Free-standing functionalized nanofilms for biomedical applications

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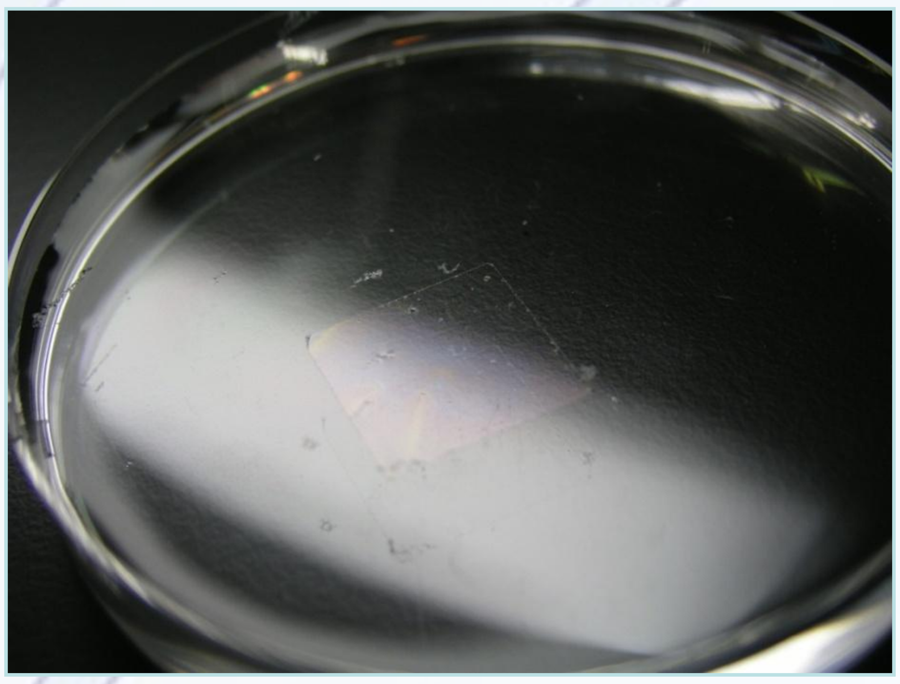
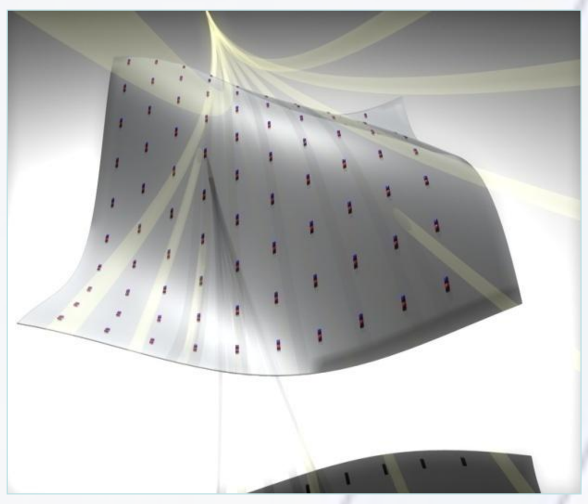
Introduction

