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Electrospun Nanofibrous Meshes and Surface Decoration with Silver/Gold Nanoparticles for Drug Delivery and Surface-Enhanced Raman Spectroscopy (SERS) Applications

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ABSTRACT

Nanotechnology has put a strong position in both academia and industry over the past two decades and is expected to lead to continuing innovations that can contribute toward addressing many of the problems facing today's society. Nanofibers, a one-dimensional (1D) nanostructure featuring high surface area to volume ratio, porous structure, excellent interconnectivity and good mechanical properties, have found significant potential as drug delivery and surface-enhanced Raman spectroscopy (SERS)-based detection platforms. Among the methods available for producing fiber-like structures, interests in the electrospinning technology has recently escalated, due to simple operation and cost-effective, wide selection of polymeric precursor materials, feasibility and batch-to-batch consistency to produce non-woven fibers on the scale required, from several microns down to a few of nanometers. In the present work, poly(N-vinylpyrrolidone) (PVP) was electrospun to produce bead-free and smooth fibers with an average diameter of 409 nm under optimized electrospinning parameters. The as-spun, non-woven PVP nanofibrous meshes was further modified through surface grafting with an organosilane compound (APTES) to incorporate amine (NH2) functional groups and utilized as a substrate material on which silver/gold nanoparticles (SNPs/GNPs) would grow. Such facile approach could provide controllable coverage density of the nanoparticles on the fiber surface. The as-spun and silver/gold nanoparticles-decorated PVP nanofibrous meshes were characterized by field-emission scanning electron microscope (SEM), X-ray diffraction (XRD), Fourier Transform infra-red (FTIR) and thermogravimetric analysis (TGA) techniques. XRD results revealed that the crystallite size and coverage density of GNPs on the fiber surface could be tailored by performing calcination treatments at different temperatures. Furthermore, the GNPs-decorated PVP nanofibrous meshes could also be employed as a potential substrate for conjugation of hydrophobic anticancer drug (curcumin) and investigation of the drug release profiles in vitro was conducted. The drug release profiles in Tween 20-phosphate-buffered saline (PBS, pH 7.4) release medium showed more sustained release of curcumin from GNPs-decorated PVP nanofibrous mesh compared to those from PVP and NH2-PVP samples, indicating that the formation of aqueous curcumin-GNPs inclusion complexes renders a controlled-release and bioavailability-enhanced delivery system to achieve the desired therapeutic effect of drug

RESULTS

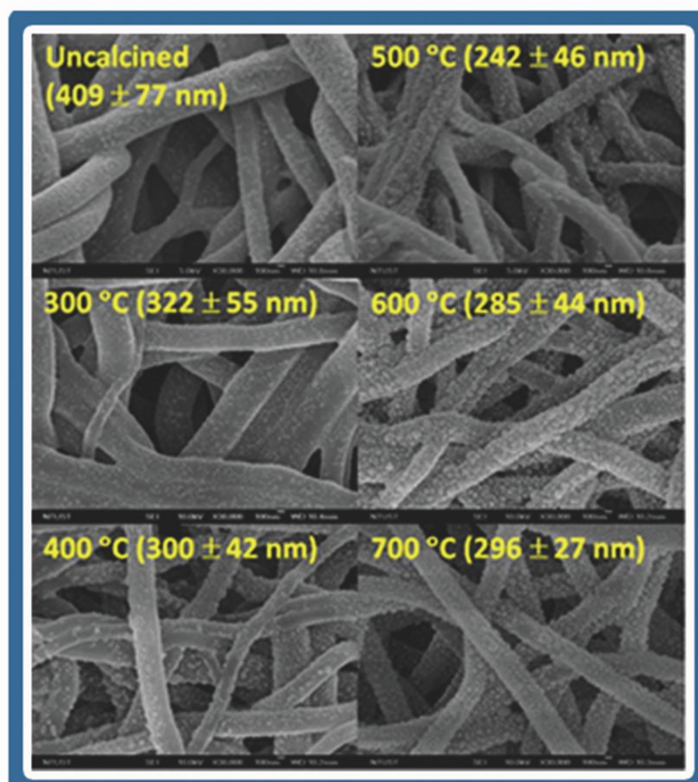


Fig. 1: SEM images of as-spun and GNPs-decorated PVP nanofibrous meshes before and after calcination treatments at 300, 400, 500, 600 and 700°C

