

COMPOSITE MATERIALS OF STARCH WITH HYDROXYAPATITE ON THE COTTON TISSUE AS MATERIAL FOR WOUND DRESSINGS

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Abstract

Materials composed of starch and calcium phosphate particles were prepared in the form of films or coatings on wound dressings. The calcium phosphates were dicalcium phosphate dihydrate or amorphous calcium phosphate, depending on the solution pH value and on the Ca/P ratio during their precipitation in situ. Starch was shown to cover the cotton fibers as a film and fixes calcium phosphate crystals on the tissue surface. XRD analysis was applied to find out the phase composition of the substances synthesized. DCPD was determined to form when $\text{Ca/P} = 1$ and $\text{pH}=5.5$. ACP was obtained at $\text{pH}=7$ and $\text{Ca/P} = 1.5$. The phase composition of precipitate depends on both the pH level and the Ca/P ratio. Starch gel covers the cotton fibers as a film and fixes crystals on the tissue surface. Cotton tissue covered by starch and containing calcium phosphate particulate can be applied as wound dressings.

Key words: biomaterials, wound dressings, calcium phosphates, starch.

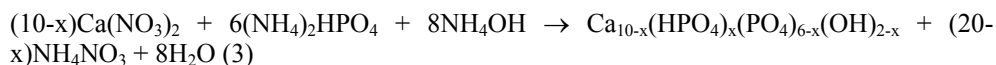
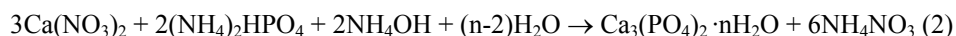
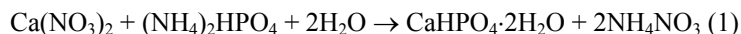
INTRODUCTION

Treatment of burns and wounds requires the application of a dressing to absorb drainage and to isolate the wound from the environment. Dressings are generally fabricated using cotton materials, which consist mainly of cellulose. Wound healing is a calcium-mediated process [1]. Calcium ions affect inflammatory phase of tissue repair and fibroblast cell proliferation [2]. Acute wounds become chronic when arrested at the inflammatory stage. To control the calcium transport to the wound surface, the addition to the dressing of a calcium releasing agent seems to be promising. Several calcium phosphates would release calcium ions when exposed to an acidic pH [3-5]. Calcium phosphate nanoparticles have been shown to decrease open wound size via contracture [4]. The contraction effect is mediated by the release of ionized calcium into the wound bed, thus providing a therapeutic benefit. The simplest way to fabricate the calcium containing dressing seems to be the precipitation of calcium phosphate (CP) particles onto the dressing with a biodegradable and biocompatible polymer as a glue to fix the CP particles. A number of polymers can be used for this aim: collagen, gelatin, chitosan, and others. However, these materials of animal origin may possess some negative influence on the biological environment of the human body, e.g. immunomodulation action, inflammatory reactions, virus infection, etc. So the development of new composite materials for dressings seems to be a timely problem. Starch is a promising material due to its resorbability, which can be regulated by chemical modification [6,7].

Porous composite materials of hydroxyapatite with starch for bone reparation were developed [8]. However, such kinds of composites in the form of films have not yet been investigated. The present investigation was aimed at development of a chemical route to fabricate the composite materials starch – calcium phosphate in the form of films or coatings on cellulose wound dressings.

EXPERIMENTAL

Non-modified potato starch was used. The calcium phosphates such as dicalcium phosphate dihydrate (DCPD), precipitated hydroxyapatite (PHA), amorphous calcium phosphate (ACP) were synthesized *in situ* in an aqueous starch gel in the presence of glyoxal, or without it. Starch concentration in the gel was 1 wt.% and 5 wt.%. Calcium nitrate solution 1 mol/l and ammonia hydrophosphate solution 1 mol/l were used to synthesize calcium phosphates. Calcium phosphates were precipitated following the reactions:



All reagents were of analytical grade. The samples of cotton tissues were placed into the reactor during synthesis and then dried in the open air. The phase composition of the powder compounds was examined by XRD analysis using a Shimadzu 6000 diffractometer. The microstructure of the powder compounds as well as the coatings on cotton tissue were examined by SEM analysis by a Tescan Vega II scanning microscope.

