Synthesis and Characterization of Copolymers Based on Styrene-Butadiene Grafted with Antimicrobial Agents

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***Abstract* — The paper describes polymer materials based on styrene–butadiene grafted with antimicrobial components. The engraftment of copolymer styrene: butadiene-1,2 with methacrylic acid has been performed. The structure of grafted copolymer was confirmed by IR spectroscopy and by elemental analysis. It has been demonstrated that a rest of methacrylic acid joins the vinyl compound. Through an analogue polymer-transformation we succeeded in coupling of antimicrobial compounds such as ampicillin and others to ST:BD copolymer grafted with methacrylic acid. The structure of medicinal copolymer as well as the content of ampicillin has been confirmed by IR spectroscopy and elemental analysis. It has been shown that 65-70% COOH groups were subjected to transformation. Antimicrobial tests of medicinal copolymer demonstrated almost an identical activity of standard copolymer N-vinylpyrrolidone with metacrilic acid. The developed medicinal copolymer can be recommended for use in manufacturing of household items as well as of items of furniture, or part of the clinical household utensils having the possibility to improve the hygienic indices.**

I. INTRODUCTION

There has been a growing interest in recent years in investigation of polymer materials and composites having extended medical and antimicrobial properties, antifungal properties, and others.[1,2]

The researches from the pharmaceutical field have led to the realization of new systems of controlled release of biologically active substances, based mostly on their targeted action.[2] In this area there are a number of results, and many of them on biologically active polymers. Many of these have exceeded the framework of just theoretical study and have been implemented in practice.[3] The immobilization of biologically active principles on polymeric media is a relatively new field, demonstrating encouraging results in the development of new synthesis technologies of polymeric drugs. Today, thanks to the development of pharmaceutical biotechnologies, antibacterial preparations become specific therapeutic agents with increased efficiency.[4]

It is known that the development of resistant pathogens or even very resistant to a number of antibiotics has become a major problem of the modern medicine. In this context an important role it is played by the polymers chemistry with specific functionality concerning the protection against bacteria/fungi and other micro-organisms.[4] One of the benefits of using medical polymers is supported by the fact that their macromolecular structure could provide effectiveness over time of the antibacterial activity for a broad spectrum of bacteria, in a short contact time, the duration of the prolonged action, plus the absence of toxicity and chemical stability. A particular importance presents the elaboration of polymeric materials of technical use for the production of films for covering, articles of furniture for medical clinics, or in household purposes from the need to give them antibacterial properties.[4]

II. EXPERIMENTAL METHODS

For the engraftment of SBS with methacrylic acid, we have carried out its preliminary purification. Methacrylic acid purification was achieved via vacuum distillation. For this purpose 50 ml of the methacrylic acid was placed in a glass tube with the round-shaped bottom, and the tube was slowly evacuated to made the acid to boil. The pure methacrylic acid is kept in the refrigerator not to polymerize. The temperature is kept at T_f = 116-118 $^{\circ}$C at the pressure P = 20 mm Hg. The SBS copolymer purification has been carried out by its precipitation in hexane. The coupling reaction of SBS copolymer (M = 89000) with methacrylic acid was achieved by the radicalized polymerization method in the nitrogen atmosphere at 80 $^{\circ}$C in the presence of azobisisobutyronitrile (AIBN) as initiator.[5]

The engrafted copolymer purification has been carried out by repeated sedimentation in the diethyl ether. The purification was done for the removal of unreacted methacrylic acid.[6] Fig. 1 illustrates the scheme for coupling of support copolymer SBS to ACM.

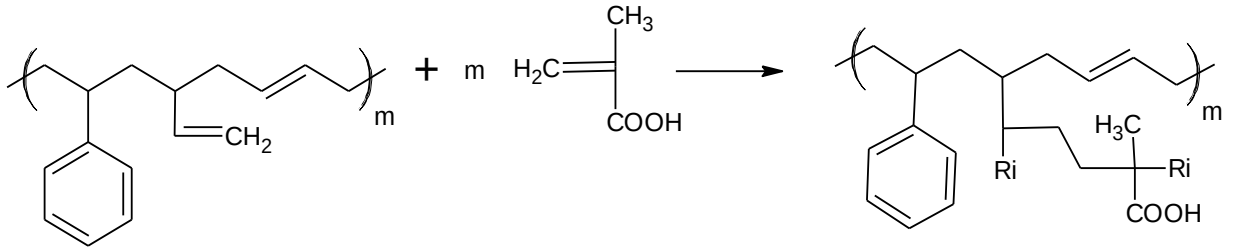

Fig. 1. Illustration of the reaction for coupling of support copolymer SBS to ACM

The polymer-analogue transformation of SBS-ACM copolymer with ampicillin was realized at 0 °C with ethyl chloroformate during three hours.