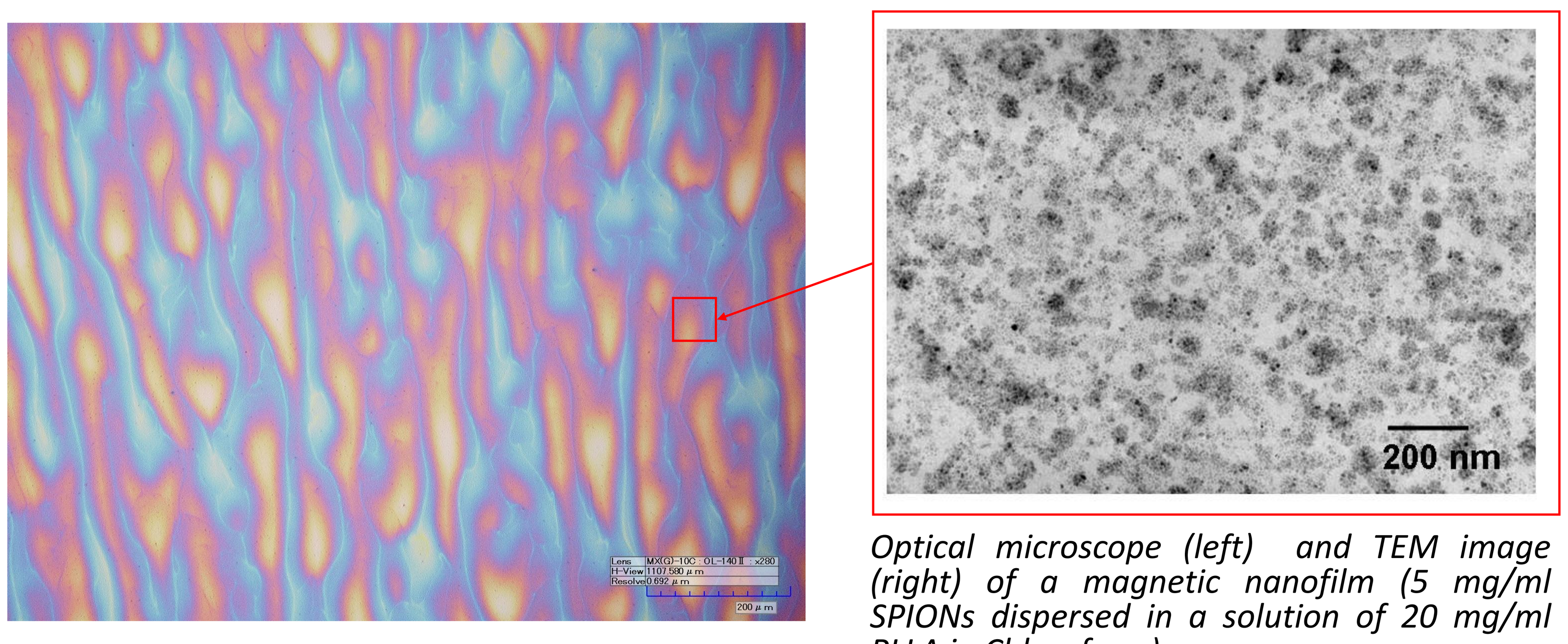
Nanofilms are polymer-based films with very large area (up to tens of cm^2) and with a thickness in the order of few tens - hundreds of nanometers[1]. Due to their peculiar properties, amongst which biocompatibility, high compliance and the possibility of carrying drugs for controlled release, these structures were recently proposed for biomedical applications, such as nanoplasters for pharmaceutical and cosmetic use, as a new solution for closing incisions after open surgical procedures[2] or as substrates for cell growth[3]. In this sense one of most challenging issues is the films control within the working environment: the possibility of including magnetic components, such as magnetic nanoparticles, will pave the way for the effective use of nanofilms in the human body, by allowing precise positioning by an external magnetic field. Moreover, the capability to obtain conductive nanofilms by using conjugated polymers is as well interesting for several applications.



Free-standing magnetic nanofilms

Free-standing nanofilms with a homogeneous magnetic loading were fabricated by spin-coating assisted deposition of a Poly(L-lactic acid) solution containing super-paramagnetic nanoparticles (SPIONs , 10 nm diameter) over a water soluble sacrificial layer (Poly(vinyl alcohol), PVA).[3]





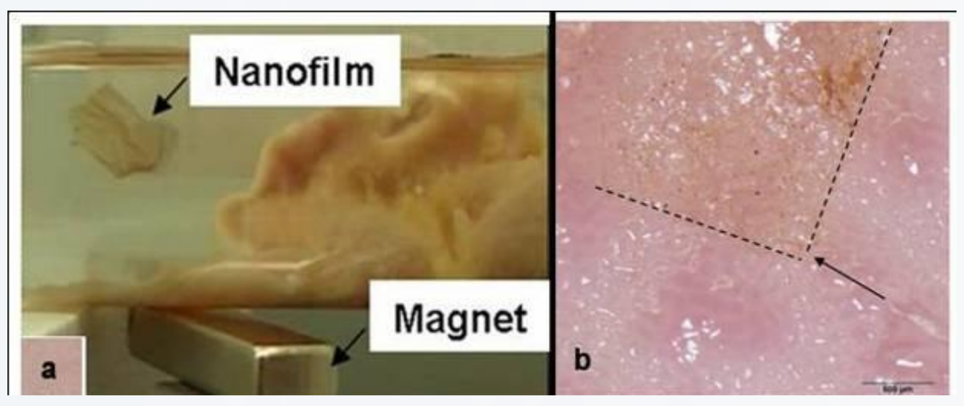
Optical microscope (left) and TEM image (right) of a magnetic nanofilm (5 mg/ml SPIONs dispersed in a solution of 20 mg/ml PLLA in Chloroform).

