

Screen Printed Sensor for Enuresis Alarm System

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Abstract. The aim of the study - the development of textile screen printed sensor for enuresis alarm system, using different concentrations of graphite in paste and various width of traces (3, 5, 7 mm).

The most optimal parameters of concentration (22%) and width (7 mm) of traces, which were printed on sateen weave cotton fabric, are found by measuring the resistivity and the change of voltage in time during dropping the salty dilution.

The more graphite concentration and width, the less resistivity is observed.

Keywords: graphite, screen printing, sensor, enuresis.

I. INTRODUCTION

Wearable electronics tend to get smaller and take over features of textile materials [17]. Smart textiles can be obtained by integrating conductive fibres and yarns, e-yarns, using conductive coatings (flexible encapsulated circuits) or conductive pastes and inks [10].

It makes it reasonable to screen-print conductive traces, circuits, antennas and sensors directly on textile substrates, using textile pastes and inks loaded with different conductive fillers [8, 10, 9]. The inks can contain: metals (gold, silver, copper, aluminum powder, flakes, fibres or nanowires), carbon (powder, nanotubes, nanofibres) and intrinsically conductive polymers (polyaniline, polypyrrole) [1, 12].

Most commercial conductive pastes, inks and paints for printed electronics are devised for printing/applying on plain and rigid surface. The most popular are DuPont, Sun Chemical®, Creative Materials, EPO-TEK®, PELCO®, Acheson Chemical, Ecojoin, Caig Laboratories Inc., MG Chemicals etc. [3, 5, 7, 15, 19, 20]. Despite non-textile application, a research of applying some of these pastes was carried out, evaluating the features of pastes/inks and their interaction with different structures and surfaces of textile materials [16, 14].

Carbon (C) is the main component of plants and life creations, and it is also used in metallurgy, electrode production, adsorbing, in chemical industry etc. In nature carbon can be met as diamond (Fig. 1 a), graphite (Fig. 1 b) and charcoal (Fig. 1 g). Carbon and its allotropes (different molecular configurations) (Fig.1) tend to take stand of usage in electronics increasingly [2].

Graphite has a layered structure, as bonds among carbon atoms in a layer are tight, but bonds between layers are weak. Thereby graphite is soft, because layers of atoms can slide along each other. Graphite is nontransparent, dark grey and a good conductor [4].

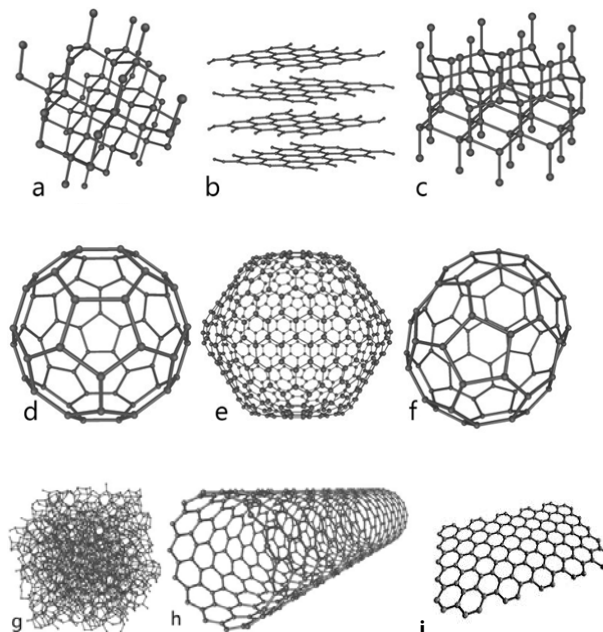


Fig. 1 The structures of allotropes of carbon: diamond (a), graphite (b), lonsdaleite (c), buckminsterfullerene (C60) (d), fullerene (C540) (e), fullerene (C70) (f), amorphous carbon (g), single-walled carbon nanotube (h), grapheme (i) [2, 6]

Screen printed sensors made by depositing graphite-based paste on textile material can be used for nocturnal enuresis alarm systems as alternative of prototyped sensors made of conductive yarns [13]. Both methods are replacing rigid sensors and increasing the comfort of usage.

