Control of Nanoparticle on Nanofiber via Magnetic Electrospinning

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ABSTRACT

Nanoparticles added into nanofibers produced by electrospinning can expand the functions of such fibers, and these nanoparticles can serve as vehicle for drugs in active drug delivery (ADR) concept. Depending on the toxicity of these nanoparticles, sometime it is desirable to cover toxic ones inside a polymer while benign ones exposed, and release them at programmed time and locations. We achieve this control of nanoparticle position on electrospun nanofiber with magnetism assisted electrospinning. Two horizontal magnet is placed at the receptor position, and nonmagnetic, superparamagnetic, and paramagnetic nanoparticles of Ag, Fe_3O_4 (<20 nm), Fe_3O_4 (>30 nm) were added inside PVP solutions in electrospinning process. We found the nonmagnetic Ag and superparamagnetic Fe_3O_4 nanoparticles exist inside the nanofiber, while paramagnetic Fe_3O_4 nanoparticles exist mainly on the surface of nanofibers. The interaction of the magnetic field and the paramagnetic Fe_3O_4 nanoparticles at the final stage of nanofiber formation makes this possible.

Keywords: electrospinning, nanofibers, nanoparticles, magnetism, nanomedicine

1 INTRODUCTION

Nanotechnology brings new aspects to drug delivery and cancer treatment not only by increased absorption rate of nano-size drug, targeting cancer cell by labeling drug with specific dangling bond or metal, now construction of its delivery vehicle and the administration of delivery scenario is also possible.

Traditional delivery vehicles like polymers or liposome offers sustained rate of delivery, with methods like medical skin patches, implanted device with external remote control, or power form which can be inhaled. Liposome coated with polymers like polyethylene glycol (PEG) can drastically reduce the attack from the immune system. Polymers, especially biodegradable ones like polylactic acid (PLA) and polylactic-co-glycolic acid (PLGA) are often used as vehicles for they are benign to human body, and they works by dissolution, diffusion, or osmosis.

Smart Drugs, also known as prodrugs, means drugs that can be activated in specific conditions inside the body, for example, monoclonal antibodies can target antigens with extreme specificity.

Engineered nanoparticles have been applied in cancer therapy for some time. Gold nanoparticles can be used to label cancer cells by binding the gold nanoparticles to an antibody for epidermal growth factor receptor (EFGR) and thus aluminates the cancer cell via its rich spectral response. Silica and C60 can damage DNA and cause cancer risk, but when placed inside the MCF-7 line of breast cancer cells, they destroy the cell. Ag nanoparticles has been long known for its cell destruction capability due to its high oxidation potential, and magnetic nanoparticles like the Iron Oxide has been proposed to kill cancer cells after they are injected directly into cancer tissue and activated by MRI machine.

Previous ADR concepts were of more common dimensions, nanotechnology may reduce the size to cellular level and control of dosage to pictogram regime. It is highly desirable a method to be discovered that can expose drugs to cells at the chosen time and location, while concealing them during the transport in order to protect the healthy cells.

We discover by introducing magnetism into conventional electrospinning process, we can control the position of magnetite to be on the surface of nanofibers or inside and covered by nanofibers. Section two describe the magnetic electrospinning, section three is the results, and finally the conclusion.

2 MAGNETIC ELECTROSPINNING

Electrospinning [1] is a method to manufacture nano-size fibers with the pulling force induced by the applied electric field. Most electrospun nanofibers are of 200-500 nm diameters, and smaller diameters are possible with very high voltage. Adding nanoparticles in the electrospinning process can change the property of nanofibers like increased conductivity, changed mechanical strength, or modified surface morphology.

Magnetite nanoparticles like Fe_3O_4 are benign to human body, and is usually superparamagnetic when the diameter

is less than 10 nm, and paramagnetic when the size is 20-50 nm. Ag nanoparticles are nonmagnetic.

Figure 1 depicts the magnetic electrospinning set up. Two magnet of 1x1x5 cm of roughly thousands of Gauss strength is placed under a glass slide with 5 mm gap in between. The glass slide serves as the nanofiber collector, and is placed under a syringe containing mixture of magnetite nanoparticles and polyvinylpyrrolidone (PVP) solutions. Magnetite nanoparticles were produced with polyols method. The electrospun nanofibers are collected from the slide and place under electron microscope for observations.

