# Formulation and Characterization of Polymerized Magnetic SBA-15 Mesoporous Nanocarrier for Targeted Doxorubicin Delivery in Cancer Treatment

Ndumiso Vukile Mdlovu (杜米)[1], Kuen-Song Lin (林錕松)[1*], Yun Chen (陳芸)[1,2], Ya-Hui Tsai (蔡雅慧)[1,2], Chun-Ming Wu (吳浚銘)[3], and Jyh-Fu Lee (李志甫)[3]

[1]Department of Chemical Engineering and Materials Science, Yuan Ze University, Taoyuan, Taiwan, R.O.C
[2]Department of Surgery, Far Eastern Memorial Hospital, New Taipei City, 220, Taiwan, R.O.C
[3]National Synchrotron Radiation Research Center, 101 Hsin-Ann Road, Hsinchu Science Park, Hsinchu, Taiwan, R.O.C
kslin@saturn.yzu.edu.tw

Drug/gene delivery systems (DGDSs) have proven to be a potential solution to overcoming the limitations of chemotherapy towards the treatment of many cancers. In this study, a DGDS made of SBA-15 and SBA-15 coated iron oxide nanoparticles (IO@SBA-15). The SBA-15 with a hexagonal structure, nanosize pores, and apiary-like structure, has attracted tremendous attention as nanocarriers for drug/gene molecules. In this study, iron oxide nanoparticles (IONPs) were synthesized through coprecipitation method followed by coating with SBA-15 to obtain IO@SBA-15. The IO@SBA-15 was further coated with Pluronic F127 to obtain IO@SBA-15-F127 nanocarrier which was used to load doxorubicin (DOX) cancer drug. The characteristic bands between 1625, 1091, and 460 $cm^{-1}$ are corresponding to the stretching vibration bends of Si-O bonds, indicating an effective coating of SBA-15 on the surface of IONPs. The nanocarriers exhibited characteristics of hexagonally ordered mesoporous structure: peaks corresponding to the (100) and (110) planes. The X-ray absorption near edge structure (XANES) spectra of Fe atom in all the nanocarriers with IONPs core exhibited an absorbance feature (Fe = 7114 eV) of 1*s* to 3*d* transition. The extended X-ray absorption fine structure (EXAFS) spectra showed that the standard Fe–O bond distance in IONP and IO@SBA-15 samples was 1.93 Å and 192 Å, with a co-ordination number of 3.95, and 3.72, respectively. The small angle neutron scattering (SANS) studies reveal that an enlargement of the high-Q region for SBA-15-20% shows Bragg peaks corresponding to an hexagonal packing of pores characteristic of the SBA-15 materials. The biocompatibility tests in all tested cells using MTT assay revealed no significant cytotoxicity of these systems.

***Keywords: Drug/gene therapy, Magnetic iron oxide nanoparticles, SBA-15, Pluronic F127, Doxorubicin, SANS/SAXS, XANES/EXAFS.***

## Introduction

Cancers are the main cause of mortality and health problem worldwide. Targeted therapies with the goal of accumulation of drug/gene inside cancer cells lead to more effective treatments with fewer side effects. Advances in nanotechnology, reform drug delivery systems (DDSs) by giving more hands on loading of wide range of drugs, biocompatibility, physiological stability, targeting means, the ability to cross the barriers, and in vivo controlled release [1, 2]. Midst various mesoporous materials, mesoporous SBA-15 coated iron oxide nanoparticles for drug delivery, controlled release, and bioseperation have attracted immense interests over the past few years. Therefore, the aim of this study was to develop a magnetic nanocarrier made from synthesized SBA-15/F127 coated IONPs. The prepared nonocarrier would be used to deliver DOX for cancer treatment.

