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The effect of micropores on output properties of laminate materials with assumed medical implantation

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Properties

ABSTRACT

Purpose: Examination of elaborated composite material in terms of specific application in medicine – as internal prostheses of oesophagus. Development of the manufacturing technology of aramid-silicon laminated material and definition of the micro-cavities amount formed during production of the laminates.
Design/methodology/approach: Aramid-silicon laminated material was made by a method of manual formation of laminates that is impregnation of reinforcement with matrix to hardening silicone process using hardening methods connected with heat. Created material was observed on Axiovert 450M light-microscope of Option Company at 100 x magnification.
Findings: The results show that the preliminary manufacturing technology of aramid-silicon laminated materials allows creating a material with specific and special properties. Aramid-silicone laminate could be used in medicine for example as oesophagus prosthesis.
Research limitations/implications: Carried out investigations show the problem with cautioning and ageing which are very important in having proper percentage of intensifier in developed material.
Originality/value: Taking the material specific properties into account it seems that the aramid-silicon laminated material would be useful in medicine. Aramid silicone laminate could be attractive alternatively for composite material used for medical purposes and the others.
Keywords: Composites; Engineering Polymers; Biomaterials; Technological Devices and Equipment; Aramid; Silicone; Application.

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1. Introduction

Polymeric materials are the fundamental group of engineering materials with diversified properties, which find wider and wider ranging application for various fields of contemporary engineering. Since the discovery of rubber and celluloid in the first half of XIX century, there has been continuous, dynamic development of this field of science – nowadays directed into development of electro-, conductive, heat-resistant and biocompatible polymers technology. The main advantages of polymeric materials are the following: low density, high mechanical strength in relation of their mass, hardness, resistance to atmospheric factors and active environments, thermostability, electric and thermal properties, as well as high ability to form finished products as a result of conducting relatively little complicated technological processes. On the contrary, disadvantages of this group of materials are the following: low creep resistance and considerably limited, long-term, operational range of temperature. This group has continuous and intensive development of additives' implementation, manufacturing processes and processing technology as well as production of finished products [1-9, 16-21].

There is a relation between structure of polymers and their properties, which results in essential possibility to select and choose polymeric and composite materials. Having knowledge in this range it is invaluable in the process of production and development of contemporary materials engineering, and what comes next, in research of new materials with defined properties and applications [6-15, 22].

Basic information on relation between structure and chemical and physical properties as well as resulting thermal, mechanical and other characteristic, determines the practicability of this group of engineering materials and modified form polymers as well as composites prepared on their base. In practice, polymer materials have different degree of modification that is realized in both, manufacture process and processing stage – in the formation process of finished products. In turn, application of these materials in engineering practice results from their attractiveness related with possibility of combination of different properties like relatively high mechanical strength, transparency, elasticity and low density. Introducing modern technologies in synthesis, processing materials and modification of their outer layer, enables formation of plastics with defined structure in macro-, micro- and nanoscale. All this activities are meant to attain functional properties corresponding to new applications, as good as possible [25-30].

In these days and age there is a necessity of combining various materials to obtain materials with completely new properties, which can fulfil more and more exorbitant demands. That is the reason why investigations are carried out to develop "new" engineering materials with specified functional properties, which enable application in difficult operational conditions, and these are composite materials.

Composite materials are the most promising and developing group of materials, which is very popular in scientific and application research. Nowadays, needs of enginery and industry prove that properties of fundamental groups of engineering materials are limited. Realization of technological goals that appear before today's engineers would not be possible without simultaneous development of advanced materials including composite materials that are popularly called composites [10-14, 28].

In simple words, composite materials are materials made from combination of at least two components – phases with different properties, which enable attainment of materials with new and/or superior properties than base materials or with properties that result from the summation of properties of particular components (Fig. 1.).

Combination of various matrixes (base) and reinforcement (filler) materials allow developing composite material with a wide spectrum of mechanical, chemical, electrical, magnetic, optic and biomedical properties.

