Monodispersed Fe–Pt nanoparticles for biomedical applications

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Monodispersed Fe–Pt nanoparticles are promising candidates for biomedical applications with an average particle diameter of 6.9 nm Fe 48 Pt 52 , 3.3 nm Fe 52 Pt 48 , and 4.2 nm Fe 70 Pt 30 . They are prepared by simultaneous chemical reduction of Pt(acac) 2 and thermal decomposition of Fe(CO) 5 in the presence of surfactant as an anti-oxidation reagent and amine as a stabilizer. The blocking temperatures, T b , of 9 K for Fe 70 Pt 30 , 11 K for Fe 52 Pt 48 and 14.4 K for Fe 48 Pt 52 and the mean diameter of the spherical magnetic particles were estimated from the calculated volume to be 3.6, 3.1, and 3.8 nm. The cytotoxicity of unmodified Fe–Pt nanoparticles was performed in brain endothelial cells. Fe 48 Pt 52 nanoparticles were not found to have any significant toxicity on bEnd3 cells during a 24 h period. © 2005 American Institute of Physics. [DOI: 10.1063/1.1860851]

I. INTRODUCTION

Biomedical applications of magnetic nanoparticles prevail in the fields of immobilization, modification determination, and isolation of biologically active compounds; modification, detection and isolation of cells; drug and radionuclide targeting, magnetic hyperthermia; etc. 1 The oxidation of a magnetite system, where must be controlled in biomedical applications, is an inevitable chemical process due to its cytotoxicity. The bimetallic Fe–Pt nanoparticles are promising candidates, not only for magnetic storage, but also for in vivo applications because they show extremely stable behaviors in the presence of oxygen. Hence, it is urgently necessary to examine the cytotoxicity of Fe–Pt nanoparticles for further biomedical applications.

The mouse brain microvascular cell line, bEnd3, is an immortal cell line achieved through transformation by infection with the Polyomavirus middle T antigen. 3 The characterization that expresses numerous transporters, for instance, GLUT-1; MCT 1 and 2; OAT1; Oatp1; mdr 1a and 1b; MRP 1 and 5; beta-alanine, system L and system y + L amino acid carriers; the nucleotide transporters cNT1 and 2, eNT1 and 2, and the tight junctional elements, ZO-1, JAM, occludin, claudin-1 and -5 confers bEnd3 standing as worthwhile cell line in transport mechanism studies of the blood-brain barrier (BBB). Therefore, this cell line can be utilized to exploit drug delivery efficiency test especially in the central nervous system (CNS). In addition, bEnd3 cells also have been programmed to examine aspects of basic cerebral microvascular cell biology, including vascular tumors. 4–7

II. EXPERIMENTAL

All chemicals were of reagent grade and used without further purifications. Iron pentacarbonyl, platinum acetylacetonate, 1,2-hexadecanediol, diocetyl ether, oleic acid, and oleylamine were purchased from Aldrich. Ethanol, hexane, and octane were purchased from VWR.

Sun’s synthetic procedure to prepare Fe–Pt nanoparticles was used here. 2 Three different compositions (Fe 48 Pt 52 , Fe 52 Pt 48 , and Fe 70 Pt 30 ) of Fe–Pt nanoparticles were prepared by simultaneous thermal decomposition and chemical reduction. The product was redispersed in 20 mL hexane by sonication, and 20 mL ethanol was added to precipitate the particles. This step was repeated three times to remove the excess surfactant and impurity phase. Finally, stock suspension of Fe–Pt nanoparticles was prepared by dispersing approximately 100 mg of dried Fe–Pt nanoparticles in 10 mL of hexane, containing 0.05 mL of oleic acid and 0.05 mL of oleylamine to avoid oxidation. Dried Fe–Pt nanoparticles were redispersed in 500 µL of Dulbecco’s minimum essential medium with 50 µL of 5 M NaOH to change the oleic acid to sodium olate. The suspension was being centrifuged for 30
min at 14 000 min$^{-1}$. After the removal of supernatant, the particles were re-suspended in DMEM medium. The mixture was filtered by using a 0.2 µm syringe filter.