## Experimental

*2.1. Preparation of SBA-15/F127 coated iron oxide magnetic nanoparticles*

The IONPs were prepared by a coprecipitation method. The synthesis of SBA-15 was performed according to previously reported studies [1]. For the synthesis of IO@SBA-15, cetyltrimethyl ammonium bromide (CTAB, 0.7 g) as a template was dissolved in 100 mL of double distilled water and 10 mL of HCl (37 wt%) was added to control the pH of the reaction system. The solution was stirred for 1 h at 35°C, 1.5 g of $Fe_3O_4$@$SiO_2$ was added and the mixture stirred for another 30 min. After that, TEOS (10 mL) as Si source was added dropwise to the acidic solution with vigorous stirring. After 2 h, the brown precipitated IONPs were aged at room temperature for 12 h. The sample was filtered without washing, and dried for 12 h at 100°C. The final product was dried and IO@SBA-15 was calcined at 550°C in air for 6 h. The heating rate was 2ºC/min from 100 to 550ºC.

## Results

The XANES spectra of the nanocarrier and iron standards show that the main peak of the magnetic nanocarrier is located between $Fe^2$ and $Fe^3$ iron and the curve with more fitting on $Fe_3O_4$. The EXAFS fitting results for the oxygen shell suggest that IONPs and IO@SBA-15 have two central Fe atoms coordinated primarily by Fe-O (Fig. 1(a,b)). The SANS shows that F127 is a temperature sensitive polymer (Fig. 2).

## Discussion

The TEM images of SBA-15 and IO@SBA-15 show 1-D cylindrical hollow channels and 2-D hexagonal pore arrangement, a common attribute for SBA-15. Moreover, the XRD analyses for SBA-15, IO@SBA-15, and IO@SBA-15 reveal that at low angle, a well-resolved diffraction peak is detected corresponding to the Miller index (100) reflection around 1º point. This peak is a characteristic of 2-D hexagonal pore arrangement, a typical signature for SBA-15 material. The pore-volume-surface analyses indicated that both samples show typical type IV isotherms with a sharp capillary condensation. The SBA-15 and IO@SBA-15 had shown excellent textural properties, such as high surface area, large pore diameter, and high pore volume. In

comparison with the standard position of Fe K–edge of 7,112 eV, the magnetic carrier yielded produced oxidation valences for Fe and shifted the outstanding peak on the absorption curve to high energy. he main peak of the magnetic nanocarrier is detected between $Fe^{2+}$ and $Fe^{3+}$ iron and the curve with more fitting on $Fe_3O_4$, and the normalized data through differential processing as shown Fig. 1(a,b) in Consequently, it can be confirmed that the magnetic nanocomposites including those coated with silica synthesized in this study is $Fe_3O_4$ structure.