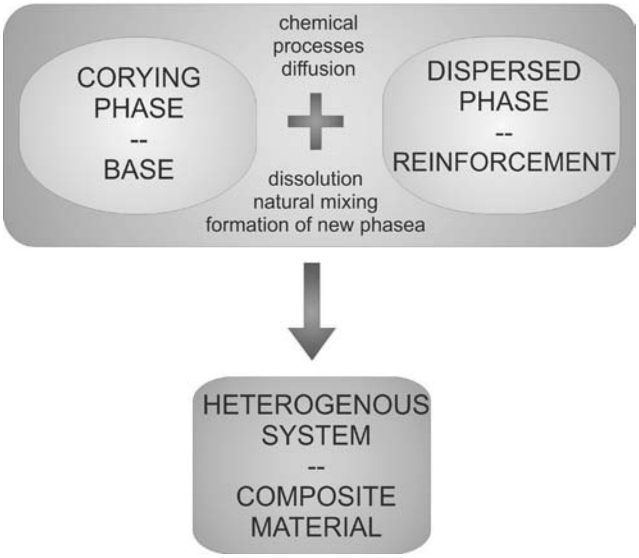

Fig. 1. Composite materials definition - graphic diagram [20]

Composite materials can be widely applied in medicine, where emphasis is placed on modern materials with very specific properties which are possible to be obtained only by linking various components.

There are a lot of premises that undoubtedly affect the interest of the present articles' authors on composite materials that could meet the requirements related to materials used in medicine, particularly as internal prostheses of oesophagus. These prostheses should have optimized functional properties, which could significantly influence on improvement of patient's comfort as well as they should reduce a number of complications after surgery [27-30].

Prostheses made from plastics that could be used in alimentary canal surgery, should be characterized by adequate softness, elasticity, and thin-wall structure. All those requirements should be fulfilled to avoid bedsores and the patient's discomfort after surgery.

The main goal of the undertaken work is to examine elaborated composite material in terms of specific application in medicine – as internal prostheses of oesophagus.

2. Material

The following materials were chosen for the production of elastic aramid silicone laminate: aramid fabric CCC120, of various basic weights, manufactured by Havel Composites PL. SP. Z O. O.; medical silicone MDX4-4159 manufactured by DOW CORNING.

Technical data of the aramid fabrics are shown on Figure 2 and Figure 3. It was applied because of its specific properties like strength, heat resistance, chemical resistance, high elastic modulus, low flammability and high strength to density ratio. Furthermore, recently there have been performed interesting researches on degree of biocompatibility aramid fabrics with living tissue that have been reported in [13-22].

The silicone is an amine functional polymer with incorporated reactive methoxy groups and has structure presented on the Figure 4. The main reason for choosing the medical silicone MDX4-4159, among the others available on the market, was its low adhesiveness – an important factor in the production of composite (it simplified soaking procedure and eliminated additional dilution of resin). Moreover, an important role biocompatibility of the discussed substance played that made obtaining biologically neutral composite possible.

Dow Corning MDX4-4159 silicone with 50% Medical Grade Dispersion consists of silicone – 50% dissolved in co-solvent system of 70% Stoddar Solvent (mineral alcohols) and 30% isopropanol (iPA). The physical data of medical silicone are shown in Figure 5.

TECHNICAL INFORMATION

	FABRIC 36	FABRIC 61	FABRIC 173
Basic weight [g/m2]	36	61	170
Fabric thickness [mm]	0.10	0.12	0.16
Matrix	Aramid 49 T 965 21,5	Aramid 49 T 965 21,5	Aramid 1210 dtex 2200
Plot	Aramid 49 T 965 21,5	Aramid 49 T 965 21,5	Aramid 1210 dtex 2200
Fabric mass density [g/m3]	1.45	1.45	--
Linear mass density [Tex]	22	22	--
Type of plait	linen	linen	linen

Fig. 2. Technical information about aramid fabric manufactured by Havel Composites PL. SP. Z O.O