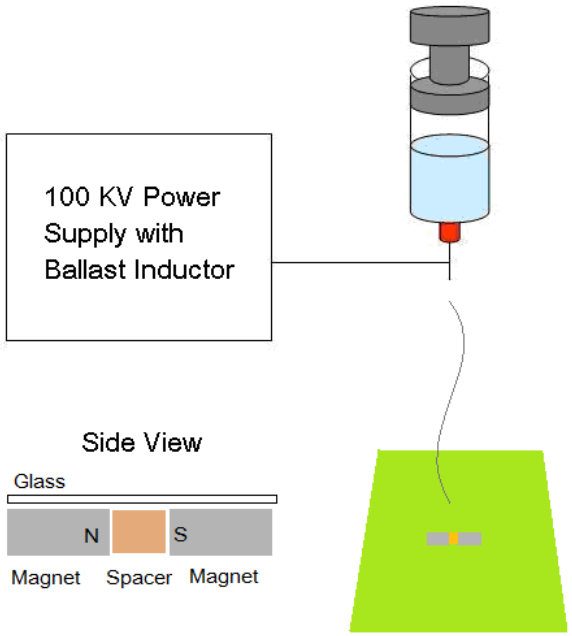

Figure 1: Magnetic electrospinning set up.

3 RESULTS

Three kinds of nanoparticles were used: Ag and paramagnetic Fe_3O_4 nanoparticles (30-50 nm) were obtained from ITRI, and superparamagnetic magnetite nanoparticles were prepared by the polyols process: 0.7 g of iron (II) acetate (Fe(COOCH3)2), 2 .0 g of polyvinylpyrrolidone powder (PVP; average MW = 58000), and 50 ml of ethylene glycol (EG) or tetra ethylene glycol (TREG) were added into a three-neck round-bottom flask equipped with a magnetic stirrer and immersed in argon. The mixture was then heated with stirring to refluxing temperature between 180 °C and 220 °C for 2.5 hrs. After cooling to room temperature, a black colloid suspension containing PVP-coated Fe3O4 nanoparticles were formed. Figure 2 is the TEM picture of produced Fe_3O_4 nanoparticles.

Figure 3 is the TEM picture of magnetic electrospun nanofiber containing superparamagnetic magnetite nanoparticles immersed inside nanofibers. The nanoparticles distribute mostly along the fiber axis, but are too few to form a continuous alignment.

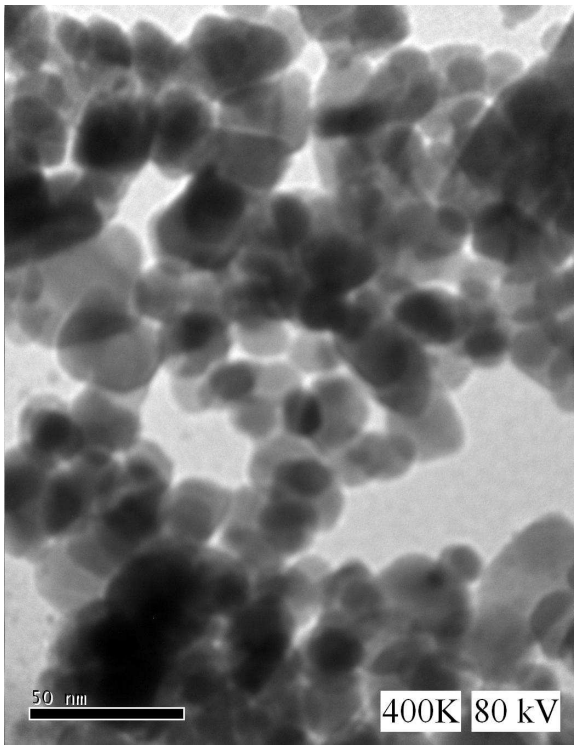

Figure 2: TEM image of PVP-coated Fe3O4 nanoparticles.

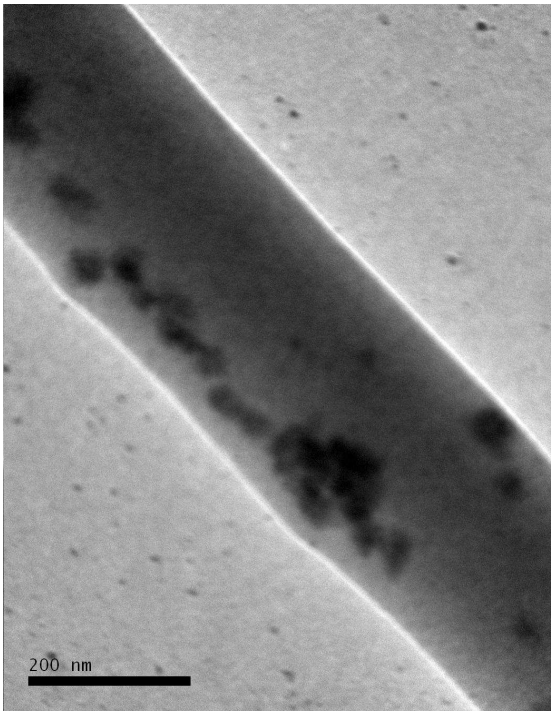

Figure 3: Superparamagnetic magnetite nanoparticles immersed inside nanofibers.