RESULTS AND DISCUSSION

The composition of coatings on the cotton tissue was shown to consist of calcium phosphate and starch. The calcium phosphate phase depends on the Ca/P ratio and reaction mixture acidity. DCPD is formed when Ca/P = 1 and pH=5.5.

According JSPDS dates, DCPD exists in two crystalline forms with peaks of maximum intensity at 11° and 26° (2θ scale). Both bands were established in XDR analysis (Fig.1a). For the composite obtained at pH=7 and Ca/P = 1.5 two wide bands at 32° and 40° (2θ scale) were attributed to ACP (Fig.1b).

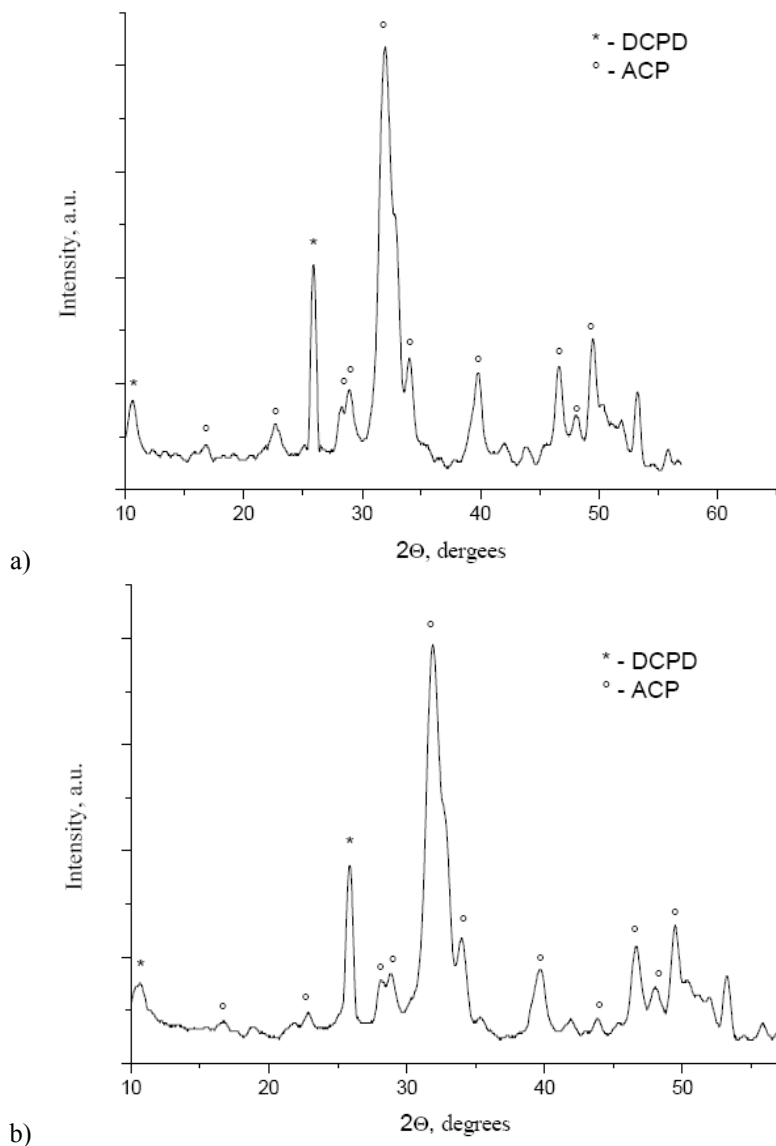


Fig.1. XRD: a - DCPD-starch obtained at pH=5 and Ca/P=1; b – ACP-starch obtained at pH=7 and Ca/P=1.5.