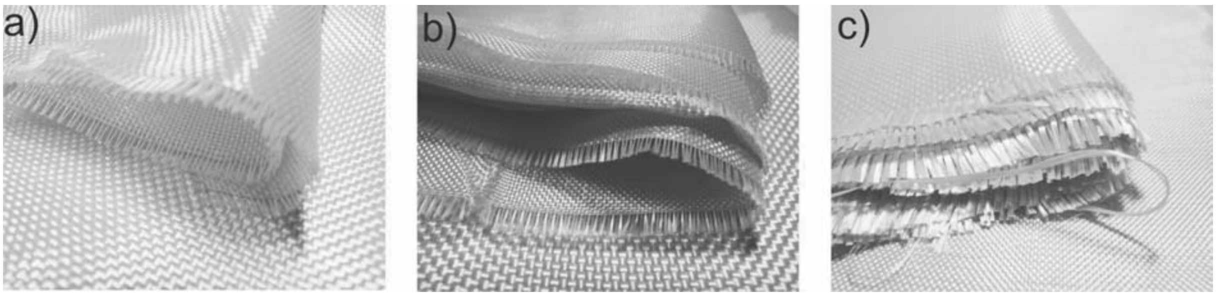

Fig. 3. Aramid fabric with basic weight a) $36 g/m^2$; b) $61 g/m^2$; c) $173 g/m^2$

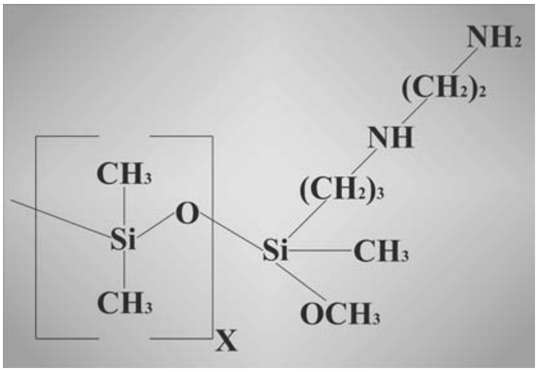

Fig. 4. The diagram of the Dow Corning silicone structure MDX4-4159, 50% Medical Grade Dispersion

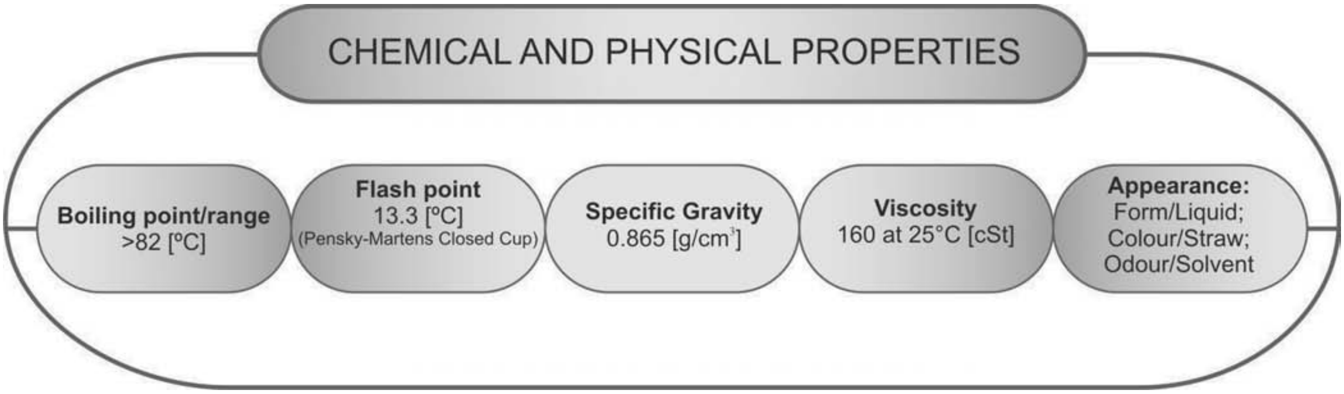

Fig. 5. Chemical and physical properties of medical silicone MDX4-4159 manufactured by COW CORNING

3. Laminate forming

Manual methods were chosen tentatively for forming polymer-polymer laminate for production. Low cost of unit production as well as easiness of its realization influenced on the choice of the manual technique. Popular methods of impregnations are also the following:

- pressure,
- vacuum,
- RTM [16]

Connection of both components (matrix and reinforcement) in laminate relies on, in some way, fusion of fibres – fabric in our case - in hardened matrix (silicone), what enables gaining solid two-component material. There is distinct interfacial surface between components – microstructure of the obtained plastic is heterogeneous [3].

