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The effect of metal oxide nanoparticles in breast cancer treatment

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Abstract

Nano-sized materials have been mostly used in scientific studies recently due to their many functional properties and wide application areas. Among them, metal oxide nanostructures are the most interesting materials. In particular, zinc oxide (ZnO) is a wide band gap semiconductor with properties suitable for cancer therapy studies. When ZnO is doped with various transition metals such as Fe, Mn, its properties such as band gap energy, morphology and crystalline structure can be changed. ZnO nanoparticles can be synthesized by many synthesis methods such as sol-gel, hydrothermal, CVD, co-precipitation. In the present study, the nanoparticles are prepared using sol-gel method for the breast cancer treatment.

Introduction

Nano-sized materials can have new and more advanced structural, magnetic and electronic properties that are not found in micron or larger sized particles composed of the same material systems. Due to these properties, they have the potential to lead to biological and medical applications [1]. In particular, ZnO is a wide band gap semiconductor (3.37 eV) with properties suitable for wide applications such as cancer therapy, bioimaging and drug delivery [2]. When ZnO is doped with various transition metals such as Fe, Mn, it shows different behavior in morphological, crystalline, electrical, magnetic and optical excitation properties [3]. Furthermore, ZnO nanoparticles have good potential in applications with low voltage x-ray or ultraviolet light (UV) radiation due to their luminescence properties. It also has the ability to act as a photosensitizer alone to generate photo-excitation and apoptotic reactive oxygen species (ROS) [4]. ZnO is also widely used in biomedical sciences, micro-electronics, converters, catalysts, textiles and other applications due to its high specific surface and small particle size [5-8]. In the process of obtaining nanoparticles, parameters such as synthesis time and temperature and annealing temperature are important in terms of particle size, morphology, and crystallinity.

Results

Popescu et al. have synthesized zinc oxide powders doped with Mn^{2+} ions (50, 500, and 2000 ppm) using co-precipitation method. These nanoparticles were prepared in PVP and SHMTP, separately. According to XRD pattern, the nanoparticles have hexagonal wurtzite structure. Crystallite sizes of the nanoparticles are about 38 and 49 nm, respectively. In this study, the cytotoxic effect of Mn:ZnO nanoparticles in murine cells was investigated. The Mn:ZnO samples prepared with PVP (polyvinylpyrrolidone) were observed to be more cytotoxic than the ones prepared with SHMTP (sodium hexametaphosphate). Also, for each sample, cell viability was found to be almost zero for concentrations above 16 µg/mL [9].

In the study of Nair et al., ZnO was synthesized in nano and micro sizes (40 nm - 1.2 μm), and its toxic effect on osteoblast cancer cells was investigated by coating it separately with PEG and starch, as well as pure ZnO. Osteoblast cancer cells were exposed to ZnO for 24 hours and it was concluded that ZnO nanoparticles were more toxic on osteoblast cancer cells than micron-sized particles. On the other hand, for PEG and starch coated ZnO, it is also very beneficial that PEG or Starch coating does not reduce cancer cell toxicity because such coatings can more protect normal cells from any cytotoxic effects [10].

In the study of Sekar et al., pure and Fe-doped ZnO (Fe; 4, 8, 12 wt%) nanoparticles were synthesized by electrospinning technique and added in Poly Vinyl Alcohol (PVA) nanofibers solution and investigated to its cytotoxic and antibacterial properties. PVA nanoparticles incorporated with 4, 8 and 12 wt% of Fe-doped ZnO nanoparticles. The nanofibers have diameter ranges from 120 to 250 nm. It was observed that as the amount of Fe-doped ZnO in PVA increased, the crystal structure of PVA deteriorated and a wurtzite ZnO crystal phase was formed. On the other hand, the viability of cell lines was decreased slowly with increasing nanoparticles concentration in PVA. Thus, these nano-structures could be one of the suitable materials for many biomedical applications [11]. The synthesis methods and crystal sizes of these metal oxides are summarized in Table 1.

Table 1. Synthesis methods and crystal sizes of some metal oxides

Samples	Synthesis Method	Crystallite size	Reference
Mn:ZnO in PVP Mn:ZnO in SHMTP	Co-precipitation	38 nm 49 nm	[9]
ZnO	wet chemical	40nm-1,2 μm	[10]
Fe: ZnO in PVA	Electrospinning	120-250 nm	[11]

Conclusion

Many study groups have shown that low concentrations and size of nanomaterials can kill human cancer cells, whereas micron-sized materials are relatively non-toxic [8, 12, 13]. Moreover, there are in vitro studies showing that certain metal oxide nanoparticles can only kill cancer cells. These nanoparticles are remarkably less toxic to normal cells [8,14]. Especially ZnO and different metal doped ZnO is a metal oxide that is mostly used in cancer studies due to its distinguished properties. The ZnO nanoparticles in the present study are in hexagonal mikro-rods which are obtained by using sol-gel method.

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