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Smart Textiles- On Review

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Abstract:Smart Textiles Are Intelligent Textile Structure That Can Sense And React To Environmental Stimuli, Which May Be Mechanical, Thermal, Chemical, Biological, And Magnetic Among Others. Research And Development Towards Wearable Textile-Based Personal Systems Allowing E.G. Health Monitoring, Protection & Safety, And Healthy Lifestyle Gained Strong Interest During The Last 10 Years. The Functionalities Include Aesthetic Appeal, Comfort, Textile Soft Display, Smart Controlled Fabric, Fantasy Design With Color Changing, Wound Monitoring, Smart Wetting Properties And Protection Against Extreme Variations In Environmental Conditions. This Paper Describes About Smart Textiles And Some Types Of Smart Textiles Used In Industry. It Also Describes The Current Status Of Research And Development Of Wearable Systems By Reporting The Salient Characteristics Of The Most Promising Projects Being Developed And The Future Challenges In This Area.

***Keywords:* Smart Textiles, Wearable Electronics, Passive Smart Fabric, Active Smart Fabric, Advanced Smart Fabric.**

1. INTRODUCTION

Smart Textiles Have Received A Lot Of Attention Of Research In The Last Decade For Their Use In Wearable Technologies (Marculescu *Et Al.* 2003). Smart Wearables Can Be Defined As Electronic Devices Intended To Be Located Near, On Or In The Body To Provide Intelligent Services That May Be Part Of A Larger Smart System Thanks To The Use Of Communications Interfaces. Smart Clothes Can Be Created By Embedding Smart Wearables Into Garments. Clothing Is The Only Wearable That Adjusts To Our Everyday Lifestyle Over The Course Of A Lifetime. It Represents A Strong Candidate To Become The Next Interface Between The Real And The Digital World, Replacing Or Extending Smart Phones And Other Portable Connected Devices. In Addition, Textiles Are Essentially The Ultimate Wearable Medium Since The Physics Of Fabrics And The Power Of flexible Electronics Are A Perfect Match: Form-fitting, Adaptable And Usually In Direct Contact With Our Body. Furthermore, Shirts Are More Natural To Wear Than A Wristband Or A Chest Strap, And Are Able To Track More Biometric Signals Due To The Larger Area Of Skin They Cover. Thus, Biometric Tracking Becomes Easier, Since Signals Are Picked Up Exactly Where They Happen And, Hence, It Is Possible To Maximize Their Meaning. Efforts To Research And Develop Smart Wearable Systems (Sws) Have Been Increasing In Both Academia And Industry (Lukowicz *Et Al.* 2004; Konstantas, 2007). The World Population Is Ageing, And The Proportion Of Young Workers In Developed Countries Has Been Shrinking (Muirgray, 2007; Kalache 1996). Elderly People Have A Greater Level Of Disability Due To Age-Related Diseases, A Greater Need For Care And Assistance, And Are More Likely To Be Admitted To A Hospital Or Nursing Home. Permanent Admission To A Care Home Is An Expensive Way Of Providing Care For Elderly, Most Of Whom Would Prefer To Remain In Their Own Home (Hedda Agüro-Torres, 2001; Mccann *Et Al.* 2011). For Example, Readings Of Heart Rate Signals From Body Extremities Are Very Different From Readings Obtained On The Chest. Thus, Smart Clothes Are Able To Monitor, Document, Augment And Actuate On Our Lives Providing Unprecedented Opportunities For Tackling Global Societal Challenges In Areas Like Smart And Crowd Sourced Health (Haghi *Et Al.* 2017), Ageing (Bhömer *Et Al.* 2013), Work Safety (Bonfiglio *Et Al.* 2011) Or Personal Productivity (Feito *Et Al.* 2018). Soft Sensors And Actuators Have Been Developed For Interaction With Environment, Increase Of Operator's Safety, Entertainment And Physiological Parameters Monitoring.