III. RESULTS AND DISCUSSION

The different composition of Fe–Pt nanoparticles were prepared by adjusting the molar ratio of Fe(CO)$_3$ to Pt(acac)$_2$. These Fe–Pt nanoparticles are regarded as mono-dispersed with a regular gap between the particles ($G_p$). Figure 1 shows TEM images of (a) Fe$_{48}$Pt$_{52}$ ($D_{TEM}$=6.9 nm, $G_p$=1.4 nm), (b) Fe$_{52}$Pt$_{48}$ ($D_{TEM}$=3.3 nm, $G_p$=2.8 nm), and (c) Fe$_{70}$Pt$_{30}$ ($D_{TEM}$=4.2 nm, $G_p$=1.5 nm) prepared by simultaneous chemical reduction of Pt(acac)$_2$ and thermal decomposition of Fe(CO)$_3$.

Figure 2 shows the magnetization curves for the three Fe–Pt nanoparticles. Figure 3 shows the zero-field cooled (ZFC) and field-cooled (FC) curves obtained on the Fe–Pt nanoparticles. The field-dependent $T_b$ is indicated by a peak in the ZFC curve and by the onset of irreversibility between the FC and ZFC curves. The average diameter ($D$) can be determined using the relation $KV > 25k_BT_b$ with $V = \pi D^3/6$.

As reported recently by Rellinghaus et al.,$^9$ the effective anisotropy constant of Fe–Pt nanoparticles is varying with the nanoparticles composition. Considering the following values for the effective anisotropy constant $K_{eff}$ of Fe–Pt: $1.7 \times 10^5$ J/m$^3$ (Fe$_{70}$Pt$_{30}$), $3.6 \times 10^5$ J/m$^3$ (Fe$_{48}$Pt$_{52}$), and the following blocking temperatures: 12 K for Fe$_{70}$Pt$_{30}$, 16.5 K for Fe$_{48}$Pt$_{52}$ and 30 K for Fe$_{48}$Pt$_{52}$, the mean diameter of the magnetic particles considered spherical, were estimated from the calculated volume to be 3.6 nm, 3.1 and 3.8 nm, respectively.

These values, slightly smaller than the values obtained from TEM analysis, are nevertheless in fairly good agreement given the fact that it is difficult to assess all possible surface effects surface in such a simple analysis. The surface effect can be very important since the as has been shown recently,$^{10,11}$ surface oxidation of Fe–Pt nanoparticles can lead to the formation of Fe-oxides with reduced magneto-
crystalline anisotropy. A second effect in the reduction of the effective anisotropy is due to intrinsic surface anisotropy of the Fe–Pt nanoparticles. A more detailed analysis is underway and will be presented elsewhere.

The bEnd3 cells were cultured in DMEM supplemented with 10% FBS on 24 wells plate coated with 50 µg/mL of collagen type I at 37 °C with 5% CO₂ for 24 h followed by addition of Fe–Pt nanoparticles of 1, 30, 100 µL in 500 µL medium, respectively. After 24 h or 72 h incubation, cells were washed twice by PBS. Then, bEnd3 cells were subjected to staining by 0.03 mg/mL of Hoechst for 20 min. After washing with PBS, the cells were fixed by 4% of paraformaldehyde for another 20 min.

Figure 4 shows cytotoxicity effects of unmodified Fe₄₈Pt₅₂ nanoparticles in brain endothelial cells. Arrows point to positively stained cells. Values are mean ±SD. Bar =40 µm.

IV. CONCLUSIONS

In this study, we report our initial results as: (1) Successful preparation of monodispersed Fe–Pt nanoparticles by a polyl process of platinium acetylacetonate, and thermal decomposition of iron pentacarbonyl; (2) characterization conducted by Physical Properties Management System (PPMS) on ZFC and FC and magnetization of Fe–Pt systems; (3) cytotoxicity effects of uncoated Fe–Pt nanoparticles performed in bEnd3.

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