Such alarm systems can be used by individuals with diagnosis of bed-wetting or nocturnal enuresis. Enuresis is intermittent incontinence during sleep of mostly children after the age of five, caused by different disturbances of physiology. The bed-wetting alarm system awakens the child when bed-wetting starts and he/she finishes voiding in the toilet [11].

The aim of the study is to develop a textile screen printed sensor for the existing [13] enuresis alarm system, using different concentrations of carbon in printing paste and printing different thickness of traces.

II. METHODS

A. Screen printing

The screen printed technology was used for printing traces for sensor [18]. Firstly, the pattern of 3 mm, 5 mm and 7 mm thick and 100 mm long traces were created digitally. Using emulsion, a picture of patterns and light, the patterns were

transferred onto a screen (mesh), which was fixed into frame (size A4).

Different quantities of graphite powder were mixed with water based transparent textile printing paste (TPrint T2000), producing various concentrations of carbon printing pastes (Table). Using rubber squeegee and patterned screen 3 mm, 5 mm and 7 mm wide traces were printed on sateen (123,2 g/m²) weave cotton fabric (Fig.2). For each concentration and trace type 5 samples were printed. The samples were dried and fixed for a minute at temperature of 120 ° C.

TABLE
CONCENTRATIONS OF GRAPHITE POWDER IN PASTES

Nr.	Concentration, %	3 mm	5 mm	7 mm
1.	10	5	5	5
2.	14	5	5	5
3.	18	5	5	5
4.	22	5	5	5
5.	26	5	5	5
Total number of trace samples:				75

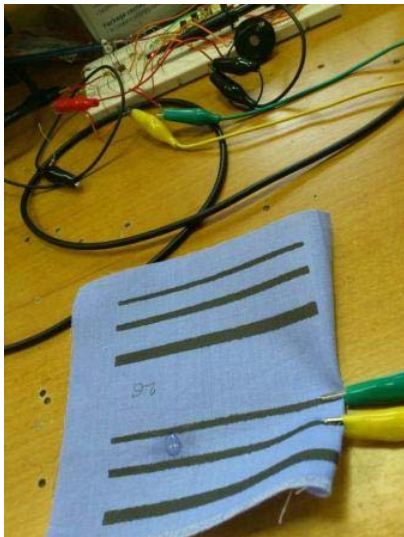


Fig. 2 Printed traces which are connected electrodes

B. Testing Reaction on Humidity

Testing the reaction on humidity salty dilution (0,2 moles of salt per 1 litre of water) was used for urine imitation, because its conductivity corresponds to the average conductivity of urine [21]. Salt (NaCl) is an electrolyte, and when it is diluted in water to form salt water, it becomes sodium ions (Na⁺) and chlorine ions (Cl⁻), each of which is a particle that conducts electricity [13]. To register the above mentioned reaction, additionally, oscilloscope and program Pico Scope 6 were used. The electrodes were connected to two parallel printed traces through a simple signal amplifier, shown in Figure 3,

which increased sensitivity of the system. In this experimental setup the electronic circuit was fed with 2V input voltage, which was connected to an amplifying transistor through a sensor with printed traces (connections SENS 1 and SENS2). The reaction of the system was indicated in two ways – with LED1 and with measuring connections (MEAS1 and MEAS2), which were connected to an oscilloscope, which measured and registered the output voltage of the system. The dilution was dropped between the traces and the increase of voltage in time between two traces was registered. The traces with width of 5 mm and 7 mm and all concentrations (Table 3) of graphite powder were measured, because they have lower resistance than 3 mm traces.

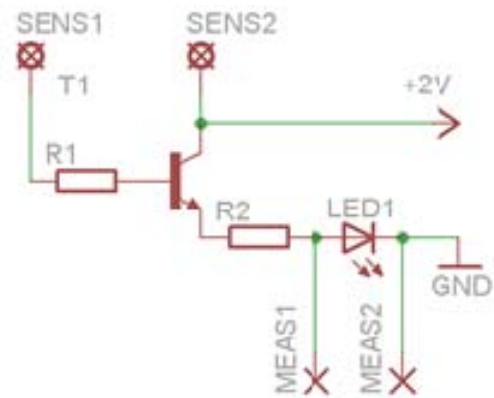


Fig. 3 Experimental set-up for sensor testing

III. RESULTS & DISCUSSION

A. Resistance of Printed Traces

After the heat treatment, the resistivity of the acquired samples of printings was measured. The observed tendency shows that by increasing the concentration of graphite paste, the electrical resistivity decreases. It happens till the concentration of 22 %, because the resistance begins to rise at the concentration of 26%. If the factors as printing mesh dimensions and size of graphite flakes remain the same, the resistivity will increase.

