Infrared study of biocompatible magnetic nanoparticles

N.Tomašovičová, M.Koneracká, P.Kopčanský, M.Timko, V. Závišová

Institute of Experimental Physics, Slovak Academy of Sciences, Watsonova 47, Košice, Slovakia

Email: konerack@saske.sk

Abstract. *Magnetic fluids mainly consist of nano sized iron oxide particles (Fe_3O_4 or γ-Fe_2O_3) that are suspended in carrier liquid. In recent years, substantial progress has been made in developing technologies in the field of magnetic nanoparticles, microspheres, magnetic nanospheres and ferrofluids. Techniques based on using of these biocompatible magnetizable complex systems have found application in numerous biological fields. Generally, the magnetic component of the particle is coated by a biocompatible polymer such as PEG, PLA or polysacharids as dextran, although recently inoganic coatings such as silica have been developed. The coating acts to shield the magnetic particle from the surrouding environment and can also be functionalized by attaching carboxyl groups, biotin, avidin, carbodi-imide and other molekules. These molecules then act as attachment points for the coupling of cytotoxic drugs or target antibodies to the carrier complex. This review is focused on describing the infrared spectrosopy as method that allows checking starting materials and following reactions while work is in progress.*

Keywords: Magnetic nanoparticles, infrared spectroscopy, biomedicine

1. Introduction

Magnetic nanoparticles offer some attractive possibilities in biomedicine. They have controllable sizes ranging from few nanometers up to tens nanometers, which places them at dimensions that are smaller then or comparable to those of cell (10-100μm), a virus (20-450nm), protein (5-50nm). This means that they can get close to a biological entity of interest. Indeed, they can be coated with biological molecules to make them interact with or bind to a biological entity, thereby providing a controllable means of tagging or addressing it. The nanoparticles are magnetic, which means thay obey Coulomb's law and can be manipulated by an external magneti field gradient. This action at a distance, combined with the intrinsic penetrability of magnetic fields into human tissue, opens up many applications involving the transport and immobilization of magnetic nanoparticles, or of magnetically tagged biological entities. In this way they can be made to deliver a package, such as an anticancer drug to a targeted region of the body, such as a tumour. These, and many other potential applications, are made avaliable in biomedicine as a result of the special physical properties of magnetic nanoparticles [1,2].

The major disadvantage of most chemoterapies is that they are relatively non-specific. The therapeutic drugs are administered intravenously leading to general systemic distribution, resulting in deleterious side-effects as the drug attacts normal, healthy cells in addition to the target tummour cells. However, if such treatments could be localized, e.g. to the site of a joint, then the continued use of these very potent and effective agents could be made possible. Recognition of this led researchers to propose the use of magnetic carriers to target specific sites (generally cancerous tummours) within the body. In magnetically targeted therapy, a cytotoxic drug is attached to a biocompatible magnetic nanoparticle carrier [3]. Generally, the magnetic component of the particle is coated by a biocompatible polymer such as PEG, PLA or polysacharids as dextran, although recently inoganic coatings such as silica have been developed. The coating acts to shield the magnetic particle from the surrouding environment and can also be functionalized by attaching carboxyl groups, biotin, avidin, carbodi-imide and other molekules. These molecules then act as attachment points for the coupling of cytotoxic drugs or target antibodies to the carrier complex [4,5]. The carriers typically have one of two structural configurations: a magnetic particle core coated with biocompatible polymer or porous biocompatible polymer in which magnetic nanopartiles are precipitated inside the pores. The physical and chemical properties of magnetic fluids are strongly influenced by details of the size distribution of dispersed colloidal magnetic particles [6]. To obtain the profile of the particles nanometer dimensions the magnetic measurements, transmision electron microscopy and atomic force microscopy is used. However, success of coating can be checked also by infrared spetroscopy. The infrared spectrosopy is method that allow to check starting materials and follow reactions while work is in progress. Thus one can avoid some improper reaction conditions. Based upon infrared evidence, process conditions can be modified in time to save unnecessary experiments.

2. Subject and Methods

Infrared radiation is usually defined as that electromagnetic radiation whose frequency is between ~$0.7x10^{-6}$ and $500x10^{-6}$ m. Within this region of the electromagnetic spectrum, chemical compounds absorb infrared radiation providing there is a dipole moment change during a normal molecular vibration, molecular rotation, molecular rotation-vibration, or a lattice mode or from combination, difference, and overtones of the normal molecular vibrations. Each of the vibrational motions of a molecule occurs with certain frequency, which is characteristic of the molecule and of the particular vibration. The energy involved in a partiular vibration is characterized by the amplitude of the vibration, so that the higher the vibrational energy, the larger the amplitude of the motion. An infrared spectrum is generally displayed as a plot of the energy of the infrared radiation (expressed in wawenumbers) versus the percent of light transmised by the compound. Within this energy range the spectrum of the molecule will appear as a series of broad absorption bands of variable intensity, each of which brings to the viewer some piece of structural information. Each absorption band in the spectrum corresponds to a vibrational transition within the molecule, and gives a measure of the frequency at which the vibration occurs. The interpretation of infrared spectra involves the correlation of absorption bands in the spectrum of an unknown compound with the known absorption frequencies for types of bonds. Significant for the identification of the source of an absorption band are intensity (weak, medium or strong), shape (broad or sharp), and position (cm^{-1}) in the spectrum. The frequenies and intensities of the infrared bands exhibited by chemical compounds uniquely characterize the material, and its infrared spectrum can be used to identify and quantify the particular substance in unknown sample. Similarly, individual components of a mixture of known compounds can usually be quantified by infrared spectroscopy provided that the spectrum of each pure component is available. In addition infrared spectra can be recorded rapidly of materials in the solid, liquid and vapor phases over a wide range of temperature. Such studies aid in elucidating the molecular structure of materials in different physical phases.