With Excellent Compliance, Wearable Electronics Present Broad Potential Impact To Produce A New Generation Smart Fabric, Such As Wearable Heating Devices, (Choi *Et Al.* 2015; Zhou *Et Al.* 2016), Large-Area Electronic Systems, (Qiu *Et Al.* 2019; Wu *Et Al.* 2016) Human Motion Detection, (Park *Et Al.* 2015; Choi *Et Al.* 2017) Wearable Communication Devices (Stoppa & Chiolerio, 2014; Agcayazi *Et Al.* 2018). Ideally, Wearable Computing Devices Provide Computational Capability And Also Function As The Clothing Being Worn, Such As A Sport Jacket That Can Also Monitor A Heartbeat. Electronic Textiles (E-Textiles), Fabrics That Contain Electronic Or Computational Devices, Are Perfectly Suited To Creating These Dual-Role Devices. E-Textiles Are Advanced Textiles That Include Electronic Functionality Ranging From Conductive Yarns/Tracks (Lund *Et Al.* 2018; Hardy *Et Al.* 2018) To Sensing/Actuating (Hughes-Riley & Dias, 2018; Katragadda *Et Al.* 2008; Michael & Howard, 2017), Communications (Singh *Et Al.* 2016; Grabham *Et Al.* 2018) And Signal Processing (Carey *Et Al.* 2017; Marculescu Et *Al.* 2018). The Potential For Developing Light-Weight, flexible, And Conformable Electronic Devices On Textile Products Is Very Significant. Textile Substrates Offer Tremendous Opportunities To Deploy Sensors And Other Devices, Built-In Or Embedded Into The Fabric-Based Network, To Create Large-Area Electrical And Electronic Systems (Windmiller, 2013; Brady *Et Al.* 2006).

A Variety Of Sensing And Output Devices Have Been Used Into E-Textiles Using Pressure Sensors (Helmer *Et Al.* 2012), Touch Sensitive Buttons (De Rossi *Et Al.* 2010) Radio Frequency Identification (Rfids), Or Electrocardiography (Ecg) Sensors In Electronic Socks And Sports Bras (Tognetti *Et Al.* 2014). The Internet Of Things (Iot) Is Already Unlocking The Benefits Of The Data Economy In Numerous Industries Like Healthcare (Baker *Et Al.* 2017), Emergency Management Or Defense And Public Safety (Wu *Et Al.* 2018; Fraga-Lamas *Et Al.* 2016). Moreover, Iot And Wearables, When Coupled With Advances In 5g Communication Networks For Device-To-Device Communications (Akpakwu *Et Al.* 2018), Virtual/Augmented Reality (Blanco-Novoa *Et Al.* 2018; Fraga-Lamas *Et Al.* 2018), Artificial Intelligence (Ai) (Javaid *Et Al.* 2018) And Smart Textiles (Loss *Et Al.* 2016), Can Bring Human-To-Human And Human-To-Machine Connectivity And Interaction To A New Level. Therefore, Smart Wearables And Smart Clothing Are On The Limit That Separates The Physical And The Digital World, And When Combined With Other Technologies (E.G., Smart Glasses (Blanco-Novoa Et Al. 2017) They Have The Potential To Transform Society Due To Their Large-Scale Use And Their Transformative Effects In Many Industries (European Commission, 2016). Several Review Works Have Been Published Which Summarize The Eclectic Collection Of Developments In Smart Fabrics And

Intelligent Clothing, As Well As E-Textiles And Wearable Fabrics (Meoli & May-Plumlee, 2002; Tao, 2001; Mccann & Bryson, 2009; Cho *Et Al.* 2009; Cherenack & Van Pieterson, 2012).