The thickness and the roughness of polymeric nanofilms depend on the selected spinner speed and time, and on the PLLA and SPIONs concentration in the solution.

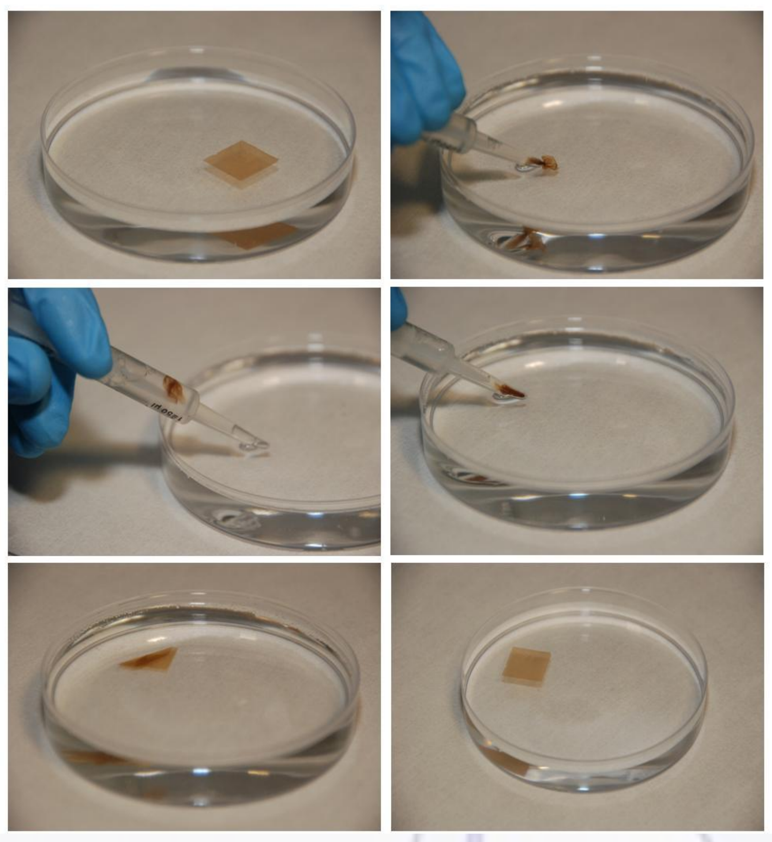
The thickness of nanofilms is in the range 30 nm - 400 nm depending on the concentration of polymer and SPIONs. The homogeneous SPIONs density per squared area is controlled by setting the SPIONs concentration in the solution.

Nanofilms can be aspired and injected through the micrometric hole of pipettes, cannulae and general use syringes fully maintaining their integrity.

The proposed magnetic nanofilms can be injected inside the human body in different fluids and spaces and then remotely controlled by permanent and gradient magnetic fields, thus opening new application scenarios, as already theoretically and experimentally demonstrated.[4]



