MECHANICAL PROPERTIES OF HYDROGELS IN A CHITOSAN/SILK/GRAPHENE SYSTEM

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Introduction

Since 1960s, hydrogels have been intensively studied and developed. Their high water content is a big advantage because it promotes biocompatibility but at the same time, their mechanical properties are very low. Thus, during surgical procedure, such implants are very prone to damage. Recent research are focused on improving their mechanical properties and vesting additional functions. One of the most promising paths of modification is to incorporate nanoparticles into hydrogel matrix. Nanoforms of carbon, e.g. nanotubes, graphene, graphene oxide, seem to be excellent choice for this purpose. Such a “hydrogel–carbon nanoparticles” combination creates multifunctional material that has a potential to be used in regenerative medicine [1-3].

Materials and Methods

In this study a natural polymer matrix – hydrogel based on combination of chitosan (CS) and silk (SP) – was reinforced with two types of carbon nanoparticles: graphene oxide (GO) and reduced graphene oxide (rGO) (ITME, Poland) with various weight content.

To obtain composite “a solution-evaporation casting method” was applied and as a result thin foils were acquired. To prepare liquid matrix, a chitosan powder mixed with a silk powder in 4:1 ratio was dissolved in lactic acid. Then, matrix modifiers were introduced in following amounts: 0.5, 1.5, 3wt%. One group of samples was modified with GO and the second one with rGO. Each type of mixture was transferred into a Petri dish and left overnight to dry. When ready, foils were physically crosslinked by neutralization in 1M sodium hydroxide solution. After rinsing in water, the samples were cut into 4mm width strips. In the end six types of composites were obtained: CS/SP/0.5GO, CS/SP/1.5GO, CS/SP/3GO, CS/SP/0.5rGO, CS/SP/1.5rGO, CS/SP/3rGO. For reference purposes, foils made of pure CS and CS/SP were prepared in the same manner. To examine their mechanical properties, static tensile tests and analyses of strain-stress curve were performed (Zwick 1435). Tensile strength R_m, Young modulus E, maximum deformation ε_{Fmax} were characterised.

Results and Discussion

Mechanical testing results were collected and compiled as shown in graphs (Fig.1-3). As all materials are hydrogels it is not surprising that obtained results are rather low. Reference samples made of CS and CS/SP have tensile strength of 1,6 MPa and 1,2 MPa, respectively. Young’s modulus values for CS/SP (4,0 MPa) were higher than for CS (3,6 MPa). When results of composites materials were analysed, it has been proven that in all cases except one (CS/SP 0.5rGO), addition of nanoparticles weakens a material and obtained composites have poorer mechanical properties than matrix itself (CS, CS/SP). The values of tensile strength for all composites foils were congruent and varied from 0,5 MPa to 0,8 MPa. Young’s modulus decrease in range of 20-30% was observed. In general, it can be stated that from mechanical point of view introducing nanoforms of carbon into chitosan and chitosan/silk matrix incurred negative effects. Compared to reference, composite samples were twice weaker and their ranges of deformation were also reduced. These effects might be a result of poor distribution of nanoparticles in a volume of the matrix, thus nanoparticles weakened the material instead of strengthening it.

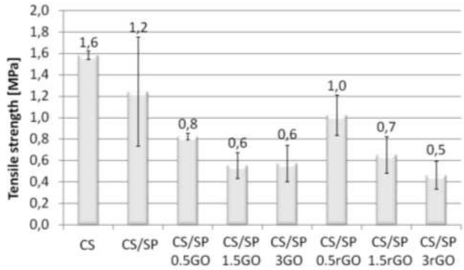

FIG. 1. Tensile strength of obtained hydrogels.

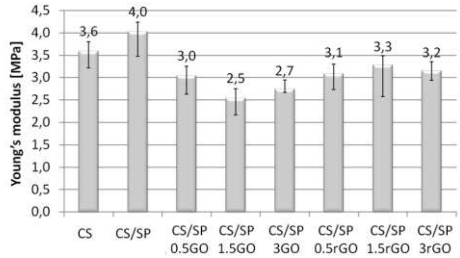

FIG. 2. Young's modulus of obtained hydrogels.

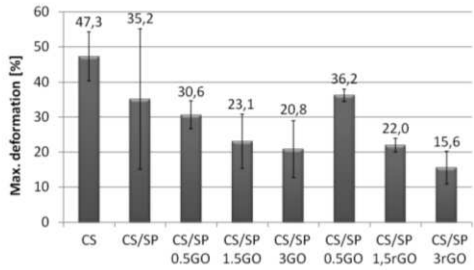

FIG. 3. Maximum deformation of obtained hydrogels.

Conclusions

The type (GO or rGO) and the quantity of carbon nanoparticles addition (0,5-1,5 wt%) have influence on material’s tensile strength and deformation. Nevertheless, Young’s modulus was not so susceptible and didn’t change as much, depending on material composition. It is suspected that no chemical bonding between additive and matrix was created. Based on the results, it can be stated that in the case of modifying CS and CS/SP matrix rGO is a better choice than GO. Although it has to be in mind that these types of nanoadditives have also an impact on other properties of the material, e.g. biological and that should be investigated in a following study.

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