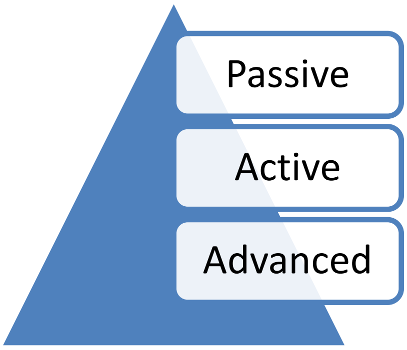
Smart Wearable System

Smart Fabrics For Personal Wearable Applications (De Rossi Et Al. 2005) Have Several Advantages Starting By Removing The Task Of Placing The Sensors By A Professional As Well As Offering A Natural Interface With The Body With Accurate, Reproductive Positioning Of The Sensors. The Sensors Are Enclosed In The Layers Of Fabric (E.G. Fiber Optic), Or It Is The Fabric Itself Which Is Used As Sensor Or Distributed Network Of Sensors. (E.G. Piezo-Resistive And Conductive Fabrics). A Smart Wearable Fabric For Personal Health Monitoring, "So Called" Intelligent Biomedical Clothing Was Initiated In The Early 2000 (A. Lymberis And S. Olsson, 2003). It Is One Of The Most Important Applications For Smart Fabric Wearable Systems. The First Promising Results (Prototypes) Have Been Achieved By Few Research Teams In Europe And Usa, Following The "Application Pull" Approach. These Prototypes Incorporate Mainly Electrocardiogram And Respiration Monitoring (And Accessorily Other Physiological And Physical Parameters Depending On The Targeted Applications) By Implementing Strain Fabric Sensors And Fabric Electrodes.

Smart Textiles Can Be Described As Textiles That Are Able *To Sense* Stimuli From The Environment, *To React* To Them And *Adapt* To Them By Integration Of Functionalities In The Textile Structure. Smart Fabric Textiles Refer To Fabric Textiles Obtained Through Spinning, Weaving And Other Processes Using Smart Textile Fibres As Raw Materials, Or Smart Fabric Textiles Obtained By Combining Other Smart Materials With Fabric Textiles. The Smart Textile Itself Is A System That Includes A Sensing Unit, Etc.

Classification Of Smart Fabric Textiles

Smart Fabrics Textiles Are Divided Into Three Types Are:



Passive Smart Fabric Textiles

It Can Only Perceive Changes Or Stimuli In The External Environment, But Cannot Adjust Themselves According To External Changes. They Are The First Generation Of Smart Fabric Textiles. Such As Anti Ultra Violet Clothing, Anti Bacterial Fabric Textiles, Ceramic Coated Fabric Textiles, And Light Guide Fabrics Are All Passive Fabric Textiles.

Active Smart Fabric Textiles

It Can Not Only Perceive Changes Or Stimuli In The External Environment, But Also Respond Accordingly To Changes In The Outside World. It Is The Second Generation Of

Smart Fabric Textiles. Such As Shape Memory Fabric Textiles, Water Proof And Moisture Permeable Fabric Textiles, Phase Change Heat Storage Clothing, And Light Thermo Chromic Fabric Textiles Are All Active Smart Fabric Textiles.

Advanced Smart Fabric Textiles

It Is Also Known As Super Smart Fabric Textiles And Adaptive Smart Fabric Textiles. It Is The Third Generation Of Smart Fabric Textiles. It Involves Communication, Sensing, Artificial Intelligence, Biology And Other High Tech Disciplines. It Can Perceive Changes Or Stimuli In The External Environment And Respond Accordingly Adapting To The External Environment Through Self Regulation (Figure 1).

Figure 1. Types Of Smart Fabric Textiles

Color Changing Fabric Textiles

Smart Color Changing Fabric Textiles Refer To Fabric Textiles Whose Color Changes With Changes In The External Stimuli (Such As Light, Electricity, Pressure, Temperature, Etc). This Type Of Smart Fabric Textiles Mainly Includes Photo Chromic Fabric Textiles, Thermo Chromic Textiles, Electro Chromic Fabric Textiles, Piezo Chromic Fabric Textiles, And Wet Chromic Fabric Textiles. Smart Colour Changing Fabric Textiles Have Better Wearability And Can Be Used In Civilian, Military And High Risk Industries. In The Military Field, It Can Be Used For Military Camouflage Such As Controllable Color Changing Camouflage Clothing; In The Medical Field, It Can Be Used For Medical Monitoring, Such As Baby Clothing, To Monitor Whether The Baby Has A Fever Through Clothing Color Changes; Special Occupational Safety Protection, Such As Long Term Exposure To Chemicals In The Environment Of Hazards Or Strong Radiation, The Color Of Clothes Will Change; The Digital Field Such As Electro Chromic Clothing, Can Realize The Function Of A Tv Screen On The Clothing; The Fashion Field Such As Photo Chromic Umbrellas, Photo Chromic T Shirts, Etc (Figure 2).