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Figure 4 shows the TEM picture of paramagnetic magnetite nanoparticles on the surface of nanofibers. These paramagnetic magnetite nanoparticles are of larger size (30~50 nm), and higher concentration in the PVP solution, thus they expels one another in the final stage of nanofiber formation due to induced magnetism.

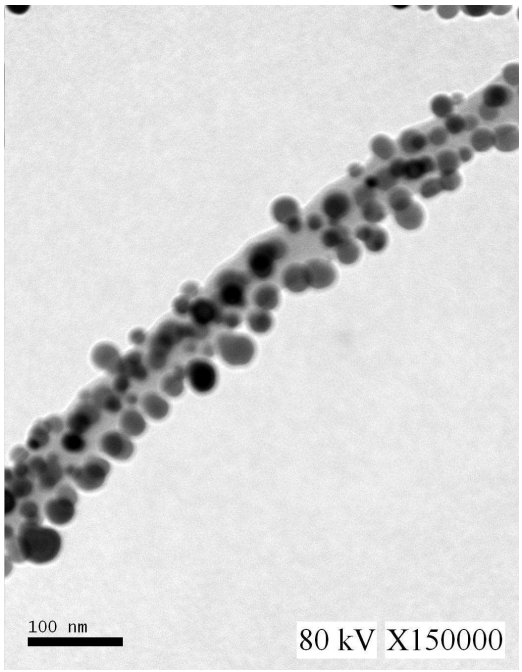

Figure 4: Paramagnetic magnetite nanoparticles on the surface of nanofibers.

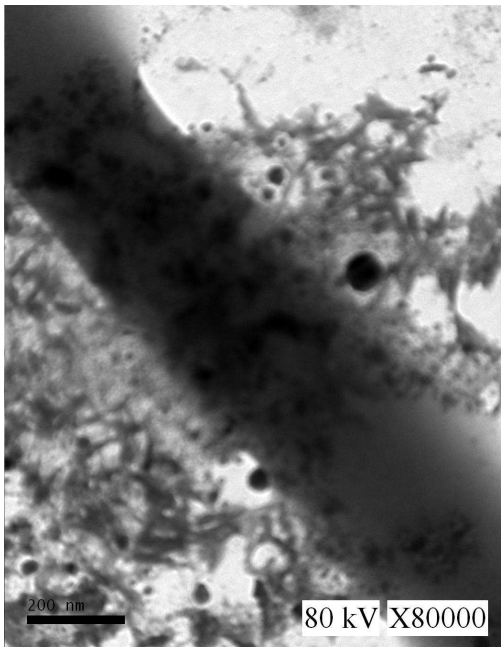

Figure 5: Ag nanoparticles inside and on the surface of the nanofibers.

Figure 5 shows the TEM picture of Ag nanoparticles after the magnetic electrospinning; some of them are covered inside the nanofiber, and some on the surface of the nanofibers, which means they are not affected by the magnets.

4 CONCLUSION

By introducing magnetic field into electrospinning process, we were able to demonstrate limited control of nanoparticle position on electrospun nanofibers. We found superparamagnetic magnetite nanoparticles reside mostly inside electrospun nanofiber, while paramagnetic (presumably anti-paramagnetic also) nanoparticles reside mostly on the surface of electrospun nanofiber in magnetic field controlled electrospinning. Magnetic field is applied with controlled magnitude and direction. The effect of magnetic field is to induce mutual repulsion of the nanoparticles at the forming stage of nanofiber, such that they have to be located on the surface of nanofiber in order to achieve maximum distance from each other.

One possible application for this technique would be ADR. If a toxic chemical meant for treatment of cancer cell is to be introduced inside patient's body, it can be coated on magnetite nanoparticles and incorporated inside nanofibers by conventional electrospinning. These nano-drugs can be safely introduced into blood stream while avoiding contact of toxic component and healthy cell in the transport process. The nanofibers can be functionalized on the surface such that they target specifically cancer cells, and then the toxic component containing magnetite nanoparticles are released on specified spot by RF heating and melting of the nanofibers such drugs begin to take effect.

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