The synthesis and biodegradability of silver nanoparticles doped ZIF-8 composites injectable hydrogel

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ABSTRACT

This study is aimed to investigate the incorporation of homemade ZIF-8 nanocarriers with PEG injectable hydrogel. ZIF-8 is currently approved to be a potential drug nanocarrier that is biocompatible for a number of biomedical applications. In this study, the ZIF-8 nanocarrier is doped with sliver nanoparticles (AgNPs) which result in a synergistic antibacterial effect. Both stability and degradation of ZIF-8 are closely related to the release rate of AgNPs. ZIF-8 based injectable hydrogel can be successfully synthesized at room temperature. By exposing in water and in PBS solution media for designated time intervals (12~72 hrs), the changes in size and morphology as well as elemental distribution in specimens were observed by scanning electron microscopy (SEM), energy dispersive spectroscopy (EDS) and X-ray diffraction (XRD).

Keywords: ZIF-8, AgNPs, degradation, nanocarriers, injectable hydrogel, water, PBS.

1. INTRODUCTION

Metal-organic framework (MOF) is recognized as a novel family of porous crystalline materials consisted of metal and organic material. Generally, ZIF-8 is highly selected as part of the zeolite imidazolate framework (ZIF) family, with zinc ions and 2-methylimidazolate (2MIm) as two major components needed to create ZIF-8[1]. ZIF-8 can be designed for the following features: (1) small compounds, proteins, and nucleic acids being loaded into MOFs due to their high surface area and adjustable pore size[2], (2) well controlled drug release from MOFs being accomplished by adjusting the pore size and chemical functionalization of the MOF, (3) high thermal and chemical stability, and (4) very good biocompatibility and wide range of bioavailability. The sophisticated combination of ZIF-8 and polymers to form injectable hydrogel can provide desirable biocompatibility and the drug delivery efficiency[3].

2. EXPERIMENTAL

Our room temperature (RT) synthesis route used methanol as solvent. With the optimized processing formulation of Zn/2MIm, sample with Zn: 2MIm: MeOH at molar ratio of 1:8:700 found to be completely crystalline and suitable in particles size distribution. The Zn salt, zinc nitrate hexahydrate ($Zn(NO_3)_2 \cdot 6H_2O$) and 2MIm were dissolved into MeOH solution separately, and then were well mixed by stirring for 1 hr at RT. The mixed solution was then centrifuged and washed twice with MeOH, then drying in an oven at 40°C overnight. Relative amount of silver nitrate ($AgNO_3$) was dissolved with ZIF-8 products in MeOH. With the addition of reducing agent, $NaBH_4$, the resultant suspension would turn into blue-gray color and was centrifuged, washed, and dried in a vacuum oven for 24 hrs for further use. The ZIF-8 and ZIF-8@AgNPs will combine with the precursor solution of injectable hydrogel as shown in Figure 1.

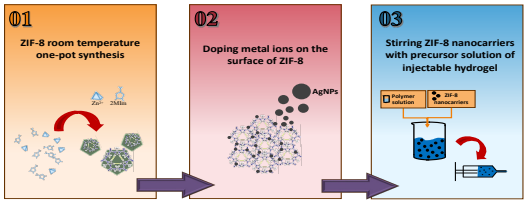

Figure 1. Steps for the synthesis of ZIF-8 composites.

3. RESULTS AND DISCUSSION

Our samples for nanoscaled ZIF-8 and ZIF-8@AgNPs were successfully fabricated by wet chemical reaction at RT. SEM micrographs in Fig. 2 depict the stability of ZIF-8 was verified to be reduced in acidic pH and phosphate containing buffer solutions[4]. Yet, with the doping of AgNPs, the stability ZIF-8 in neutral pH solutions was evidently enhanced, where lesser defected parts were observed with the same duration. When exposed to PBS (pH 5.5), the morphology of the both ZIF-8 and ZIF-8@AgNPs become rounded edges, evidenced by a weakening of ZIF-8 main XRD peaks shown in Figure 3. Our observations imply favorable sensitivity and selectivity towards acidic pH environments. The weak peak in 2θ = 38° shown there were few AgNPs on the surface of ZIF-8 structure, and the signal diminished when exposed to PBS (pH 5.5), shown the release of AgNPs. With designed AgNP dopants, the stability of our specimens was augmented compared to raw ZIF-8. With PEG hydrogel as medium to avoid aggregation of nanoparticles, so the biocompatibility can be fulfilled.

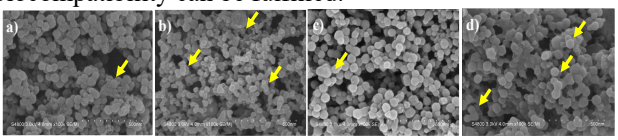

Figure 2. SEM micrographs of (a, b) ZIF-8 and (c, d) 20%AgNPs@ZIF-8 in PBS with pH 7.4 and pH5.5 for 0.5 hr.

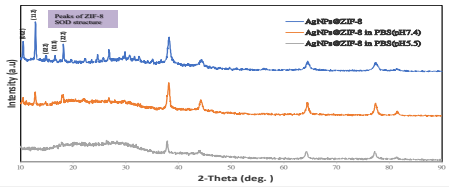

Figure 3. XRD graphs of (a) AgNPs@ZIF-8 in PBS (b) pH 7.4 and (c) pH 5.5 for 0.5 hours.

4. CONCLUSIONS

The synthesis of ZIF-8 injectable hydrogel demonstrates significant applicability and promising biomedical potential. Here we proposed a novel design system for MOFs-based nanocomposites, serving as versatile cores for biomolecules or therapeutic drugs as nanocarriers. Integrating MOFs with injectable hydrogel lead us a promising future in drug delivery applications, with great sensitivity in the selection of drug release.

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