Figure 2. Photo Chromic Textiles

Temperature Changing Fabric Textiles

Temperature Changing Fabric Textiles Can Be Divided Into Various Types According To Their Stimulus Response To External Temperatures. Thermal Insulation Fabric Textiles Use Sunlight Thermal Storage Fibres Or Far Infra Red Fibres To Achieve Thermal Insulation. The Solar Thermal Storage Fiber Is To Radiate The Visible Light And Near Infra Red Rays From The Absorbed Sunlight To The Human Body In The Form Of Heat To Achieve The Effect Of Heat Preservation; The Far Infra Red Fiber Converts The Heat Emitted By The Human Body Into A Certain Wavelength Range Of Far Infra Red Rays. Re-Radiate To The Human Body To Reduce Heat Loss By Accelerating Blood Circulation And Achieve The Effect Of Heat Preservation. Therefore, The Heat Preservation Performance Of Far Infra Red Fiber Is Better.

Cooling Fabric Textiles Mainly Include Ultraviolet And Heat Shielding Fabrics, Cool Fabrics And Heat Dissipating Fabrics. Ultra Violet And Heat Shielding Fabrics Are Uniformly Mixed With Fine Ceramic Powder That Can Reflect Ultra Violet Rays In A Polymer Solution And Then Spun Into Fibres. Its Absorption Rate Of Visible Light And Near Infra Red Is Lo, Which Makes The Human Body Feel Cool.

Automatic Temperature Regulating Fabric Textiles Can Adjust The Temperature In Both Directions. Generally, It Is A Combination Of Phase Change Technology And Fiber Manufacturing Technology. It Can Absorb And Release Heat Energy According To The Rise And Fall Of The Ambient Temperatures. Temperature Changing Fabric Textiles Can Be Used For Civilian Clothing, Such As Cooling Vests, Sportswear, Ski Suits, Etc; Professional Clothing Such As Space Suits, Fire Suits, Diving Suits, Etc; For Medical Purposes, Constant Temperature Bandages Can Be Made To Protect Wounds. To Prevent Local Temperature From Being Too High Or Too Low; In Automobile Manufacturing, It Can Be Used For Seats And Roofs Inside Cars (Figure 3).

Figure 3. Photo Chromic Textiles

Phase Changing Fabric Textiles

Protection From Extreme Environment Has Always Been A Critical Requirement Of Textile Industries. Clothing That Protects From Water, Extreme Winter Intensive Heat, Open Fire, High Voltage, Propelled Bullets, Toxic Chemicals, Nuclear Radiations And Biological Toxins, Etc Are Some Of The Examples. Phase Change Is The Process Of Going From One Physical State To Another I.E. From Solid To Liquid. Substances That Undergo The Process Of Phase Change Are Better Known As Phase Change Materials. These Material Stores Release Or Absorb Heat As They Oscillate Between Solid And Liquid Form. They Give Off Heat As They Change To A Solid State And Absorb As They Return To Liquid State. The Three Fundamentals Phases Of Matter Solid, Liquid And Gas Are Known.

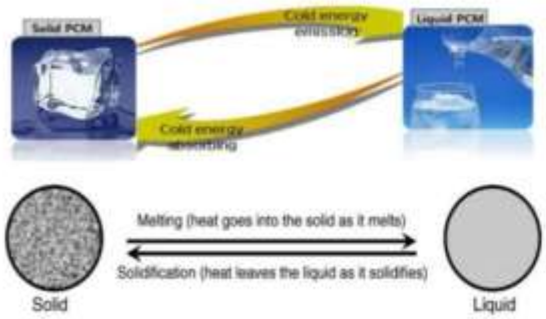


Figure 4. Pcm Process

Some Of These Phase Changing Materials Change Phase Within A Temperature. This Property Of Certain Substance Is Used For Making Protective All Season Outfits, And For Abruptly Changing Climatic Conditions. Fibre, Fabric And Foam With Built In Pcms Store The Warmth Of Body And Then Release It Back To The Body, As It Needs It. Since The Process Of Phase Change Is Dynamic, The Material Are Constantly From A Solid To Liquid And Back Depending Upon Level Of Physical Activity Of The Body And Outside Temperature (Figure 4). The Amount Of Heat Absorbed By A Pcm During The Actual Phase Change With Amount Of Heat Absorbed In An Ordinary Heating Process Can Be Compared By Considering Water As Pcm.

