Electronic Supplementary Material (ESI) for Nanoscale.

On-Demand Electrically Controlled Drug Release from Resorbable Nanocomposite Films

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Table S1. Brief overview of advances in electroresponsive drug delivery systems

Material class	Carrier material	Drug	Stimulation condition	Advantages	Disadvantages	References
Swellable hydrogels Release mechanism: Deswelling of hydrogel upon electric stimulation	Sodium alginate/ Polyacrylic acid composite	Hydrocortisone	9 V	• Biodegradable • FDA-approved materials	• High voltage • Drugs must be hydrophilic for hydrogel loading	[1]
	Poly(vinyl alcohol)	benzoic acid, sulphanilamide	1-5 V (3-5V needed for meaningful difference)	• Biodegradable • FDA-approved materials	• High voltage • Drugs must be hydrophilic for hydrogel loading	[2]
Erodible hydrogels Release mechanism: Erosion of hydrogel upon electric stimulation due to local pH changes	Poly(ethyl oxalamine)/ Poly(methacrylic acid) or Poly(acrylic acid)	insulin	10 mA	• Electrically erodible	• High current • Non-FDA-approved materials (PEOx) • Drugs must be hydrophilic for hydrogel loading	[3]
Conducting polymers Release mechanism: Oxidation/Reduction of highly conjugated backbone of polymer	Polypyrrole nanoparticles	fluorescein, daunorubicin, piroxicam, insulin	-0.5 V (lowest reported)	• Low voltage • Generalizable: can incorporate drugs of varying charge, size, and hydrophobicity	• Non-biodegradable • Non-FDA-approved material	[4–6]
	Graphene oxide / Polypyrrole nanocomposite films	Dexamethasone	-0.5 V	• Low voltage	• Non-FDA-approved material • Non-biodegradable	[7]

					• Drugs must be negatively charged for film incorporation	
	PEDOT nanotubes	Dexamethasone	+1 V	• Low voltage	• Non-biodegradable • Non-FDA-approved material • Drugs must be hydrophobic for nanotube incorporation	[8]
Biodegradable conducting polymers Release mechanism: Oxidation/Reduction of highly conjugated backbone of polymer	Films composed of a co-polymer of aniline and polyethylene glycol (PEG) or polycaprolactone (PCL) linked with ester bonds	Dexamethasone	+0.6 V	• Low voltage • Biodegradable • Theoretically generalizable (although system has only been verified with dexamethasone)	• Non-FDA-approved material • Aniline has demonstrated toxicity *in vivo*	[9]
Layer-by-layer films Release mechanism: Induced dissolution or destabilization of film layers upon electric stimulation	Prussian Blue nanoparticles (+ layer) and gentamicin (- layer)	gentamicin	+0.5 V (lowest reported)	• Low voltage • Electrically erodible • FDA-approved materials	• Not generalizable (gentamicin incorporation depends on the electrostatic properties specific to the drug)	[10]
	Poly(lysine) (+ layer) and heparin (- layer)	heparin	+1.8 V	• Low-voltage • Electrically erodible • FDA-approved materials	• Not generalizable (heparin incorporation dependent on the electrostatic properties specific to heparin)	[11]
	poly(beta-amino ester) (+ layer), ovalbumin (- layer) with graphene oxide & reduced graphene oxide additives	ovalbumin	+0.4 V	• Low-voltage	• Non-resorbable • Non-FDA-approved materials • Not generalizable	[12]

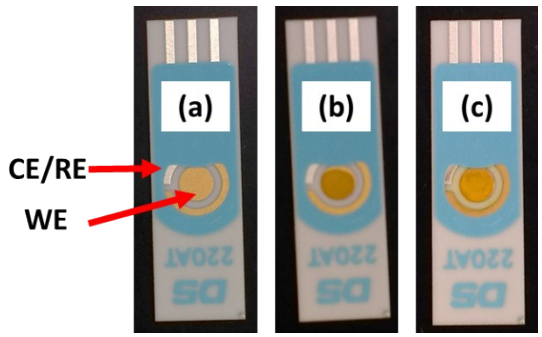

Figure S1. (a) Screen printed electrode with gold working electrode (WE) and silver counter/reference (CE/RE) electrode, (b) WE coated with EGT, and (c) WE coated with EGT and CHT.

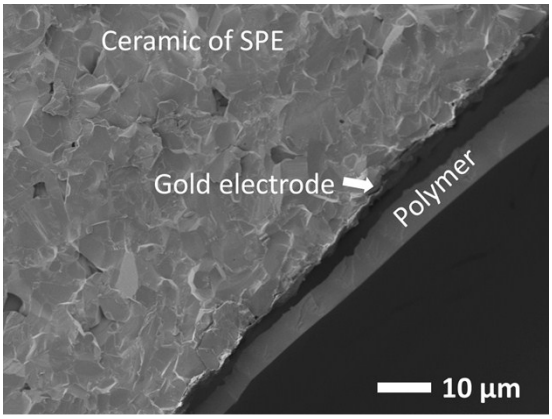

Figure S2. Cross-section of film near film edge. The film is thicker near the edges due to the coffee-ring effect during dropcasting.

Figure S3. Serum pH before and after electrical stimulation. The overall pH of serum remains unaltered at 7.4 even after 5 pulses of -1.5 V for 20 s are applied.

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