PERSPECTIVES IN USING OF THE 3D TEXTILE COMPOSITES TO PRODUCE RECHARGEABLE BATTERIES

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REZUMAT. Această lucrare prezintă câteva aspecte privind compozitele 3D textile cu funcționalizare controlată a suprafeței la nivel micro/nano pentru a obține compozitul adecvat cu capacitate de a stoca energia. Bateriile clasice nu sunt flexibile, nu sunt uşoare, şi generează probleme la integrarea în produsele textile. Recent bateriile pe bază de textile utilizează acoperiri metalice (de exemplu: argint, nichel, cupru, zinc) sau materiale pe bază de carbon pentru realizarea supercapacitorilor (SCs). În plus, prin intermediul tehnologiei Polymer-Assisted Metal Deposition (PAMD), metalele cu conductivitate mare cum ar fi cuprul (Cu) şi nichelul (Ni) pot fi depuse uniform, pe materialele textile pretratate pentru a realiza baterii pe suport textil flexibil pe bază de litiu. Interesul crescut în realizarea bateriilor flexibile cu consum redus de energie pentru sisteme de monitorizare purtabile este datorat faptului că bateriile clasice sunt rigide şi produc disconfort la purtare. O alternativă o reprezintă dezvoltarea bateriilor flexibile, a capacitorilor utilizând acoperiri prin peliculizare, impregnare, printare directă, printare 3D pe bază de soluții polimerice conținut de micro/nanoparticule. În literatura ştiințifică, câteva abordări constau în electrozilor din argint, cupru, argint/nichel, nichel/cupru, cupru/argint, oxizi de grafen şi nanotuburi de carbon (CNTs) combinate cu materialele pentru electroliți cum ar fi sulfonat de polistiren (3,4-etilen-dioxitiofen) (PEDOT: PSS) sau triiodura de potasiu (KI3). Câteva grupuri de cercetare au raportat SCs flexibili pe bază de electrozi flexibili 1D integrați prin procedee mecanice şi electrozi capacitivi integrați într-o singură fibră sau fir. O provocare o reprezintă dezvoltarea de materiale flexibile pentru electrozi 2D şi 3D care permit stocarea energiei şi asigură suportul bateriei.

Cuvinte cheie: textile, baterii, supercapacitor, stocare de energie, electroconductiv, micro/nano, nichel, composite 3D

ABSTRACT. This work presents several perspectives concerning the using of 3D textile composites based on controlled micro/nano surface functionalization in order to obtain the adequate composite capable of being used for energy storage. The conventionally used batteries are not flexible, not lightweight, and generate difficulties in integration into textile products. Recently textile-based batteries using metal (e. q. silver, nickel, copper, zinc) coated fabrics or carbon-based materials were used to create textile supercapacitors (SCs). Moreover, through the newest technology Polymer-Assisted Metal Deposition (PAMD), highly conductive metal, copper (Cu), and nickel (Ni) can uniformly be deposited onto pre-treated fabrics in order to develop the flexible textile lithium battery. The increased interest in producing a low powering system for a wearable monitoring system is because batteries are rigid and produce discomfort when it is worn. A solution to this impediment is to develop flexible batteries, capacitors on the textile surface by using a coating, padding, direct printing, 3D printing, and thin-film deposition based on polymers with micro/nanoparticle content. In the scientific literature, several approaches consist of using silver, copper, silver/nickel, nickel/copper, copper/silver, graphene oxides or carbon nanotubes (CNTs) as electrodes combined with electrolyte materials such as poly(3,4-ethylene dioxythiophene) polystyrene sulfonate (PEDOT PSS) or iodine-triiodide (KI3). Some research groups reported flexible SCs based on coaxial, twisted, or parallel 1D electrodes flexible by integrating mechanical support, current collector, and capacitive electrode materials in a single fiber/yarn/thread. A challenge is to develop 2D or 3D electrode materials that provide energy storage and mechanical support.

Keywords: textile, batteries, supercapacitors, energy storage, electroconductive, micro/nano, nickel, 3D composite

1. INTRODUCTION

Composite materials [1] represents a combination of two or more different materials, from the chemical in the composite. The use within the framework of a composite of more than three materials leads to the designation of hybrid composite. The textile coated with copper or nickel in order to obtain electrodes with appropriate conductive properties in order to be used in supercapacitor or batteries can be considered as composite materials because are made from textile and conductive polymeric paste with copper or nickel microparticles.