The Use Of Phase Change Material Technology In Different Applications For Automotive Interior Could Supply Energy Savings As Well As Increasing The Thermal Comfort Of Car Interior. Active Wear Needs To Provide A Thermal Balance Between The Heat Generated By The Body While Engaging In A Sport And The Heat Released Into The Environment. Normal Active Wear Garments Do Not Always Fulfill This Requirement. Lifestyle Apparel Such As Smart Fleece Vest, Men's And Women's Hats, Gloves And Rainwater. Outdoor Sports Apparel Like Jackets And Jacket Linings, Boots, Golf Shoes, Running Shoes, Socks And Ski And Snowboard Gloves. Medical Textiles: To Increase The Thermo Physical Comfort Of Surgical Clothing Such As Gowns, Caps And Gloves. In Bedding Materials Such As Mattress Covers, Sheers And Blankets. A Product Which Supports The Effort To Keep The Patient Warm Enough During An Operation By Providing Insulation Tailored To The Body's Temperature (Figure 5).

Figure 5. Pcm Textiles

Electronic Information Smart Fabric Textiles

Electronic Information Smart Textile Is A Combination Of Flexible Microelectronic Components And Fabric Textiles, So That The Sensor Can Perceive Changes In The External Environment, The Information Processor Processes The Information, And Makes Judgments And Issues Instructions, And Then Changes The Initial State Of The Material Through The Driver To Adapt To The Outside World Changes In The Environment, So As To Achieve Self Diagnosis, Self Regulation, Self Repair And Other Functions. The Main Technologies Adopted According To The Different Ways Of Combining Microelectronic Components And Fabric Textiles Are Modular Technology, Embedded Technology And Fiber Based Technology.

Electronic Information Smart Fabric Textiles Are Widely Used And Are One Of The Most Promising Smart Fabric Textiles. It Can Be Used In Medical And Health Aspects, Such As Medical Shirts. It Can Monitor The Wearer's Body Temperature, Heartbeat, Blood Pressure And Other Data To Realize Remote Monitoring Of Patients In The Hospital. When An Emergency Occurs, The Hospital Can Find It Through The Positioning System On The Shirt. For Emergency Patients, There Are Smart Socks, Smart Baby Jumpsuits And Other Similar Smart Clothing Used For Medical Purposes; For Sports And Fitness, It Is Convenient For Users To Check Their Exercise Time, Intensity, Distance, Energy Consumption And Other Exercise Parameters, Such As Heart Rate. The Monitoring Bra Is Shown In Colmar Smart Sportswear, Etc; Used In Multimedia Digital Products, Such As The Music Jacket. It Can Not Only Play Music Stored In Advance By The User, But Also Listen To Radio Programs. The Music Play Back Function Is Provided By A Full Fabric Capacitive Keyboard Control, The Main Source Of Energy Is Solar Energy, Wind Energy, Etc; For Military Purposes Such As Combat Uniforms Embedded With Ultra Micro Sensors, Which Can Identify The Wounded And Bleeding Parts Of Soldiers. The Uniforms Of This Part Can Immediately Expand And Contract To Stop Bleeding. There Are Also Smart Parachutes That Can Detect The Air And Ground Conditions And Change The Flight Direction And Speed In Time (Figure 6).

Figure 6. Electronic Information Textiles

2. CONCLUSION

The Aim Of This Study Was To Provide The Overview Of The Smart Fabric And Types Of Smart Textiles Related To Health Care. Smart Textiles Must Be Flexible Enough To Worn For Long Periods Of Time Without Causing Any Discomfort In Order To Become A Viable And Practical Product. Smart Textiles Have A Largely Range Of Applications, Often Starting As A Highly Specialized Application Before Becoming A More Generally Available Consumer Product. The Topics Covered Here Show That The Types Of Smart Fabrics That Must Involve In Colour Changing Fabrics, Temperature Changing Fabrics, Phase Changing Fabrics, Electronic Information Fabrics. Creating A Wearable Garment Integrates Textiles And Fashion Design With Input From The End Uses Such As Health Care Workers, Defense Forces And Sport Physicians. Market Trends Suggest Great Opportunities For Smart Fabrics Within The Textile Market; Given The Current Pace Of Development, Smart Textiles Will Form A Ubiquitous Part Of Our Lifestyle. Our Clothing Is Becoming Contextually Aware And Is Learning To Adjust To Suit The Individual Needs Of The User.