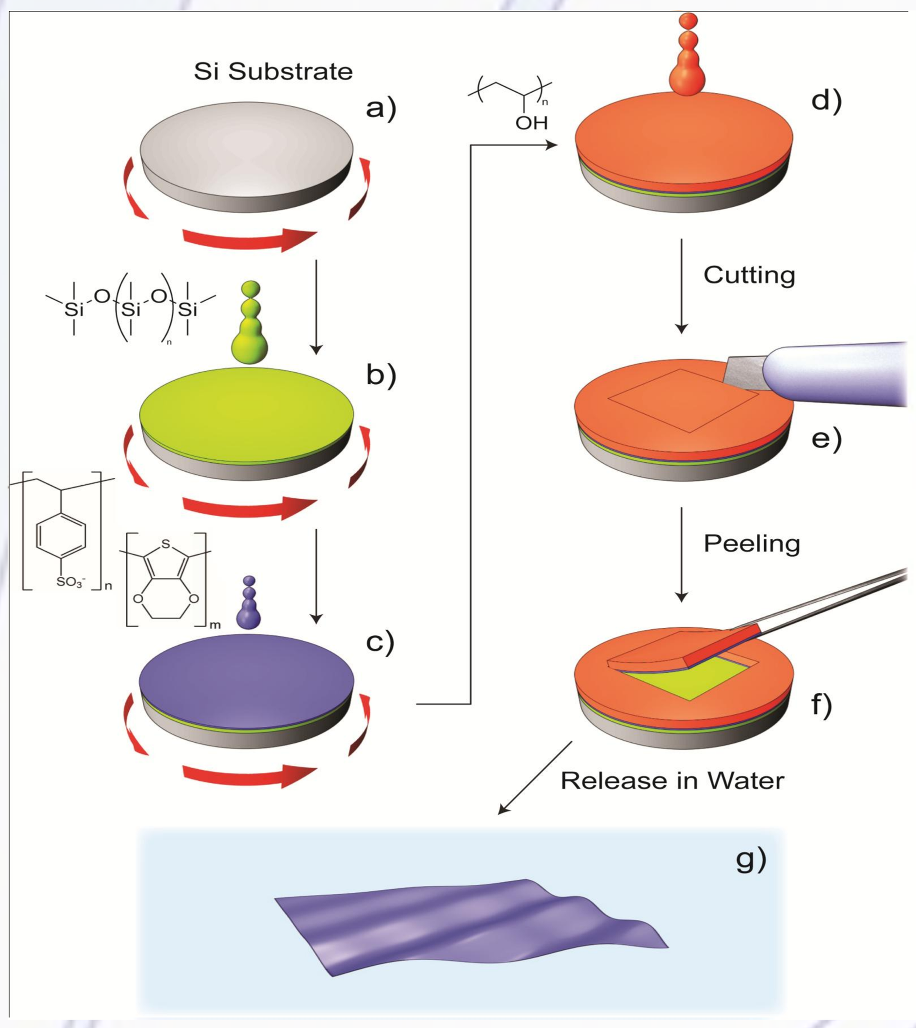
Up: Free-standing magnetic nanofilm floating in water and moved towards a mucosal tissue with the aid of a permanent magnet (a). Optical microscope image of the same nanofilm adhering on the tissue (b).

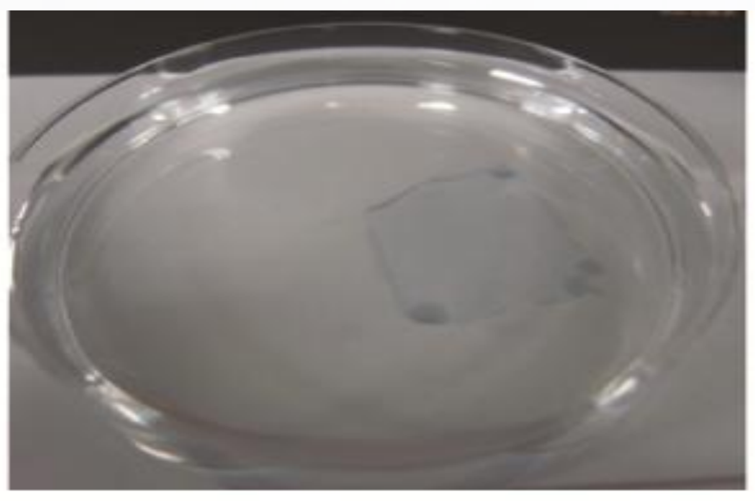


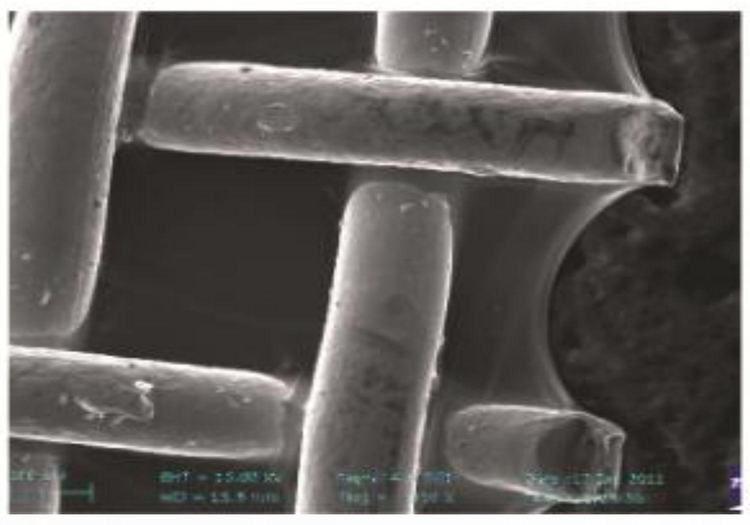
Right: Nanofilm aspiration and release using a pipette.