The XRD spectra of ACP-starch and precipitated HA (PHA)-starch obtained at pH=9 and Ca/P=1.67 are practically the same.

According to SEM micrographs, platelet crystals of 10-30 μm size are observed on the cotton fibers (Fig.2). The form of crystals is typical for DCPD.

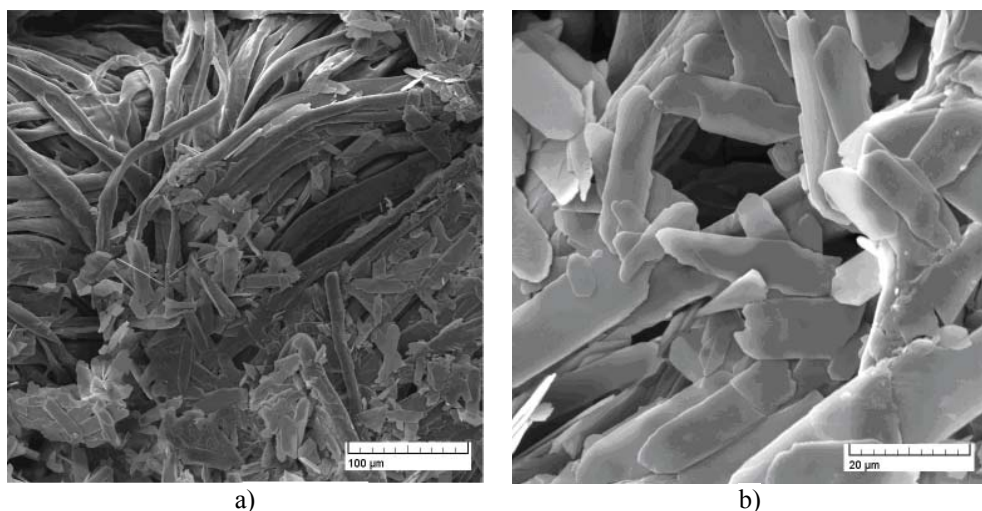


Fig.2. SEM image of cotton fibers coated with composite starch-DCPD.

When the pH rises to 7 and Ca/P to 1.5, the structure corresponding to $\text{Ca}_3(\text{PO}_4)_2 \cdot x\text{H}_2\text{O}$ is formed. At pH=9 and Ca/P=1.67 the same compounds were observed according XRD analysis. Hence at Ca/P = 1.5 and 1.67 and pH 7 and pH 9 the same compound is formed $\text{Ca}_3(\text{PO}_4)_2 \cdot x\text{H}_2\text{O}$. SEM micrographs of the respective CP particles are shown in Figs.3 and 4. ACP presents itself as two crystal forms - large platelet crystals about $10 \times 50 \mu\text{m}$ and small ungeometrical crystals less then $1 \mu\text{m}$.