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3. REFERENCE

[1] D. Marculescu D. Et Al., Electronic Textiles: A Platform For Pervasive Computing, Proceedings Of The Ieee, 91 (2003) 1995 – 2018.

[2] Lukowicz P, Kirstein T, Tröster G. Wearable Systems For Health Care Applications. Methods Of Information In Medicine 2004; 43:232–8.

[3] Konstantas D. An Overview Of Wearable And Implantable Medical Sensors. In: Imia Year Book Of Medical Informatics; 2007 P. 66–9.

[4] Muirgray Ja. Better Value Health Care–The 21 Stcentury Agenda. Zeitsch Riftfür Ärztliche Fortbildung Und Qualität Im Gesundheitswesen – German Journal For Quality In Health Care 2007; 101(5):344–6.

[5] Kalachea. Ageing Worldwide.In: Ebrahims, Kalchea, Editors. Epidemiology In Old Age. London: Bmj; 1996. P. 22–31.

[6] Hedda Agüro-Torres H, Von Strauss E, Viitanen M, Winblad B, Fratiglioni L. Institutionalizationintheelderly:Theroleofchronicdiseasesanddementia. Cross-Sectionalandlongitudinaldatafromapopulation-Basedstudy. Journal Of Clinical Epidemiology 2001; 54:795–801.
[7] Mccannm, Donnellym, O'reilly D. Living Arrangements, Relationship To People In The Household And Admission To Care Homes For Older People. Age And Ageing 2011;40:358–63.
[8] Haghi, M.; Thurow, K.; Stoll, R. Wearable Devices In Medical Internet Of Things: Scientific Research And Commercially Available Devices. Healthc. Inf. Res. 2017, 23, 4–15.
[9] Bhömer,M.;Tomico,O.;Hummels,C.Vigour:Smarttextileservicestosupportrehabilitation. Inproceedings Of The Nordic Design Research Conference (Nordes 2013), Copenhagen, Denmark, 9–12 June 2013; Volumne 9, P. 12
[10] Bonfiglio,A.;Curone,D.;Secco,E.L.;Magenes,G.;Tognetti,A. Emergencyandwork. Inwearablemonitoring Systems; Springer: Boston, Ma, Usa, 2011; Pp. 205–219.
[11] Feito, Y.; Moriarty, T.A.; Mangine, G.; Monahan, J. The Use Of A Smart-Textile Garment During High-Intensity Functional Training. A Pilot Study. J. Sports Med. Phys. Fit. 2018.
[12] C. Dalsgaard And R. Sterrett White Paper On Smart Textile Garments And Devices: A Market Overview Of Smart Textile Wearable Technologies. Http://Www.Ohmatex.Dk/Pdfer/Whitepaper_Smart_Textiles.Pdf
[13] Choi, S.; Park, J.; Hyun, W.; Kim, J.; Kim J.; Lee, Y. B.; Song, C; Hwang, H. J.; Kim, J. H.; Hyeon, T.; Kim, D.-H. Stretchable Heater Using Ligand-Exchanged Silver Nanowire Nanocomposite For Wearable Articular Thermotherapy. Acs Nano 2015, 9(6), 6626−6633.
[14] Zhou, J.; Mulle, M.; Zhang, Y.; Xu, X.; Li, E. Q.; Han, F.; Thoroddsenc, S. T.; Lubineau, G. Highampacity Conductive Polymer Microfibers As Fast Response Wearable Heaters And Electromechanical Actuators. J. Mater. Chem. C 2016, 4, 1238−1249.
[15] Qiu, Q.; Zhu, M.; Li, Z.; Qiu, K.; Liu, X.; Yu, J.; Ding, B. Highly Flexible, Breathable, Tailorable And Washable Power Generation Fabrics For Wearable Electronics. Nano Energy 2019, 58, 750–758.
[16] Wu, C.; Kim, T. W.; Li, F.; Guo, T. Wearable Electricity Generators Fabricated Utilizing Transparent Electronic Textiles Based On Polyester/Ag Nanowires/Graphene Core-Shell Nanocomposites. Acs Nano 2016, 10, 6449−6457.
[17] Park, J. J.; Hyun, W. J.; Mun, S. C.; Park, Y. T.; Park, O O. Highly Stretchable And Wearable Graphene Strain Sensors With Controllable Sensitivity For Human Motion Monitoring. Acs Appl. Mater. Interfaces 2015, 7, 6317−6324.
[18] Choi, D. Y.; Kim, M. H.; Oh, Y. S.; Jung, S.-H.; Jung, J. H.; Sung, H. J.; Lee, H. W.; Lee, H. M. Highly Stretchable, Hysteresis-Free Ionic Liquid-Based Strain Sensor For Precise Human Motion Monitoring. Acs Appl. Mater. Interfaces 2017, 9, 1770−1780.
[19] Stoppa, M.; Chiolerio, A. Wearable Electronics And Smart Textiles: A Critical Review. Sensors 2014, 14, 11957−11992.
[20] Agcayazi, T.; Chatterjee, K.; Bozkurt, A.; Ghosh, T. K. Flexible Interconnects For Electronic Textiles. Adv. Mater. Technol. 2018, 3, 1700277.

