distributing various properties through the material or across the membrane of the material, such as electrical current, light energy, thermal energy, molecular or particulate matter. In some cases, physical characteristics or phases may be changed, such as color, shape, size, rigidity, porosity, or permeability [1]. In this way, SITS provides an intelligent environment to it's users by protecting the wearer from harmful environmental conditions and the wearer's own health problems. To deliver these benefits of safety and comfort to the users, miniaturization of health monitoring tools and protective systems and their integration into flexible textiles should be achieved.

Technical Objectives

1. Sensor Technology

To realize smart fabrics or interactive textiles, physical detection sensors such as respiration, ECG, temperature, posture sensors and biochemical detection sensors such as blood glucose, sweat rate sensors have been developed by several research groups. Because the sensors should be incorporated in the garment unnoticeable to the wearer, an important property for sensors applied in this field is flexibility. As a fabric based biophysical monitoring solution, a piezoelectric poly(vinylidene fluoride) film sensor coated with silicon was developed for respiration and pulse detection. The mechanical to electrical conversion of the piezoelectric PVDF film sensor is used as the voltage source to detect pressure, load, acceleration, and strain. Changes in circumference during respiration generate voltage variation in the PVDF film sensor wrapped around the chest or abdomen. This variation is monitored as a function of time using voltage mode amplification circuitry. Respiratory monitoring of a patient under sedation using a PVDF film sensor was carried out [2].

A fabric based conductive polymer composite sensor can detect environmental conditions for potential risks such as toxic chemical gases. Polyaniline(PANI)-Nylon6 composite fabric obtained by *in situ* polymerization was developed for gas sensing applications. The electrical resistance of the composite fabric increased when exposed to ammonia gas but reversely recovered after flushing with fresh air. Among the dopants tested, formic acid doped PANI-nylon6 composite fabric provided the best sensing property for NH_3 gas [3].

2. Data Processing & Communication Technology

Ubiquitous data-logging and monitoring can be realized with an interactive textile based information processing system via advanced wireless technology. Bluetooth and wireless LAN are convenient technologies, and for this purpose an integrated textile antennae is essential. The user can get feedback on one's conditions and be alarmed by visual or audio means. For concealed, portable, lightweight continuous monitoring with low power consumption, miniaturization of the devices is important.

Electronic jackets coupled with iPods or cell phone devices, electroluminescent textile displays, textile-based microphones and biophysical monitoring garments are examples of interactive textile based information processing systems that are currently offered commercially.

3. Actuation and Protection Technology

As part of actuating and protecting technology for SITS, application of instantly hardening materials as soft body armor and multifunctional metal composite fabrics were researched. Liquid armor utilizing shear thickening fluid (STF) and magnetorheological fluid (MRF) on fabrics were developed. Rheological and mechanical properties of these systems were investigated and analyzed by simulations based on the 3-element viscoelastic yarn model. The STF impregnated fabrics showed recognizable improvements in spike and knife stabbing tests as well as the relatively low velocity ballistic tests whose projectile speed was around 250m/s (Figure 1). The improvement in the back ply deformation was outstanding compared to the material which was not treated with STF. On the other hand, the STF impregnated fabrics did not exhibit noticeable improvement in the knife-cutting tests and high velocity impacts whose velocity exceeds 470m/s. The strengthening effect seems to come from the increase of fabric friction. In order to bring out the maximum performance of STF, it is desirable to introduce stronger fibers than Kevlar, or to develop the material applicable for stabbing attack protection.

The energy analysis method was employed for the understanding of impact behavior of multi-ply plain-woven fabrics considering the energy of projectile. Three-element viscoelastic model was used to describe the dynamic behavior of fibers. Yarn slippage on the warp-weft crossover points was considered by updating the element length. Crimp effect was taken into account by assigning some portion of the strain to crimp. Fabric slippage on the clamped area and yarn pullout on the edge of the fabric were also considered. Bending resistance of the fabrics was assumed as the reaction force of a node arising from the curvature of the nodes. The inelastic collision of fabric layers as well as the collision with the projectile was considered. The numerical model describing all of the features was implemented as in-house code. Each of the energy dissipation mechanisms was characterized to clarify the contribution to the total energy absorption and performance of the fabrics against ballistic impacts. Three cases representing no-perforation, mature-perforation and premature-perforation were chosen to explain different energy dissipation characteristics depending on the impact velocity (Figure 2). The difference in reaction of each layer with projectile was also examined.