In previous pilot-experiments traces of the graphite paste of 50% and 60% concentration were printed on fabric. It was observed that the paste is not absorbed into textile structure and cracks appear in the printed traces, which cause more resistance. This can be explained by excessive size of graphite powder flakes for the chosen fabric and its structure. The graphite powder stays on the surface of fabric, while the textile paste is absorbed into fabric, so fabric acts like a filter.

The concentration of 10% and 14% of graphite pastes shows that the width of traces affects electrical resistance – thicker traces of 7 mm have lower resistance than traces of 5mm and 3mm (Fig. 4). But resistance becomes less different with 18%, 22% and 26% concentration of graphite despite the various widths of traces.

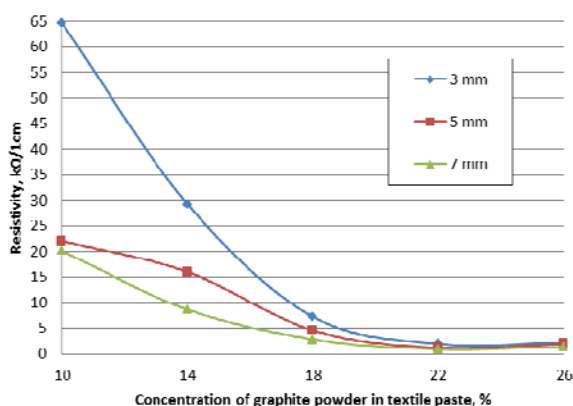


Fig. 4 Dependence of coating resistivity on graphite concentration and thickness of traces on cotton sateen weave fabric

B. Reaction of Sensor on Humidity

The graph in Figure 5 shows that traces with graphite concentration of 10% and 22% have one of the best characteristics, because they reach 1,6 V after 2,5 seconds. The printed traces with graphite concentration of 18% reach this level after 3,6 seconds, 14 % - after 5,7 seconds. The longest delay was observed for the traces with graphite concentration of 26 %, the mentioned level was reached only after 7,4 seconds. It can be explained by the high concentration of graphite, which made the printing paste more viscous and less absorbing into the structure of the fabric. So it takes some time for dilution to absorb into the fabric under printed traces and then to reach the printed area.

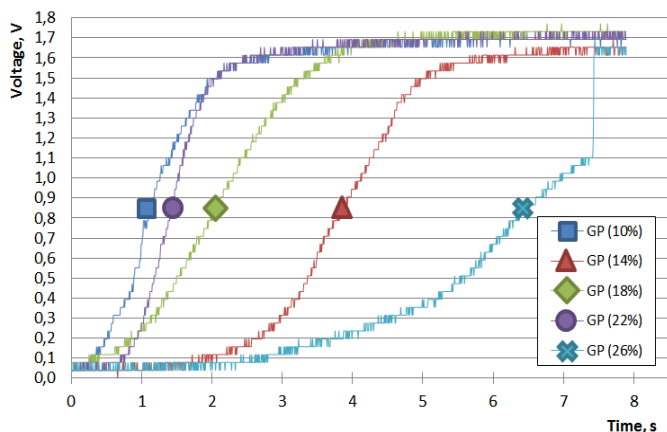


Fig. 5 Reaction on humidity between 5 mm trace and 7 mm trace in different concentration of graphite paste (GP)

IV. CONCLUSIONS

Screen printing electro conductive traces are affected by such factors as: the features of printing paste (viscosity, concentration of graphite, the size of graphite flakes), the size of cells of the screen, the structure of a textile material.

The bigger concentration of graphite powder in printing paste, the less electrical resistance of printed samples was

observed, using definite printing stuff and materials. To avoid cracks in printings, thereby improving conductivity, a cohesive substance in the paste must be used.

The traces with graphite concentration of 22% are the most suitable ones for humidity sensor, because of their low resistance and good conductivity.

