# Nanocomposite of Poly(propylene fumarate) with Crosslinkable Hydroxyapatite

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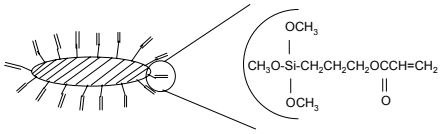
**Introduction:** Poly(propylene fumarate) (PPF) can be crosslinked through its fumarate double bonds for diverse orthopedic applications. Bioactive ceramics such as hydroxyapatite (HA) have been used for a variety of applications including bone fixation devices and implant coating. Synthetic HA is especially attractive to serve as a filler material for biodegradable polymer-ceramic composites. Advantages include similarity to composition to bone mineral, bioactivity and promotion of cellular function, and osteoconductivity. Previous studies indicate that interfacial bonding between the HA surface and the matrix can significantly improve mechanical properties of polymer-ceramic composites. In this study, nano-HA has been grafted with a crosslinkable coupling agent, 3-acryloylpropyl trimethoxysilane, shown in Scheme 1. Such grafted-HA can be used as a crosslinkable filler to react with PPF matrix to fabricate biodegradable and bioactive composites with improved mechanical properties for orthopedic applications.

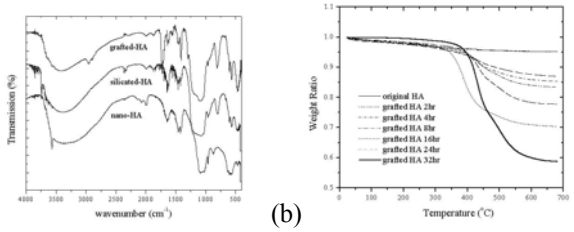



**Scheme 1**

**Methods:** HA whiskers (Berkeley Advanced Biomaterials) with long and short axis of 100 and 20 nm, respectively, was used for grafting. The HA was silicated as below.[1] Briefly, 1 g of sodium metasilicate (Aldrich) was dissolved in 50 ml of distilled deionized water, 1 g of HA was added, and the mixture was stirred for 3 hr. The pH was adjusted to 6.8 with HCl and the mixture was allowed to stir overnight. The mixture was centrifuged and the solid silicated HA (SiHA) product was dried in vacuum at 150 $^{o}$C for 2 hr. 3-acryloylpropyl trimethoxysilane was grafted to SiHA using the following procedure. 3-acryloylpropyl trimethoxysilane was dissolved in 50 ml of 70/30 acetone-water mixture and the SiHA was added to the solution in nitrogen atmosphere and under vigorous mixing. After removal of acetone and water at 100 $^{o}$C, 3-acryloylpropyl trimethoxysilane and SiHA were condensed at 120 $^{o}$C for 2 hr or longer for higher grafting ratios. The grafted HA was extracted with THF overnight and then centrifuged. PPF with $M_n$=2109 g/mol and $M_w$=3834 g/mol was used to make composites with nano-HA or grafted HA at different weight ratios from 1% to 30% by blending in excess $CH_2Cl_2$ with the help of ultrasonic treatment.

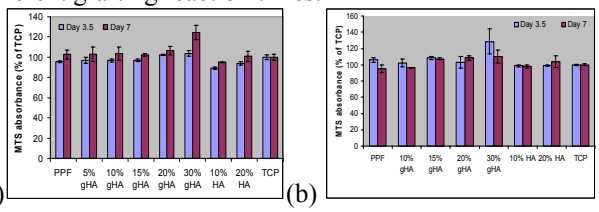
The chemical structures were verified by FTIR spectra. The thermal properties were determined by DSC, TGA. The dynamic frequency sweep measurements of the nanocomposites as well as PPF have been performed on a TA AR2000 rheometer and viscosities have been obtained. Both chemical and photo-crosslinking procedures have been used to make disks. After soaking the disks in acetone and sterilized in 70% ethanol, the cell viability of them was tested using MTS assay.

**Results/Discussion:** In Fig.1a, it can be seen that the absorption peaks can be well assigned to the chemical structure of nano-HA, silicated-HA, and grafted-HA. Particularly, the –C=O group at 1730 cm$^{-1}$ and –CH=CH- group at 1645 cm$^{-1}$ can be well indicated for grafted-HA. Only one glass transition occurs around 10 $^{o}$C for all the composites as well as PPF itself. TGA results in Fig.1b show that the grafting ratio increases with the grating reaction time. When the reaction time is 32 hr, the grafting ratio can be as high as 40%. The decomposition temperature for the PPF/HA composites is in the range of 325-345 $^{o}$C depending on the nano-HA content in the composites. Both chemical and photocrosslinked composites using nano-HA or grafted HA show no toxicity for bone marrow stromal cells (Fig.2).




(a) (b)

Fig. 1: (a) FTIR spectra of nano-HA, Si-HA, and grafted-HA; (b) TGA curves of nano-HA and grafted-HA with different grafting reaction times.




(a) (b)

**Fig. 2:** Marrow stromal cell viability of the composite disks (a: photo-crosslinked; b: chemical-crosslinked) compared to that of TCPS.

**Conclusions:** A crosslinkable grafted-HA and the nanocomposites of both nano-HA and grafted-HA with PPF has been prepared and characterized. The results show such materials can be used as an injectable material in orthopedic applications.

**References:**

1. Khorasani SN. In Bone Ceramics; Yamamura T Eds; Kobunshi Kankokai: Kyoto, 1992.

**Acknowledgments**

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