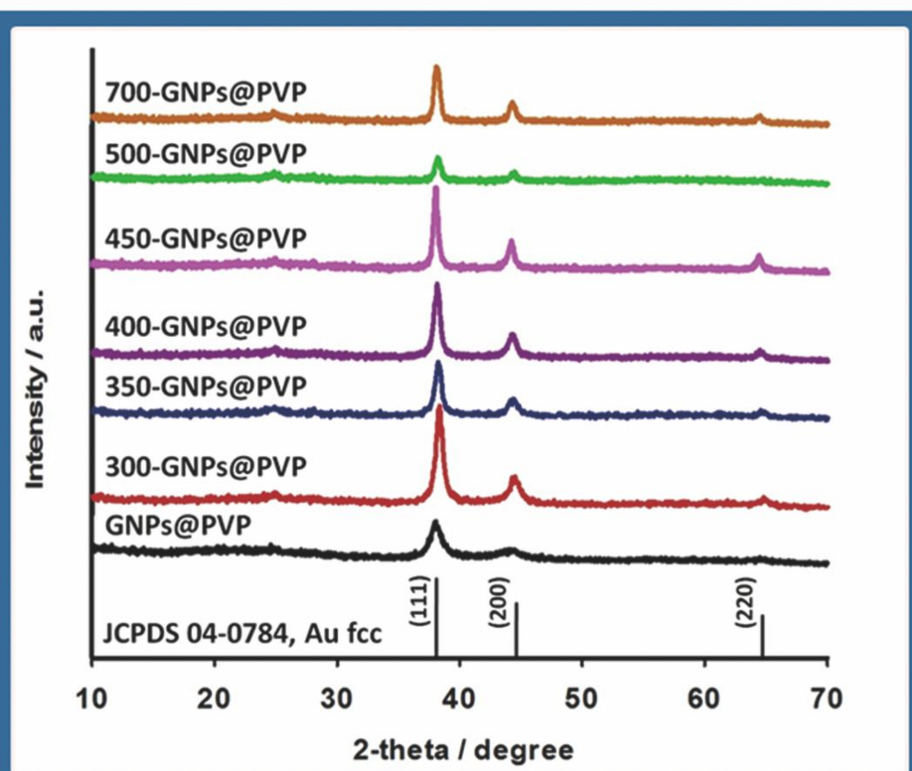


Fig. 2: XRD patterns of GNPs-decorated PVP nanofibrous meshes before and after calcination treatments at 300, 400, 500, 600 and 700°C

Samples	Crystallite Size (nm)
GNPs@PVP	8.2
GNPs@PVP-300	13.2
GNPs@PVP-350	13.6
GNPs@PVP-400	14.3
GNPs@PVP-450	19.5
GNPs@PVP-500	14.1
GNPs@PVP-700	14.0

Table 1: Effects of calcination temperatures on the crystallite size oAf GNPs on the fiber surface

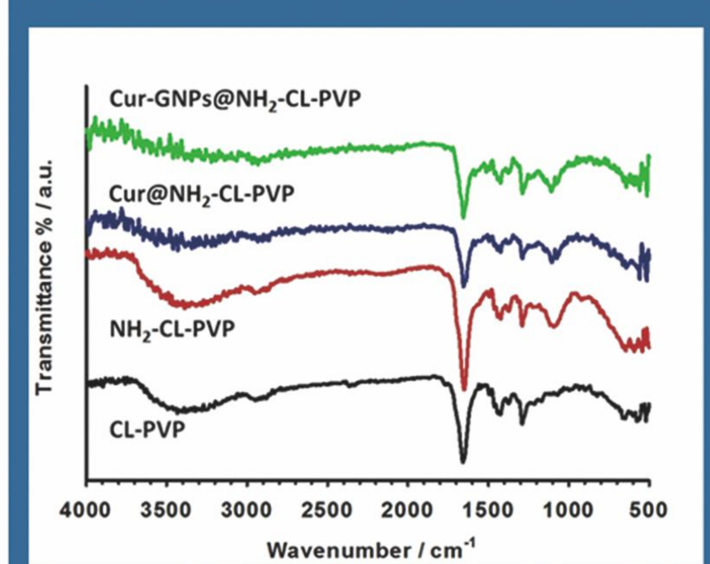
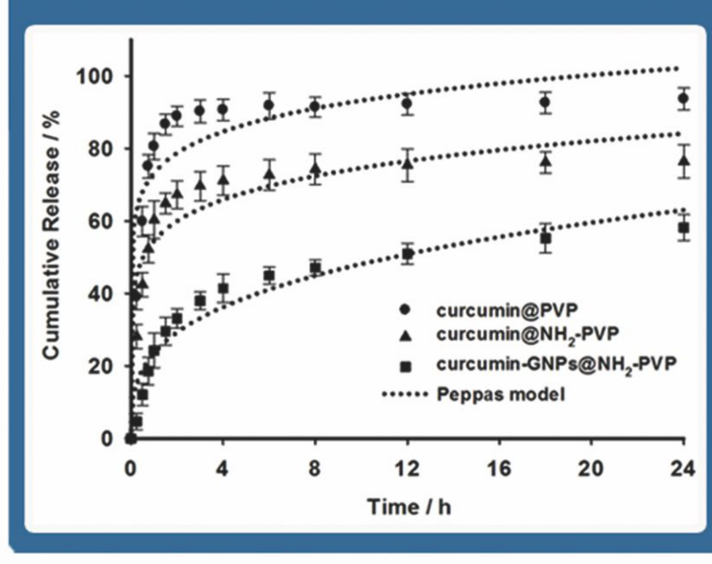