From the particular ingredients point of view it would be an ideal situation if the silicone adhered to the whole surface of reinforcement and adhesive force of silicone to the aramid fibres would be at least as high as cohesion force inside the silicone. In reality interactions that occur on the interface are much more complicated and are determined by factors presented on the Figure 6, which should be always kept in mind. All presented factors are strictly connected with each other and influence, in the same degree, on relation between reinforcement and matrix in the point of connection [1-6, 12].

To the impregnation problem, the matter of matrix – silicon resin hardening is also related. Duroplasts, the group of plastics that once it is handled with they have reactive groups in macro-particle and in the presence of cross-linking agent (curing agent) and/or heat they undergo chemical reaction of cross-linking, what results in spatially cross-linked structure it is formed [1-10]. Nowadays, many methods of curing silicon resins exist and this article's authors paid attention to methods placed on the following diagram (Fig. 7).

Viscosity of this binder (silicon resin) is decreased by typical volatile solvents application, whose task is to make technological process easier but without affecting the final product. The general binding principle in processing of such composites is to remove solvent completely before the resin is cured. So, they are generally used in the technological processes, in which epoxide composite is coated with a thin layer on the subsoil, where in high enough temperature evaporation of volatile ingredients is possible before final curing of laminate in adequate temperature. The lack of solvent removal from the resin, before it is cured, provokes into appearing numerous blisters and remaining solvent in already partially cured resin and it considerably impairs its final properties [11-18, 29].

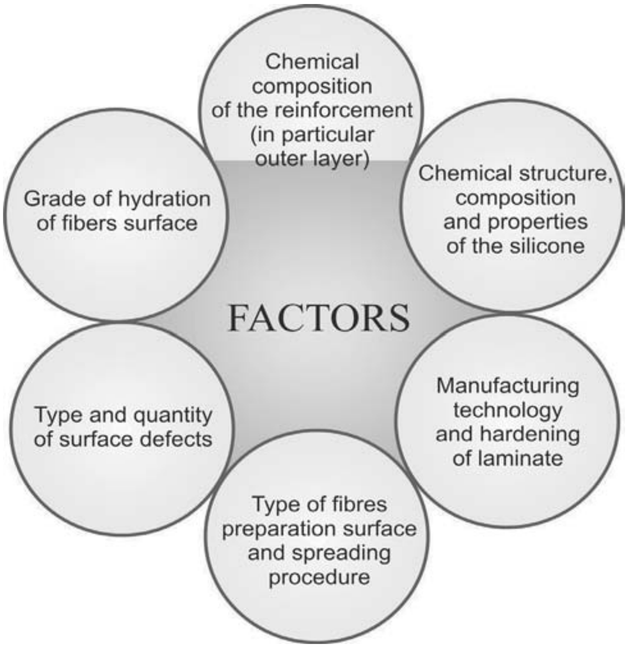

Fig. 6. Factors influencing relations that occur in the interface of the components [16]

Considering the above factors and directives about technological process, manufacturing of aramid silicone laminate goes as follows. At the beginning from the aramid fabric with base weights 36, 61 and 173 g/m^2 respectively, samples with the size of 5×5 cm (Fig. 8) were excised. Then samples were impregnated with silicone. The process was repeated five times to obtain uniform, smooth surface. Particularly, attention was paid to a correct course of the first impregnation process; care was taken of complete penetration of reinforcement by matrix material. Good adhesives of matrix to reinforcement had essential influence on properties of final product.

Process of silicone coating was carried out in room temperature under normal pressure in the atmosphere of air.

Due to the continuous curing process, the samples were placed in a heating chamber KC 100/200, as well as in the heating vacuum chamber Heraeus Instruments – Vacutherm (Kelvtron:t). It was five days since the samples had been placed in a dryer type KC 100/200, where samples were checked to determine whether the silicon cured totally or the surface, and subsequently they were separated from the subsoil, turned upside-down and left for another three days to let them dry in their whole cross-section. The samples, which were left in the vacuum dryer, were not out of operation.