Medicinal polymer was dried out in air and in vacuum oven at temperature T = 40 °C until obtaining a constant mass. The structure of the support polymer SBS-ACM (I_0), as well as the structure of medicinal polymer (II_0) has been confirmed by IR spectroscopy and elemental analysis. The scheme, illustrating the process of coupling of support copolymer SBS-ACM to ampicillin is represented in Fig. 2.

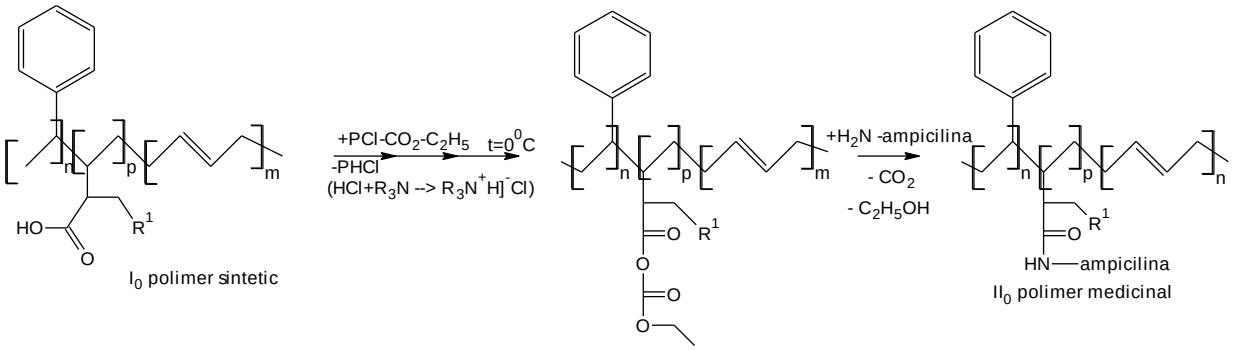

Fig. 2. Illustration of coupling of support copolymer SBS-ACM to ampicillin

III. RESULTS AND DISCUSSIONS

The chemical structure of the initial copolymer (ST:BD) and the engrafted structure of ST:BD:ACM was confirmed using IR spectroscopy. As is observed from the IR spectrum of the initial copolymer ST: BD, one can see that the frequency band with the vibration of $\nu = 1087$ cm^{-1} disappears, which is characteristic to the vinyl bond (-CH = CH2). There are new vibrations in the copolymer ST:BD:ACM characteristics for methacrylic acid links: $\nu = 3417$ cm^{-1} (for OH groups of acid); $\nu = 2568$ cm^{-1} (for carboxylic group); $\nu = 1696$ cm^{-1} (Carbonyl groups > C = O); $\nu = 2845$ cm^{-1}, 2921 cm^{-1} (methyl and methylene group). The IR spectrum of SBS is represented in Fig. 3 and Fig. 4 illustrates the IR spectrum of SBS coupled with methacrylic acid.