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Marianna Grecka, Aleksandrs Vališeviskis, Inese Parkova, Ausma Vilumsone. Sietspieduma tehnikā drukāts enurēzes signālsistēmas sensors

Tekstiliju apdrucku ar elektrību vadošiem celiņiem, shēmām, antenām un sensoriem iespējams izmantot kā alternatīvu elektrību vadošiem tekstila pavedieniem. Apdruckas pastas var saturēt metāliskas, oglekļa daļiņas un elektrību vadošus polimērus.

Pētījuma mērķis ir izstrādāt uz auduma drukātu enurēzes signālsistēmas sensoru kā aizvietotāju esošajam, palielinot lietošanas ērtuma līmeni. To var izmantot indivīdi, kuriem konstatēta nakts enurēze jeb nekontrolēta urīna noplūde miega laikā, parasti bērniem vecākiem par 5 gadiem, ko izraisa dažādi fizioloģiski traucējumi. Enurēzes sensors reaģē uz pirmajiem urīna pilieniem un ar audio signālu pamodina bērnu, kuram ir jāceļas un jādodas uz tualeti.

Sensora izstrādei tika pielietota sietspieduma apdruckas tehnoloģija. Kokvilnas saftina audums apdruckāts ar dažāda platuma joslām (3mm, 5 mm, 7 mm), izmantojot caurspīdīgu tekstila apdruckas, kurai dažādās koncentrācijās piejaukts grafiņa pulveris.

Pēc drukāto joslu termofiksācijas, izmantojot multimetru, tika noteiktas to vidējās pretestības, izmantojot multimetru. Pieslēdzot paralēlās grafiņa joslas pie elektrodiem un pilinot sāls šķīdumu, tika reģistrēta šo joslu reakcija uz mitrumu jeb sprieguma (V) izmaiņas, kas piefiksētas oscilogrāfu un ilustrētas datorprogrammā *Pico Scope 6*.

Elektrību vadošas apdruckas kvalitāti ietekmējošie faktori ir: pastas viskozitāte, grafiņa koncentrācija un daļiņu lielums, drukas sieta šūnu izmērs, apdruckājamās tekstilijas struktūra un absorbcijas spējas. Jo lielāka grafiņa koncentrācija pastā, jo mazāka ir drukāto celiņu pretestība. Lai izvairītos no drukas slāņa plaisāšanās, ieteicama saistvielas pievienošana pastai. Sensoram atbilstošākā drukas pasta ir ar 22 % grafiņa koncentrāciju, jo tai ir zema pretestība un laba vadāmība.

Марианна Грека, Александр Валишевский, Инесе Паркова, Аусма Вилумсоне. Трафаретная печать для сенсора сигнальной системы энуреза

Нанесение электропроводящих полос, схем, антенн и датчиков методом печати по текстилю может быть использовано как альтернатива электропроводным нитям. Пасты для печати могут содержать частицы металлов, углерода и токопроводящие полимеры.

Целью исследования является разработка напечатанного на ткани сенсора сигнальной системы энуреза, взамен существующих датчиков и более удобного в использовании. Датчик может быть использован индивидами с диагнозом *ночной энурез* (неконтролируемое выделение мочи во время сна) у детей в возрасте старше 5 лет, вызванный различными физиологическими расстройствами. Сенсор реагирует на первые капли мочи и срабатывает аудио-сигнал в качестве будильника.

Для разработки датчика была использована технология трафаретной печати. Используя полупрозрачную пасту для печати на текстильной основе, которая была смешана с различными концентрациями графитного порошка, на хлопковом атласе были напечатаны полосы различной ширины (3 мм, 5 мм, 7 мм).

После термической фиксации графитных полос, с помощью мультиметра было определено их среднее сопротивление. Подключив электроды к параллельным полосам и капая солевой раствор между полос, была зарегистрирована реакция на влажность, то есть, изменения напряжения (V), которое зафиксировано осциллографом и программой *Pico Scope 6*.

На качество токопроводящей печати влияют такие факторы как вязкость пасты, концентрации графита и размера частиц, размер ячейки печатной сетки, структура и абсорбционная способность ткани. Чем выше концентрация графита, тем ниже сопротивление напечатанной дорожки. Чтобы избежать растрескивания слоя печати, рекомендовано добавить в пасту вяжущее вещество. Наиболее подходящая концентрация графитного порошка является 22 %, из-за его низкого сопротивления и хорошей проводимости.