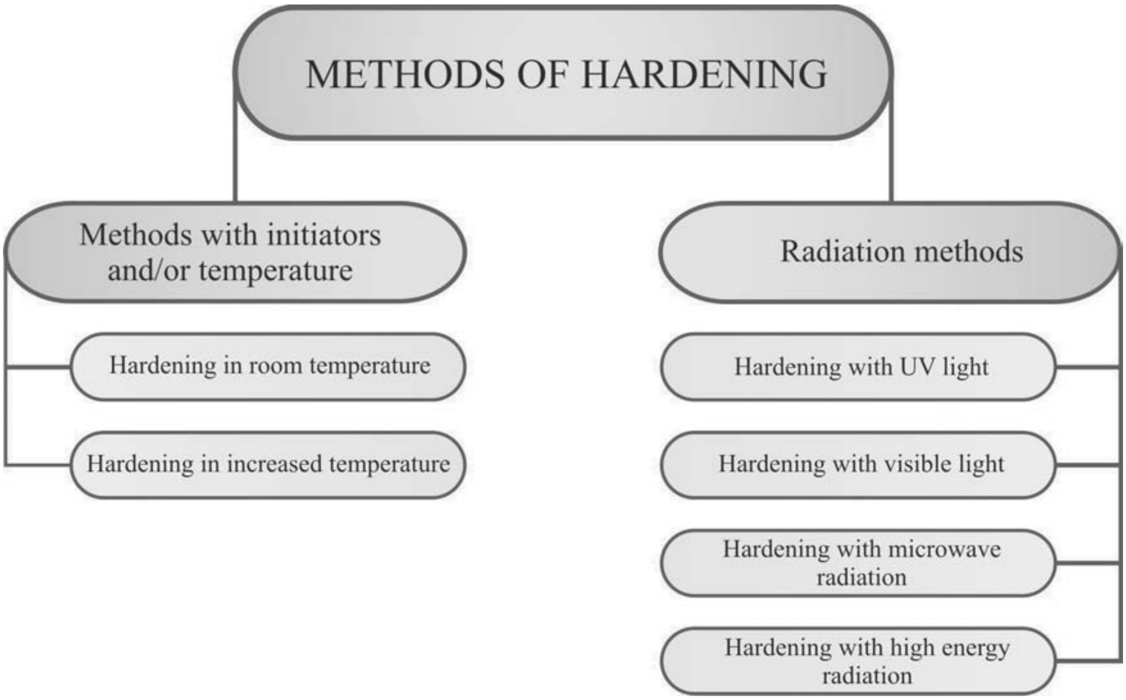

Fig. 7. Division of hardening methods - graphic diagram [6-13]

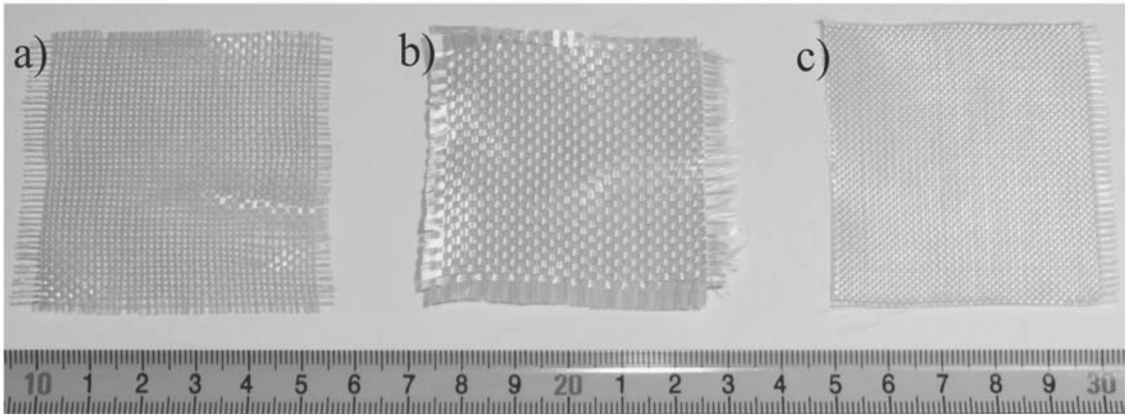

Fig. 8. The survey of prepared samples taken from aramid fabric with basic weight a) 36g/m^2; b) 61 g/m^2; c) 173g/m^2

4. Research

Materialographic observations were carried out on the Axiovert 450M light-microscope of Option Company at 100 x magnification. Samples were properly prepared or examined including cleaning and placing an especially prepared stand (Fig. 9) to avoid over-exposure of the samples.