Today modern infrared instrumentation allows spectra to be recorded of samples avaliable in only low nanogram quantities. No other technique allows examination and identification of materials under such a wide variety of physical conditions.

3. Results and Discussion

In order to obtain biocompatible magnetic nanopartile carriers magnetic component of the particle were coated by dextran and polyethylene glycol (PEG). The general procedure of immobilization was described in [5,7]. Nanoparticles formulated from dextran and PEG are being extensively investigated for different therapeutic applications. Dextran and PEG can be used as a carrier for attachment, via end goups, of drugs.

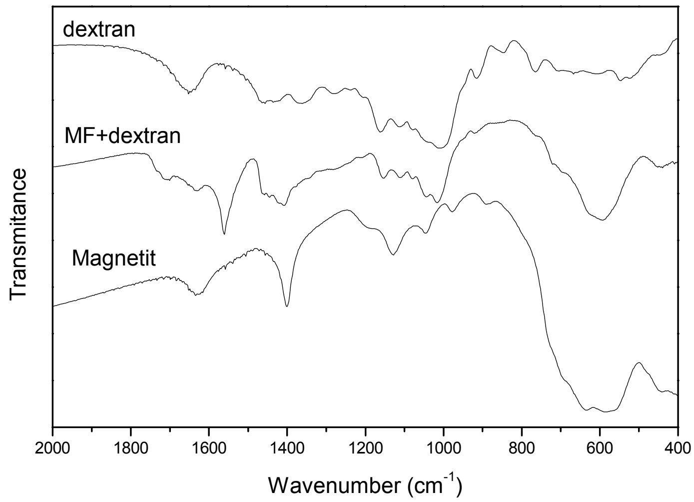

Fig.1. The infrared spectra of magnetite, pure dextran and magnetite/dextran composite particles. The spectra are shifted verticaly for clarity.

With the aim to confirm immobilization of dextran and PEG to the magnetic particles, infrared spectra of pure dextran and PEG, magnetite and composite particles were obtained by the KBr pellet method. In this method, the solid sample is finely pulverized with pure, dry KBr, the mixture is pressed in a hydraulic press to form a transparent pellet, and the spectrum of the pellet is measured. The results of measurements two types of samples are shown in figure 1 and 2. As observed, the spectrum of the composite particles is very similar to that of pure dextran and PEG, respectively. Fig.1 shows the infrared spectra of the magnetic nanoparticles, pure dextran and magnetic nanopartiles coated by dextran. Fig. 2 shows the infrared spectra of the magnetic nanoparticles, pure PEG and magnetic nanopartiles coated by PEG. The main feature of these figures is the presence of all the bands of the polymers in the spectrum of the composite particles, this clearly demonstrate particles coating.

In next work, composite particles can be effectively coated with drugs and so can be efficiently used for biomedical application. Success of coating by drug will be checked also by infrared spetroscopy. The infrared spectrosopy is method that allow to check starting materials and follow reactions while work is in progress. Thus one can avoid some improper reaction conditions. Based upon infrared evidence, process conditions can be modified in time to save unnecessary experiments.

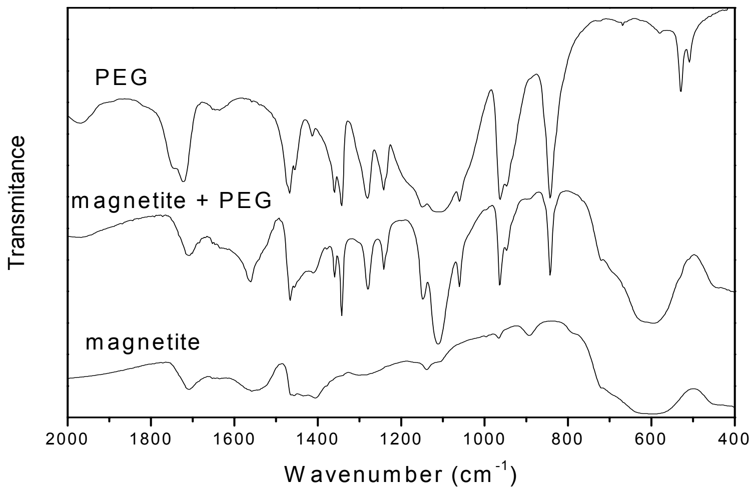

Fig.2. The infrared spectra of magnetite, pure PEG and magnetite/PEG composite particles. The spectra are shifted verticaly for clarity.

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