[21] Lund, A.; Van Der Velden, N.M.; Persson, N.-K.; Hamedi, M.M.; Müller, C. Electrically Conducting fibres For E-Textiles: An Open Playground For Conjugated Polymers And Carbon Nanomaterials. Mater. Sci. Eng. R. Rep. 2018, 126, 1–29.
[22] Hardy, D.; Moneta, A.; Sakalyte, V.; Connolly, L.; Shahidi, A.; Hughes-Riley, T. Engineering A Costume For Performance Using Illuminated Led-Yarns. Fibers 2018, 6, 35.
[23] Hughes-Riley, T.; Lugoda, P.; Dias, T.; Trabi, C.; Morris, R. A Study Of Thermistor Performance Within A Textile Structure. Sensors 2017, 17, 1804.
[24] Katragadda, R.B.; Xu, Y. A Novel Intelligent Textile Technology Based On Silicon flexible Skins. Sens. Actuators A Phys. 2008, 143, 169–174.
[25] Michael, B.; Howard, M. Activity Recognition With Wearable Sensors On Loose Clothing. Plos One 2017, 12, E0184642.
[26] Singh, N.K.; Singh, V.K.; Naresh, B. Textile Antenna For Microwave Wireless Power Transmission. Procedia Comput. Sci. 2016, 85, 856–861.
[27] Grabham, N.J.; Li, Y.; Clare, L.R.; Stark, B.H.; Beeby, S.P. Fabrication Techniques For Manufacturing flexible Coils On Textiles For Inductive Power Transfer. Ieee Sens. J. 2018, 18, 2599–2606.
[28] Carey,T.;Cacovich,S.;Divitini,G.;Ren,J.;Mansouri,A.;Kim,J.M.;Wang,C.;Ducati,C.;Sordan,R.;Torrisi,F. Fullyinkjet-Printedtwo-Dimensionalmaterialfield-Effectheterojunctionsforwearableandtextileelectronics. Nat. Commun. 2017, 8, 1202.
[29] Marculescu, D.; Marculescu, R.; Zamora, N.H.; Stanley-Marbell, P.; Khosla, P.K.; Park, S.; Jayaraman, S.; Jung, S.; Lauterbach, C.; Weber, W.; Et Al. Electronic Textiles: A Platform For Pervasive Computing. Proc. Ieee 2003, 91, 1995–2018.
[30] De Rossi, D.; Veltink, P. Wearable Technology For Biomechanics: E-Textile Or Micromechanical Sensors? Ieee Eng. Med. Biol. Mag. 2010, 29, 37–43.
[31] Tognetti,A.;Derossi,D.;Lorussi,F.;Dallemura,G.;Pacelli,M.;Carbonaro,N.;Paradiso,R.Newgeneration Of Wearable Goniometers For Motion Capture Systems. J. Neuroeng. Rehabil. 2014, 11, 56.
[32] Baker, S.B.; Xiang, W.; Atkinson, I. Internet Of Things For Smart Healthcare: Technologies, Challenges, And Opportunities. Ieee Access 2017, 5, 26521–26544.
[33] Wu, F.; Rüdiger, C.; Redouté, J.; Yuce, M.R. We-Safe: A Wearable Iot Sensor Node For Safety Applications Via Lora. In Proceedings Of The 2018 Ieee 4th World Forum On Internet Of Things (Wf-Iot), Singapore, 5–8 February 2018; Pp. 144–148.
[34] Fraga-Lamas, P.; Fernández-Caramés, T.M.; Suárez-Albela, M.; Castedo, L.; González-López, M. A Review On Internet Of Things For Defense And Public Safety. Sensors 2016, 16, 1644.
[35] Akpakwu, G.A.; Silva, B.J.; Hancke, G.P.; Abu-Mahfouz, A.M. A Survey On 5g Networks For The Internet Of Things: Communication Technologies And Challenges. Ieee Access 2018, 6, 3619–3647.
[36] Blanco-Novoa,Ó.; Fernández-Caramés, T.M.;Fraga-Lamas, P.;Vilar-Montesinos, M.A.Apractical Evaluation Of Commercial Industrial Augmented Reality Systems In An Industry 4.0 Shipyard. Ieee Access 2018, 6, 8201–8218.
[37] Fraga-Lamas, P.; Fernández-Caramés, T.M.; Blanco-Novoa, Ó.; Vilar-Montesinos, M.A. A Review On Industrial Augmented Reality Systems For The Industry 4.0 Shipyard. Ieee Access 2018, 6, 13358–13375.
[38] Javaid, N.; Sher, A.; Nasir, H.; Guizani, N. Intelligence In Iot-Based 5g Networks: Opportunities And Challenges. Ieee Commun. Mag. 2018, 56, 94–100.