Free-standing conductive nanofilms

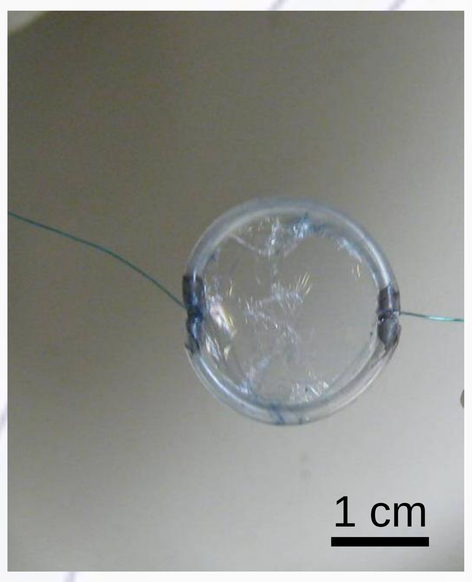
The fabrication of robust free-standing nanofilms based on conductive polymers was performed via spin-assisted deposition of a dispersion of polyethylene(3,4-dioxythiophene)/polystyrene sulfonate (PEDOT/PSS) in water, in conjunction with the Supporting Layer technique (patented technologies[5]).







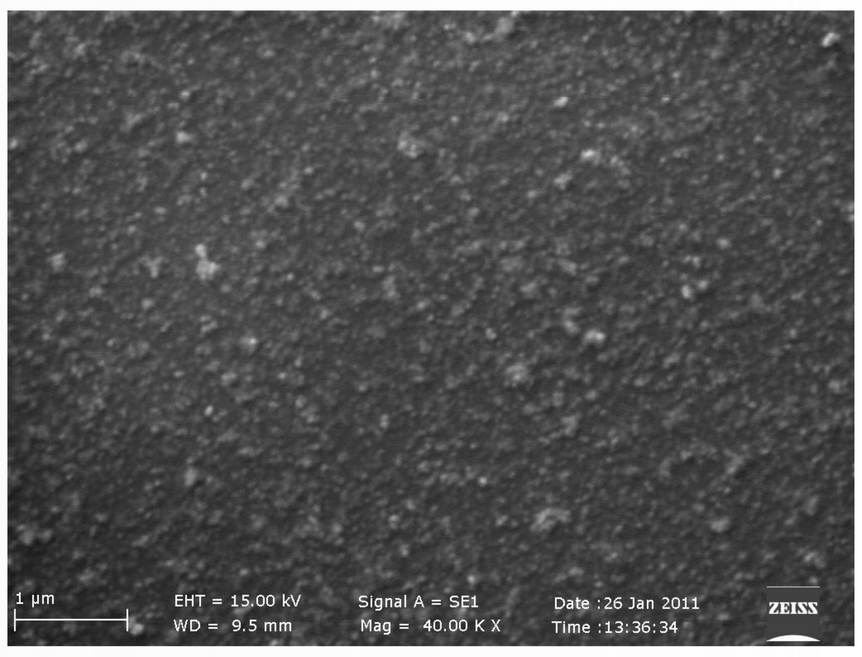
Despite their low thickness (40- 200 nm), PEDOT/PSS conductive nanofilms are relatively robust: they can be manipulated, folded and unfolded in water many times without suffering from cracks or disaggregation nor from loss of conductive properties. The conductive properties of these nanofilms vary in dependence on materials formulation, employed processes and, particularly, on water or moisture content. Typical values of conductivities range from 10^{-1} up to 100 S/cm.



Applications for conductive nanofilms could include:
•deposition of nano-scale conductive films over insulators through a "soft", simple, cost effective, non destructive technique;
•sensing and actuating membranes;
•smart substrates for cell adhesion, growth, differentiation, stimulation;
•development of bio-hybrid actuating devices.

Very recent developments regards the integration of both magnetic and conductive functionalities inside the same nanofilm with the development of multilayer or composite structures.

Right: SEM micrograph of composite PEDOT/PSS nanofilm loaded with SPIONs .



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