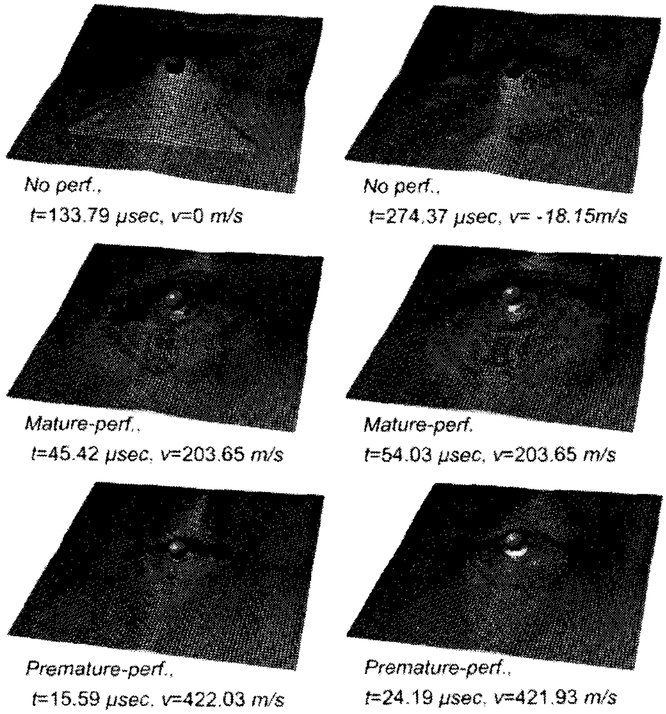

Figure 1. Deformation shapes of the 3 typical cases (initial velocity of 150, 300 and 450 m/sec, respectively)

A method for fabricating a multifunctional metal composite fabric with metal filaments was developed successfully. Metal composite fabrics were weaved in various formations and their electromagnetic shielding effectiveness (EMSE) and thermal comfort factors were evaluated. Copper/polyester and stainless steel/polyester composite fabrics were produced with silver plated copper and stainless steel filaments of 0.040mm or 0.035mm in diameter.

Plane wave shielding properties of the composite fabrics have been measured between 30~1500 MHz using the coaxial transmission line method. The parameters influencing EM shielding properties of the metal composite fabrics were investigated. Metal type, insulating coating on the metal filament, metal yarn volume fraction and the aspect ratio of the openness all affected the EMSE. The overall EMSE increased with metal content, but different frequency dependence was observed related to the aspect ratio of metal grid structure. For stainless steel composite fabrics with same openness, fabric with open grids with lower aspect ratios showed better EMSE in the lower and higher frequency range. Contrarily, fabrics with open grids of higher aspect ratios showed better EMSE in the medium frequency range. It has been shown that the EMSE of the metal composite fabrics can be tailored by modifying the metal grid size and geometry.

Thermal emissivity and thermal radiation reflectance of the metal composite fabrics were noticed as important factors affecting the thermal comfort of these fabrics. Metals are great conductors of thermal energy but the low thermal emissivity of metals reflect the thermal radiation from the body back to the body and reflect the heat radiation from the outside to keep the body cool. The effects of metal type, metal yarn densityand metal grid shape factor on the thermal comfortability of the metal composite fabrics were investigated and discussed for potential applications.

4. Integrating Technology

For SITS to be realized, inter-connections among the sensors, actuators, power source, data processing device and communication device must be established through a textile infrastructure. Materials used for conductive textiles include metallic yarns, yarns made from conductive polymers, polymeric threads containing high levels of conducting particles (carbon, silver, etc), and conducting thin inorganic films [4]. Textile processing aspects such as spinning, weaving, knitting, embroidery and finishing technology are adapted for the production of conductive textiles to form the base of this infrastructure.

A conductive composite sewing thread to be used as a textile transmission line in interactive textile systems was developed. This electrically conductive sewing thread is composed of insulated metal filaments and polyester yarns and produced on standard textile-processing equipment. Thus, it has practical advantages such as low cost and an easy application. One can just sew a transmission line onto a fabric where ever needed. The electrical and tensile characteristics of this thread were studied.

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