Additionally, visual observation of the given samples was made to determine possible occurrence of surface defect, including:

- Teeming laps,
- Superficial holes,
- Defects caused by bad adhesion of silicon – bubbles,
- Pressure-breaks,
- Non-impregnated reinforcement [11].

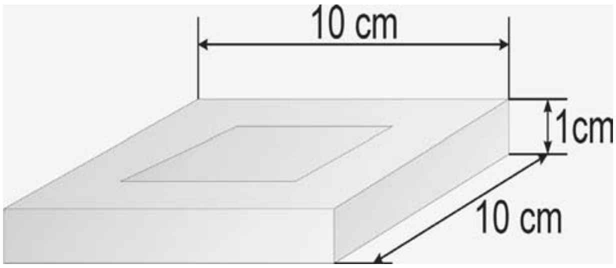

Fig. 9. The demonstrative pattern of the stand for samples

Results of the examinations for the prepared silicone matrix composite materials reinforced with aramid fabric are shown on the Figures 10 and 11.

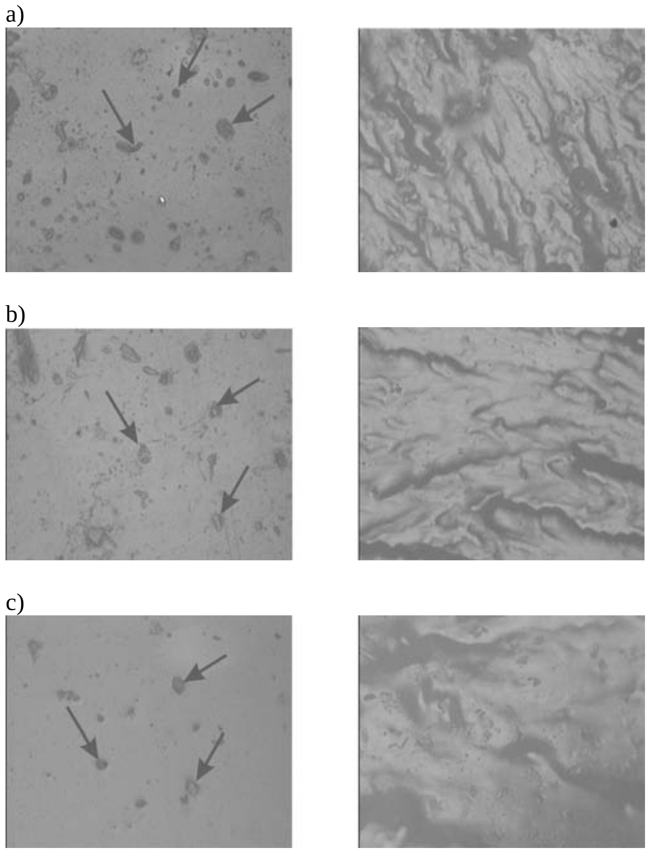

Fig. 10. Surface of samples made based on aramid fabric with basic weight a) 36 g/ m^2, b) 61 g/m^2 , c) 173 g/m^2; 40x. Left side – top surface of samples, right side – contact with base bottom surface