However, the possibility to use textile is batteries are numerous, such as:

- In thermoelectric battery. Thermoelectric energy conversion presents an excellent potential to use human body heat to generate power for low power computing systems. The thermoelectric materials and TEG based textile have the advantage in body heat energy conversion to the air permeability, flexibility, and wearing comfort [2, 3, 4].

- In a textile-based hybrid supercapacitor–biofuel cell (SC–BFC) system that strips electrons from lactate (sweat), generating a low electrical current [5].

Hybrid composites can be obtained by combining the classical methods, advanced materials (plasma RF and microwaves), methods of manufacture at the stage of solid, liquid, and vapor [6], used in electrochemistry (Solid State, Liquid State, semi-solid state, Physical Vapor Deposition).

The materials used in the framework of a composite plays the role of the array, forming phase continues, and the armature (reinforcement), representing the discontinuous phase. The armature matrix is added to enhance or change the properties of the final composite material. The combination of materials and frame type array generates composite material properties and characteristics that differ from those of the material components (the matrix and the frame).

Composite reinforcement may be:

➔Continue through the use of fabrics, knits, fiber, and yarn (carbon, silicon carbide) filamentary;

➔Discontinued through the use of short fiber or metal micro/nanoparticles, magnetic and non-metallic.

3D composites based on polymeric array [7] shall be made on the basis of thermosetting resin (epoxy, polyimide or polyester yarns) or thermoplastics (acid polylactic, acrylonitrile styrene-butadiene), armed with glass fibers, carbon, boron or aramid (Kevlar), with ceramic monocrystal or with metallic fibers/card reader. Composites with polymeric array involve relatively low temperatures or up to approximately 200 °C for 3D printing materials thermoplastics or conductive parts (graphene [8], the polymers with the content of metal micro/nanoparticles). For obtaining polymeric array 3D with electroconductive properties can be used the standard technologies (padding, coating, and direct printing) and advanced (microwave, RF plasma, 3D digital printing), which are very important for obtaining 3D electroconductive composites. The raw materials necessary used for developing the 3D composites based polymeric array are:

- Polymers with insulating properties, conductive, semiconductors, resistance to impact, and hardness. The polymers with insulating properties may be used as such or transform into conductive materials by adding metal micro/nanoparticles;
- Metallic or magnetic micro/nanoparticles;
- Fibers, yarn, flat structures (knits, fabrics, non-woven).

Polymeric materials with electroconductive properties may be used:

- Directly in the 3D structure of the composite array by techniques of 3D digital printing;

- In the layer of the surface, in order to achieve the finishing treatments directly on the surface of the 3D structures obtained by digital printing.

In order to obtain 3D polymeric arrays shall be used:

➔The appropriate classical technologies (padding, coating and direct printing) for surface treatment in order to obtain the surfaces with conductive, semiconductors properties, insulating antistatic properties, and water-repellent;

➔RF plasma technology for changing the material surface (hydrophobic, oleophobic, or hydrophilic) in order to ensure optimum surface adhesion for subsequent treatments (deposits of layers conductive, semiconductive by direct printing or 3D printing). Also, an alternative can be the plasma sputtering method (PVD based argon plasma) using different metal targets. The physicochemical processes which occur on the surface of the fabric refer to the interaction between the electron-ion and chemical composition of the textile substrate. Using the RF plasma can be four types of Physico-chemical processes, such as cleaning, activating, graphing, and submission of thin coats.

➔Microwave technology is based on electro-magnetic waves with a frequency of 300 MHz-300 GHz and wavelength of 1 m - 1 mm and can be used for initial or final rapid drying of surfaces or the pretreatment areas by generating the heat.

2. EXPERIMENTAL PART

The goal of the investigation is to study the applicability of the nickel microparticle in textile coating for electrodes by investigating the electrical or optical properties of the textiles coated with Ni. It is already known that nickel has intensively used in batteries, such as nickel-cadmium (NiCd) and the longer-lasting nickel-metal hydride (NiMH) rechargeable batteries.