Fig. 3: Infrared spectra of PVP, NH_2-PVP and curcumin-GNPs@NH_2-PVP nanofibrous meshes

Compound	IR assignment	Wavenumber (cm^{-1})
Curcumin	O–H	3508 (sharp)
	O–H	3293 (broad)
	ν(C=C) & ν(C=O)	1626 (sharp)
	ν(C=C)ring	1601 (strong)
	ν(C=O)	1508
	C–O (enol group)	1272
	C–O–C	1023
	trans-CH (benzoate)	959
	cis-CH (benzoate)	713
PVP / NH_2-PVP	C=O (amide)	1780-1630
	C–N	1335-1250
	Si–O–R	1110-1000

Table 2: Vibration modes and band frequencie incurcumin, PVP and NH_2-PVP



Nanofibrous Samples	Peppas Release Parameters		
	Release constant (k_p)	Release exponent (n)	R^2
curcumin@PVP	73.2	0.10	0.87
curcumin@NH_2-PVP	54.6	0.14	0.88
curcumin-GNPs@NH_2-PVP	23.6	0.31	0.92

Table 1: Predicted Peppas release parameters of curcumin from different nanofibrous meshes

Release exponent (n):
0.5 (Fickian diffusion); $0.5 < n < 1.0$ (anomalous transport); 1.0 (Case-II transport); >1.0 (Super Case-II transport)

Fig. 4: Release characteristics of curcumin from PVP, NH2-PVP and curcumin-GNPs@NH_2-PVP nanofibrous meshes in Tween 20-PBS release medium at 37°C

RESEARCH MAIN POINTS

- Surface decoration of electrospun PVP fibers with nanosized silver (SNPs) or gold particles (GNPs)
- Tuning the size and coverage density of silver/gold nanoparticles on the surface of electrospun PVP fibers
- Formulation of curcumin-GNPs inclusion complexes for controlled-release and

RESEARCH EXPERIENCE

Working with Dr. Suryadi Ismadji, my first research project, as an undergraduate, focused on the treatment of water and wastewater polluted with heavy metals, textile dyes, pharmaceuticals and personal care products by adsorption method and the production of biofuels (e.g., biodiesel) from renewable resources. After graduating from college, I worked as a senior laboratory assistant on modern analytical instrumentation for about two years and then pursued a full-time Master's degree program in chemical engineering at National Taiwan University of Science and Technology (Taiwan Tech). During my first year of graduate school in Taiwan Tech, I have taken compulsory and elective courses offered by the department and worked hard to obtain satisfactory grades in all courses. Also, I had great opportunities to learn and develop skills in operating a variety of precious analytical instruments, such as scanning electron microscopy (SEM), X-ray diffraction (XRD), thermogravimetric analysis (TGA), Fourier Transform infrared (FTIR), BET surface area analyzer, etc. Furthermore, I am still learning and practicing to improve my Chinese skills for easy communication with local people and my lab-mates. My current research interests focus on the electrospinning technology to fabricate submicron/nanofibers and surface decoration with metallic nanoparticles for emerging applications in areas such as biomedical, energy and environment.

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