Characterization of smart and biocompatible materials based on chitosan:cellulose composites containing sporopollenin exine capsules

Budasheva H[(1)], Cazon Diaz P[(1)], Korte D[(1)], Franko M[(1)*], Tran CD[(2)]

(1) Laboratory for Environmental and Life Sciences, University of Nova Gorica, Vipavska 13, Nova Gorica, SI-5000, Slovenia

(2) Department of Chemistry, Marquette University, P.O. Box 1881, Milwaukee, WI 53201, USA

*Mladen.Franko@ung.si

Healing of chronic ulcerous infected wounds is nowadays one of the biggest public health challenges that affect a significant number of people. The proper wound dressing should not only provide the antimicrobial activity but should also have some other characteristics. Among them proper porosity is of high importance since it enables controlling the moisture around wound and provide oxygen/water vapour exchange between wounded tissue and environment. Furthermore, surface of dressing should have proper roughness to enhance epidermal migration and synthesis of connective tissue [1]. Of high importance are also the dressing thermal properties that maintain appropriate tissue temperature ensuring the proper blood flow, as well as expresses the extent of metabolic heat transfer from the tissues under the dressing, outward through the dressing structure. Excessive heating of skin under a dressing leads to perspiration that correlates with a state of tissue inflammation. Thus, both the structural and thermal properties of wound dressing materials belong to the fundamental physical properties of high clinical relevance in both prevention and treatment of acute and chronic wounds. All of these factors strongly affect the healing process. Thus, should be carefully designed when developing a new type of functionalized dressing for wound healing. Because of that, big efforts are made to invent smart materials that can react to the environmental conditions present at the site of a wound (presence of moisture, oxygen, temperature etc.) and adapt their properties to ensure optimal functionalization as sophisticated wound dressings. Since such materials tend to be used in medicine, they are required to be biodegradable and biocompatible, thus, must be generated from renewable biomass feedstock. It has been already shown that such biocomposite materials can be obtained from natural and sustainable biopolymers as cellulose (CEL) from plants, chitosan (CS) from animals and keratin (KER) from wool, hair or chicken feathers [2]. Furthermore, they have many required properties provided by their components as superior mechanical strength delivered by CEL or anti-inflammatory/antimicrobial activity provided by the presence of both CS and CEL [10-13]. Unfortunaltely, their porosity appears to be rather low (below 0.1 % according to our preliminary measurements), which represents one of the key obstacles to final application of such materials. The solution of this problem requires application of novel approaches to determination of porosity of such materials since existing techniques based on pichnometry or SEM analysis, do not provide sufficient accuracy [3]. For this reason, a photothermal beam deflection spectrometry (BDS) [4] was further developed, validated and applied for characterization of CS:CEL based biocomposite materials with different concentration of natural sporopollenin microcapsules (SEC) and different content of CS and CEL synthesised by the latest green chemistry approaches [2]. It was found that these materials exhibit rather low porosity (below 0.1 %), that can be increased to 0.44 % with increase in CEL content or by addition of sporopollenin exine capsules. The increase in CEL content from 25 % to 75 % results in 50 % increase in total porosity (from 0.4 to 0.6 %) and by nearly 100 % in case of opened one (from 0.05 % to 0.09 %), whereas the addition of SEC at the level of 50% shows up to 4 times increase in both types of porosity, depending on the CS:CEL content.

Futhermore, addition of sporopollenin exine capsules increase significantly the surface roughness of the biocomposites what can mask the low porosities values and make the material useful for desired application. The biocomposites without SEC have rather flat surface with the amplitude of the roughness at the level of single nm and its periodicity at the level of single µm. After deposition of SEC the surface roughness significantly increases to the value of around 0.4 µm and 50 µm for 10 % of SEC loading in case of the roughness amplitude and periodicity, respectively. Increasing the amount of SEC up to 30 % increases the amplitude of surface roughness 10 times, whereas its periodicity nearly twice. Further increase in the amount of SEC deposited on the biocomposite surface causes nearly 50 % further increase in the surface roughness.

It was also found the presented biocomposites material have low values of thermal properties- The obtained values were at the level of 10s mW m-1 K-1 and fraction of mm2 s-1 in case of thermal conductivity and diffusivity, respectively and are decreased by about 25% with increase of CEL content from 25 % to 75 % (0 % SEC concentration). Addition of SEC also reduces the values of thermal diffusivities and conductivities up to 30 % for the SEC concentration at the level of 50 %.

The physical properties of wound dressing play a key role in the healing process. They create a specific microenvironment that provide protection from contamination, enhance the activity of enzymatic and cellular systems required for effective re-epithelialization, as well as control the fluids exchange with external world to control the moisture around the wound.

The results obtained by BDS measurements are in good agreement with those obtained by SEM, AFM and optical microscopy and indicate that the presented biocomposites are interesting materials with their possible applications in medicine.

References

[1] P.G. Bowler, B.I. Duerden, D.G. Armstrong, Wound microbiology and associated approaches to wound management, Clin. Microbiol. Rev. 14 (2001) 244–269.

[2] C.D. Tran, F. Prosenc, M. Franko, G. Benzi, Synthesis, structure and antimicrobial property of green composites from cellulose, wool, hair and chicken feather, Carbohyd. Polym. 151 (2016) 1269–1276.

[3] L. Cui, J. Gong, X. Fan, P. Wang, Q. Wang, Y. Qiu, Transglutaminase-modified wool keratin film and its potential, Eng. Life Sci., 13 (2013) 149–155.

[4] D. Korte, M. Franko, Application of complex geometrical optics to determination of thermal, transport, and optical parameters of thin films by the photothermal beam deflection technique, J. Opt. Soc. Am. A, 32 (2015) 61–74.