In our experiment, we used to treat the textile by direct printing method in order to obtain a composite material based on textile support (100% cotton) and polymeric nickel (Ni) paste. The textile samples were coated with polymeric paste based nickel microparticles, and after this procedure, the samples have been dried for 24 h, 3 min. Condensation at 150 ˚C, and we investigated the surface resistance and surface resistance after treatments in alkaline and acid transpiration. In table 1 are presented the surface resistance before and after the treatments in alkaline and acid transpiration. We can observe that the surface resistance is reduced with 10^3-10^5 in case of the samples treated with alkaline or acid sweat.

We investigated the reflectance/ transmittance report [R/T] by using spectrophotometry based on electromagnetic radiation absorbed by materials (samples treated with nickel, and several Ni samples treated in alkaline/acid sweat). In figure 2.1 are presented the reflectance of sample 2 (Ni-based textile) without transpiration treatment, with acid transpiration, and with alkaline sweat treatment. In figure 2.2, a and b are presented the surface analysis of the sample no. 2 coated with Ni only on one side, respective of the sample no. 8 coated with Ni on both sides, using an optical microscope. In figure 2.3 is presented the reflectance/transmittance of the sample no. 8.

Table 1. **Yarn specifications – weft and warp**

Proba	Ni Sample untreated	Sample treated with an alkaline solution	Sample treated with an acid solution
1	1.6×10^{12}	10^8	10^9
2	2.5×10^{12}	10^8	10^7
3	3.86×10^{12}	10^8	10^9
4	5.2×10^{12}	10^8	10^9
5	1.7×10^{12}	10^8	10^8
6	3.15×10^{12}	10^8	10^8
7	6.5×10^{12}	10^8	10^8
8	4.4×10^{12}	10^7	10^8

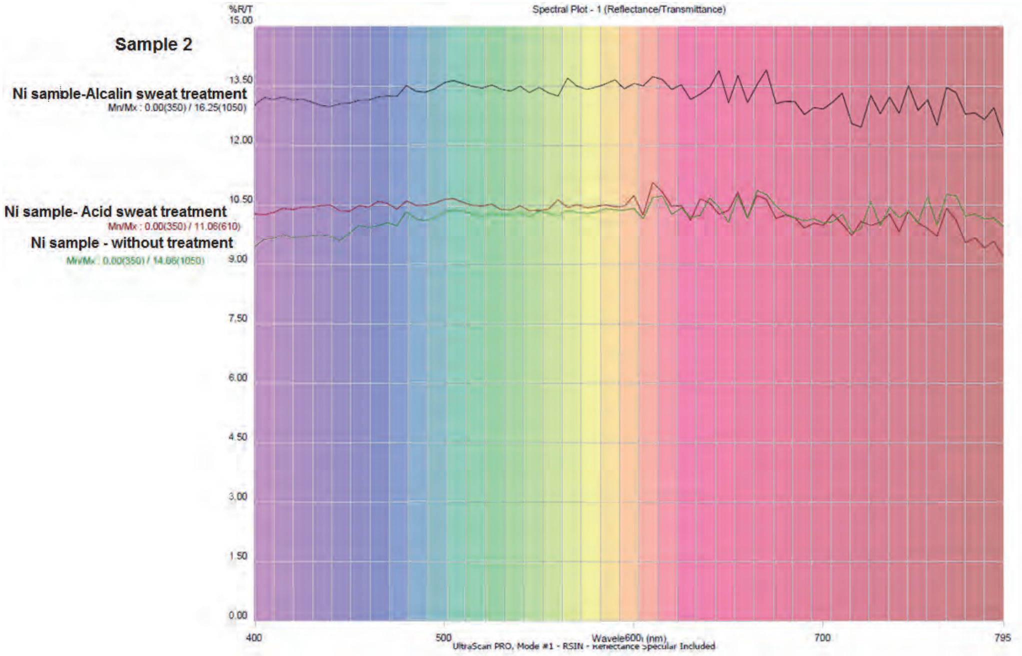
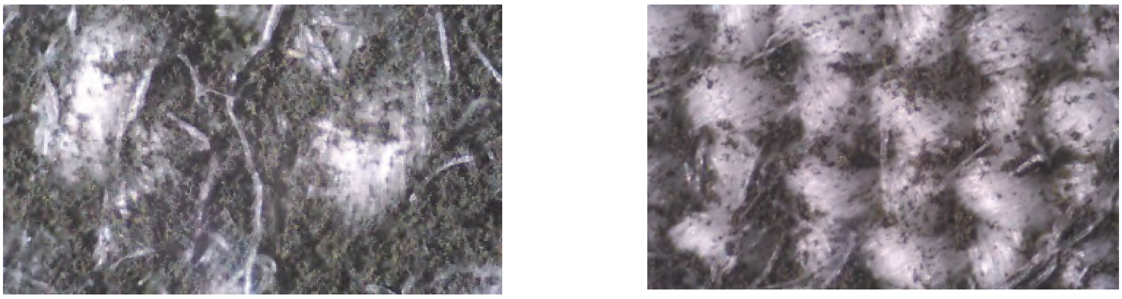