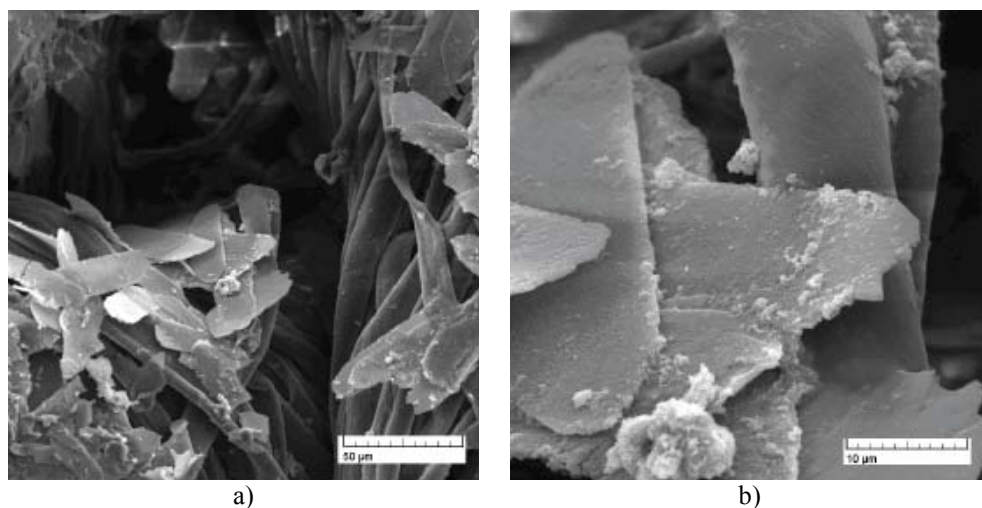


Fig.3. SEM micrographs of cotton sample coated with starch-calcium phosphate at pH=7 and Ca/P=1,5.

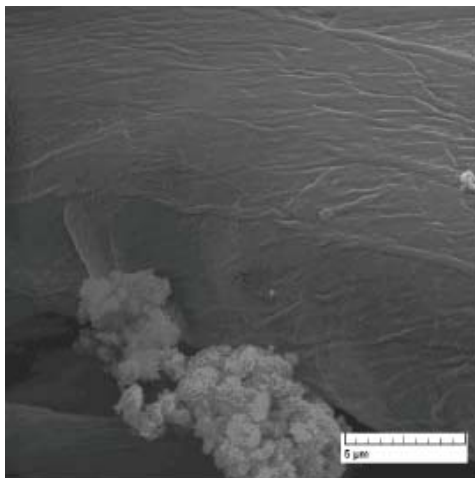


Fig.4. SEM micrograph of cotton sample coated with starch-calcium phosphate at pH=9 and Ca/P=1,67.

One can see that cotton fibers are coated with starch film (Fig 3a, 4) and calcium phosphate crystals are presented as two different crystals – large platelet crystals of size 20-50 μm and small crystals less than 1 μm situated on the surface of large crystals (Fig.3b). Because the XRD revealed the ACP is the main phase constituent, the large crystal morphology seems to be very similar to that of DCPD crystals.

CONCLUSION

Calcium phosphates particles such as DCPD and ACP were precipitated *in situ* on the cotton fiber surface from a starch aqueous gel. The phase composition of precipitate depends on both the pH level and the Ca/P ratio. Starch gel covers the cotton fibers as a film and fixes crystals on the tissue surface. Cotton tissue covered by starch containing calcium phosphate particulate can be applied as wound dressings.

Acknowledgements

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REFERENCES

- [1] Lansdown, AB.: Wound Repair Regen., vol. 10, 2002, p. 271
- [2] Bikle, DD., Ng, D., Tu, CL., Odo, Y., Xie, Z.: Molecul. and Cell. Endocrinology, vol. 177, 2001, p. 161
- [3] Barinov, SM., Komlev, VS.: Calcium Phosphate Based Bioceramics. Moscow : Science, 2005
- [4] Kawai, K., Larson, BJ., Ishise, H., Carre, AL., Nishimoto, S., Lonhaker, M., Lorenz, HP.: Plos One, vol. 6, 2011, no. 11, p. e27106
- [5] Featherstone, JD., Rodgers, BE.: Caries Res., vol. 15, 1982, p. 377
- [6] Chen, Y., Wang, G.: Colloids and Surfaces A: Physicochem. Eng. Aspects, vol. 289, 2006, p. 75
- [7] Pashkuleva, I., López-Pérez, P., Azevedo, HS., Reis, RL. et.al.: Materials Sci. and Engineer. C, vol. 30, 2010, p. 981
- [8] Sundaram, J., Durance, TD., Wang, R.: Acta Biomaterialia, vol. 4, 2008, p. 932