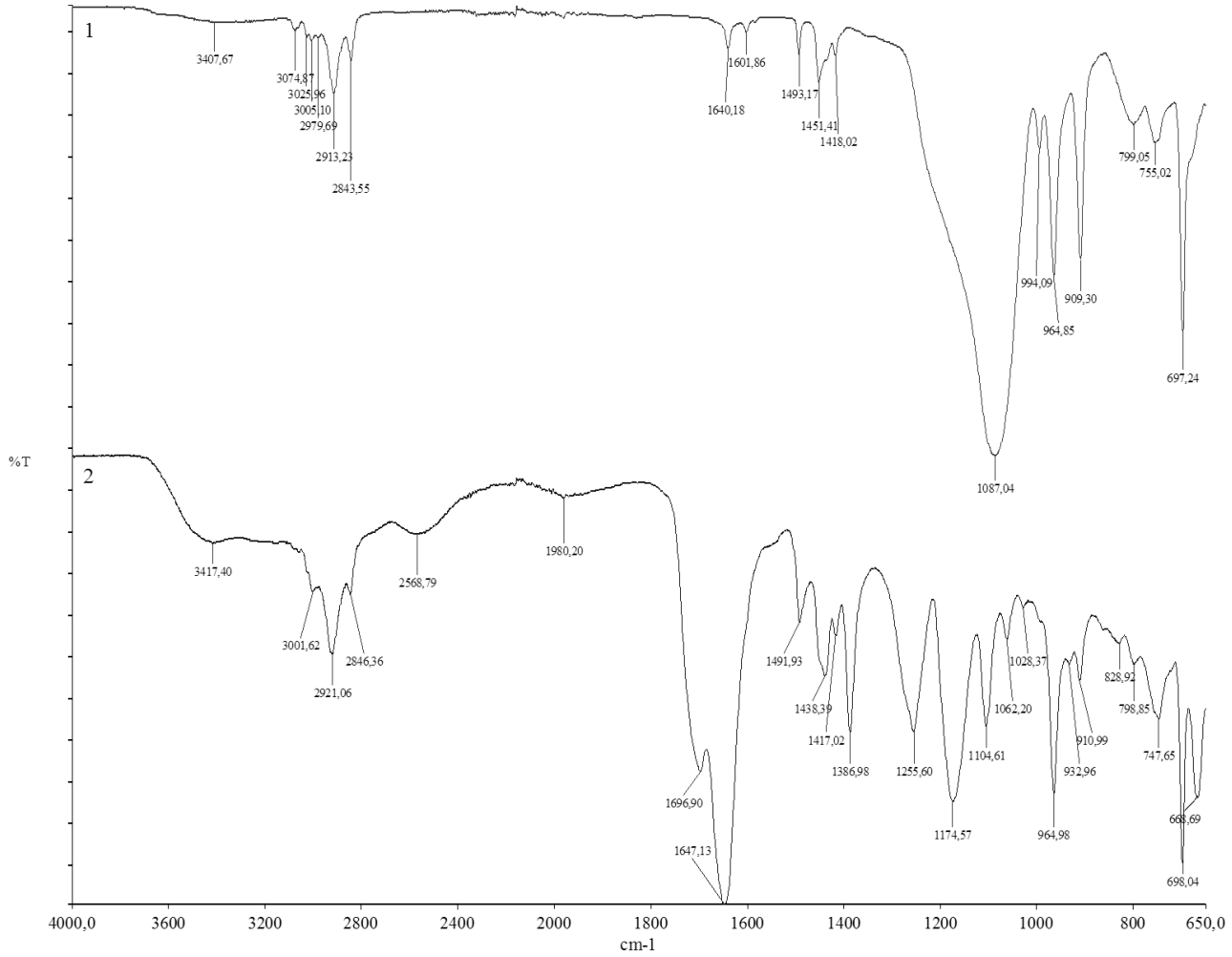

Fig. 3. IR Spectrum of SBS copolymer (1) and IR spectrum of SBS copolymer coupled with methacrylic acid (2)

Elemental analysis for the C atom in the copolymer ST:BT:ACM has been carried out and the results are as follows: C (calculated carbon) = 75.4% and C (carbon discovered by EA) = 63.65%. From elemental analysis it has been established that the number of the methacrylic acid links in a fragment constitution of the copolymer, represents a functional and structural unit.

IR spectroscopy has been used to demonstrate that the ampicillin coupling with the copolymer SBS:ACM took place. IR spectrum of SBS-ACM copolymer and of the medicinal copolymer SBS:ACM:Ampicillin is represented in Fig. 4. From the IR spectrum one can observe that there are new vibrations in the medicinal copolymer as: ν_1 = 3330-3270 cm^{-1} (-CO-NH-linked); ν_2 = 2606, 2534, and 2498 cm^{-1} (characteristic to S-H group); ν_3 = 1650, 1630 cm^{-1} (characteristic for the phenyl radical); ν_4 = 1774 cm^{-1} (for group >C=O from ampicillin).

The structure of medicinal copolymers was confirmed by IR spectroscopy. From the IR spectra one can observe the interaction of the rest of methacrilic acid from the ST:BT:ACM with the ampliciline.

Further there was carried out the elemental analysis of nitrogen from the medicinal copolymer (only the ampicillin contains nitrogen atoms). The elemental analysis results for N in the copolymer ST:BT:ACM coupled with ampicillin are as follows: C (calculated nitrogen) = 9% and C (nitrogen found through EA) = 8.3%.

Once more it is confirmed that due to these values the ampicillin coupling to the support copolymer (ST:BT:ACM) went successfully. Through the elemental analysis it was determined that about 80-85% of COOH groups have been subjected to processing and we conclude that getting of the medicinal copolymer may be carried out on an industrial scale.

The bacteriological tests demonstrated the high antimicrobial effect towards gram-positive and gram-negative microorganisms and the fact that the new material can be used for shaping objects with clinical uses.