Fig. 2.1. [R/T]-Sample no.2, 100% cotton, covered with a layer of nickel (without sweat treatment –green line, with alkaline sweat treatment-black line and with acid sweat treatment –red line)



Sample no. 2

Sample no. 8

Fig. 2.2. Surface analyses using an optical microscope.

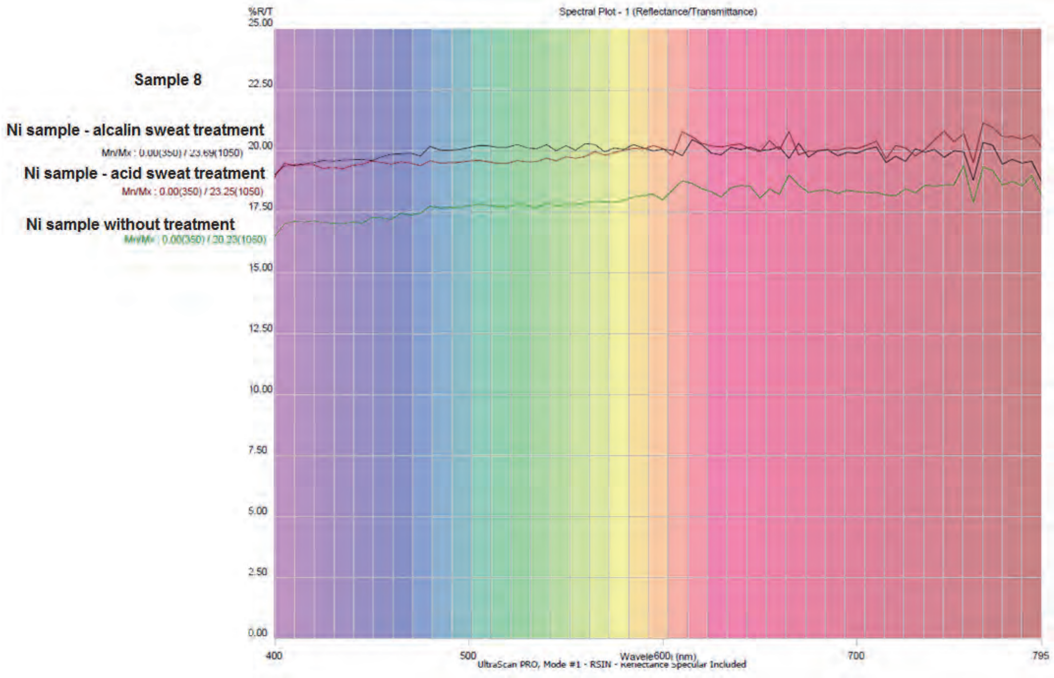


Fig. 2.3. [R/T]-Sample no.8, 100% cotton, covered with a layer of nickel (without sweat treatment –green line, with alkaline sweat treatment-black line and with acid sweat treatment –red line)

3. CONCLUSIONS

However, the nickel electrodes have good conductivity and can be used as parts in flexible batteries. As can be observed from figure 2.1 and 2.3, the report R/T has the values over 9% for sample no. 2 and over 16% for sample no. 8.

Considering that the transmittance [9] is the fraction of electromagnetic wave passed through the material, and the reflectance [10] is the fraction of incident electromagnetic power that is reflected at an interface (material), we can conclude the report $[R/T]_{sample\ 2} < [R/T]_{sample\ 8}$, and $R_{sample\ 2} < R_{sample\ 8}$ and this mean that sample no. 8 reflect much more electromagnetic radiation and this can be a result of coating on both material side. Transmittance is in an inverse proportional relationship with the concentration of the solution, and this means that transmittance will be reduced with increasing the concentration of a solution. In fact, by comparison with the material coated on one side, the material coated on both sides contains many more particles, which will block the electromagnetic radiation (light), and the transmittance will be reduced.

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