[39] Loss, C.; Gonçalves, R.; Lopes, C.; Pinho, P.; Salvado, R. Smart Coat With A Fully Embedded Textile Antenna For Iot Applications. Sensors 2016, 16, 938.

[40] Blanco-Novoa,O.; Fraga-Lamas, P.;Fernández-Caramés, T.M.;Vilar Montesinos, M.Estudiode Aplica Bilidad De Tecnologías De Realidad Aumentadaparala Construcciónde Buquesenel Astillero 4.0. In Proceedings Of The V Congreso Nacionaldei+Den Defensay Seguridad(Desei+D2017), Toledo, Spain, 22–24 November 2017.

[41] European Commission. Smart Wearables Reflection And Orientation Paper; Technical Report; European Commission: Brussels, Belgium, 2016. Available Online: Ec.Europa.Eu/Newsroom/Document.Cfm?Doc_Id=40542 (Accessed On 31 October 2018).

[42] Meoli D And May-Plumlee T 2002 Interactive Electronic Textile Development: A Review Of Technologies J. Text. Apparel, Technol. Manag. 22

[43] Tao X 2001 Smart Fibres, Fabrics And Clothing (Cambridge: Woodhead Publishing)

[44] Mccann J And Bryson D 2009 Smart Clothes And Wearable Technology (Cambridge: Woodhead Publishing).

[45] Cho G, Lee S And Cho J 2009 Review And Reappraisal Of Smart Clothing Int. J. Hum.–Comput. Interact. 25582–617.

[46] Cherenack K And Van Pieterson L 2012 Smart Textiles: Challenges And Opportunities J. Appl. Phys. 112091301.

[47] D. De Rossi, A. Lymberis, Guest Editorial, Ieee Transactions On Information Technology In Biomedicine, Special Section On New Generation Of Smart Wearable Health Systems And Applications, September 2005, Volume 9, Number 3, P. 293-294, Guest Editors D. De Rossi, A. Lymberis .

[48] A. Lymberis And S. Olsson, “Intelligent Biomedical Clothing For Personal Health And Disease Management: State Of The Art And Future Vision,” Telemed. J. E-Health, Vol. 9, No. 4, Pp. 379–386, 2003.