Antimicrobial testing of medicinal copolymer were comparable to those of N-vinylpyrrolidone standard

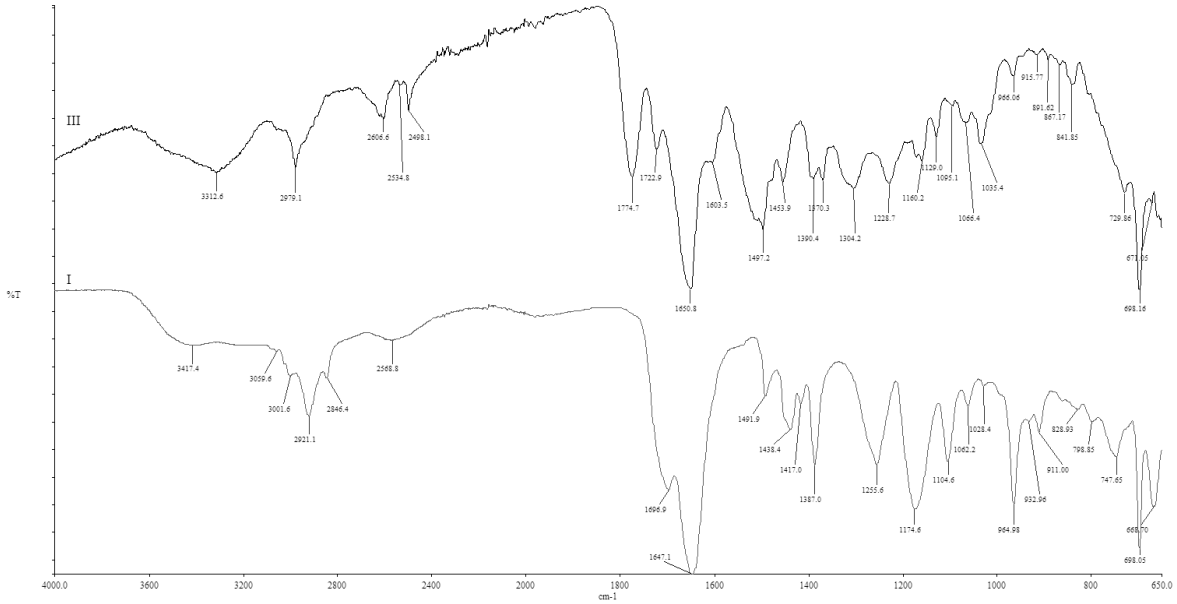

Fig. 4. IR spectrum of SBS-ACM copolymer (I) and of the medicinal copolymer SBS:ACM:Ampicillin (III)

copolymer with methacrylic acid coupled with ampicillin.

Antibacterial activity was tested on reference cultures as follows:

- Staphylococcus aureus (strain 209-P);
- Enterococcus faecalis (E. faec.);
- Escherichia coli (strain ATCC 25882);
- Pseudomonas aeruginosa (strain ATCC 27853);
- Proteus vulgaris (strain HX 19222).

The tests consist in investigation of the following:

a) The minimum bacteriostatic activities "CMI", which indicates the lack of growth of microorganisms in the nutrient medium;

b) The bactericidal activities "CMB" which is determined on the basis of lack of growth of micro-organisms within 24 hours.

Table 1. The results of antimicrobial test for investigated polymers

Medicinal polymer	Test- bactericidal culture (mg/ml)							
	S. aureaus		E. faecalis		E. coli		P. vulgaris	
	CM I	CMB	CMI	CMB	CMI	CMB	CMI	CMB
I. N- VP:ACM (1:1) Coupled with ampincilin	1.17	4.68	9.37	300	150	150	9.5	18.5

IV. CONCLUSIONS

Engraftment of copolymer styrene: butadiene-1,2 with methacrylic acid has been obtained. The structure of grafted copolymer was confirmed by IR spectroscopy and by elemental analysis. It has been demonstrated that a rest of methacrylic acid joins the vinyl compound.

Through an analogue polymer-transformation we succeeded the coupling of antimicrobial compounds such as ampicillin and others to a St: BD copolymer grafted with methacrylic acid. The structure of medicinal copolymer as well as the content of ampicillin has been confirmed by IR spectroscopy and elemental analysis. It has been shown that about 65-70% COOH groups were subjected to transformations.

Antimicrobial tests of medicinal copolymer demonstrated almost an identical activity with the standard copolymer N-vinylpyrrolidone with metacrilic acid. The developed medicinal copolymer can be recommended for use in technical needs for preparation of household items as well as items of furniture, part of the clinical household utensils having the possibility to improve the hygienic indices.

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