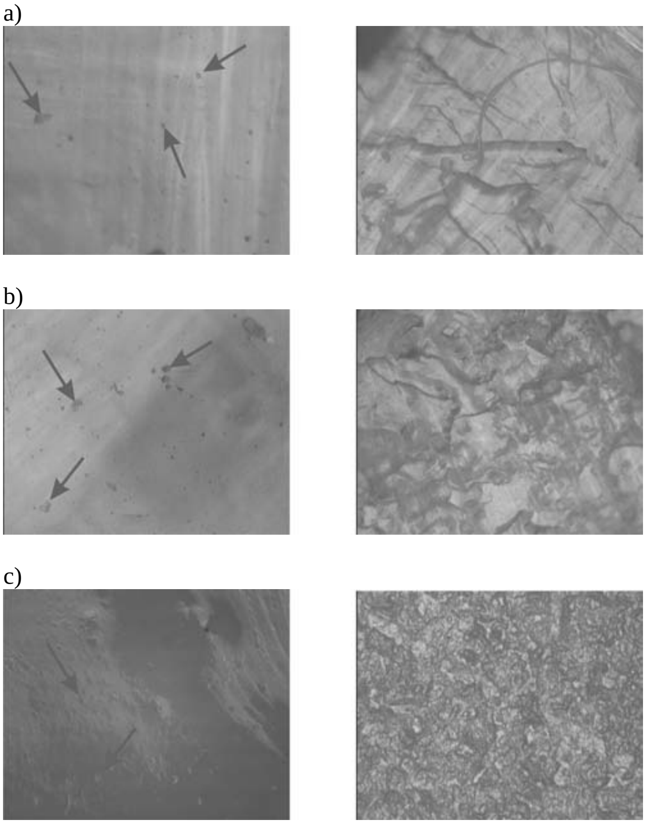

Fig. 11. Surface of samples made based on aramid fabric with basic weight a) 36 g/m^2, b) 61 g/m^2 , c) 173 g/m^2(the vacuum chamber); 40x. Left side – top surface of samples, right side – contact with base bottom surface

5. Results

On the basis of carried out researches, it can be stated that composite materials, obtained as a result of manual forming, are characterized by differentiated degree of surface roughness. After these observations (done for both series of samples) it can be assumed that the "upper" part of samples is very nicely covered by silicone resin (low roughness degree of the surface) (Fig. 10 and 11 – left side). This surface – regarding its application in the future as internal prostheses of oesophagus – will influence positively on transport of food that is eaten by patient after surgery. On the contrary, the "down" side is characterized by high degree of roughness, what can be observed in the Fig. 10. That surface - analogically regarding future application of the material – will influence positively on stabilization of the prosthesis in human body. Irregular surface will be favourable ground facilitating its overgrowth by human tissue. Unfortunately, microscopic examinations have revealed occurrence of so called "superficial holes" as well as bubbles in prepared samples (Figs. 10 and 11 – right side). Occurrence of these types of defects in given material informs that the drying process of particular layers of laminate has not proceeded completely. The solvent that was used in applied silicone resin did not evaporate – again, regarding the future application of material – remains of solvent in final product could be the reason of allergic reaction when the material will contact with the human tissue.

The positive is that the number of this kind of defects can be diminished by application of vacuum dryer (Fig. 11).

Organoleptic examinations allow determining that given material is characterized by excellent elasticity, and also plasticity, as far as a given group of materials is concerned. Particular elasticity demonstrates the sample, in which reinforcing fabric has the lowest basic weight (32 g/m^2). According to these observations it can be assumed that influencing on elasticity of a given material is possible by changing basic weight of reinforcing material and its impregnation degree.

6. Summaries

According to researches that were done in this work, it can be said that produced novel biocompatible aramid-silicone composite material is characterized by specific properties as far as a given group of materials is concerned (laminates). Elasticity of given material as well as plasticity of silicone layer will positively influence on contact point – prosthesis-tissue. It is highly probable that this type of material will not cause bedsores in human body, after the prosthesis is implemented. As mentioned above, it is very important to differentiate roughness degree of the "upper" and "lower" surface of obtained material. This effect will have huge influence on both food digestion ("upper" side) as well as stabilization of the prosthesis in human body.

Referring to superficial defects determined in a given material, it is still technological problem which left to be solved. Its solution would evoke minimization of superficial holes and bubbles being a confirmation of the residual solvent in final product.

From the point of view of future application of tested material, it is necessary to avoid this type of defects. Possibility to get unwanted allergic reactions being the point of direct contact between internal prosthesis and living body is limited in this way.

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