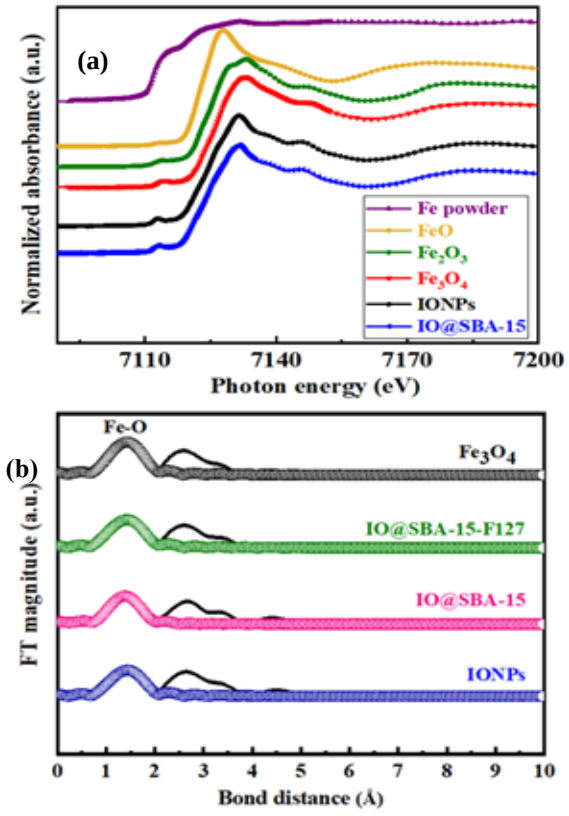


*Fig. 1. (a) Fe K–edge XANES/EXAFS spectra of IO@SBA-15 and IO@SBA-15-F127.*

The SANS studies are crucial to extract structural information and changes in the environment's temperature. As shown in Figure 2(a), the silica SBA-15 with 10% and 20% weight present, the results show that main peak (M) of SBA-15-20% has higher intensity than 10% one. The scattering signal of peak (M) belongs to the layered structure accumulation of SBA-15, high percentage of SBA-15 can allow the different porous structure which can compare with nitrogen desorption (BET). The loading amount of DOX is considered highly connected with porous size distribution. The enlargement of the high-*Q* region for SBA-15-20% shows Bragg peaks corresponding to a hexagonal packing of pores characteristic of the SBA-15 materials. The program SAS view has been used for SANS analysing for SBA-15 as shown in Table 1. The SBA-15-F127 particles are thermo-sensitive; there was an increase in the structure of the particles when the temperature increased from 25 to 37°C (Fig. 2(b)). When the temperature rose from 37 to 55°C, there was a slight increase in the structure because it has reached its maximum increase. It can therefore be concluded that the structural changes of the Pluronic can be observed up to a certain temperature, in this case 37°C, and the increase of temperature about 37°C would not show any significant structural changes. In relation to the concentration, there were no structural changes resulting from the increase in the concentration of the sample. To determine the reversion of Pluronic F127, after scattering finished at 55ºC. The prepared nanocarrier may serve as a suitable nanocarrier due to unique crystal structure of magnetite. The SBA-15 shell causes a core-shell structure that is suitable for high drug loading capacity.

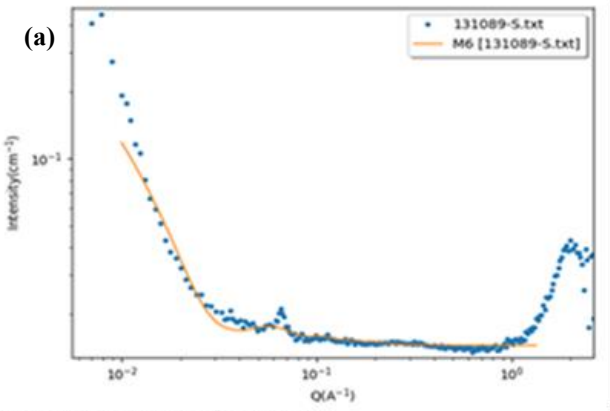


**Table 1.** The parameters of SBA-15 20%.

| | Scale | Background | Radius(Å) | Thickness(Å) | Length(Å) |
|---|---|---|---|---|---|
| Values | 3.57E-05 | 0.014503 | 7.1493 | 128.1 | 359.34 |
| Error | | | 0.2011 | 0.95243 | 61.261 |

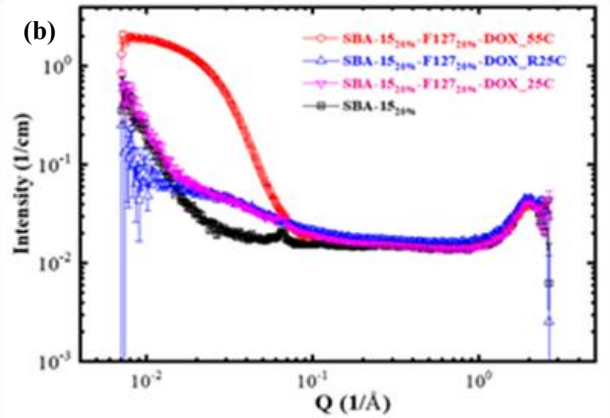


*Fig. 2. SANS for IO@SBA-15 and IO@SBA-15-F127 before and after addition of DOX and at different temperatures.*

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