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AND MATERIALS SCIENCE
Polish Academy of Sciences

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Multiscale surface functionalization of blood contacting materials

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Interdisciplinary PhD Studies in Materials Engineering with English as the language of instruction
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MAIN RESEARCH INTEREST

Fabrication of tissue analog

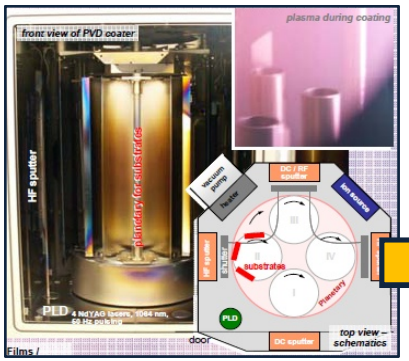
for application

in cardiovascular devices

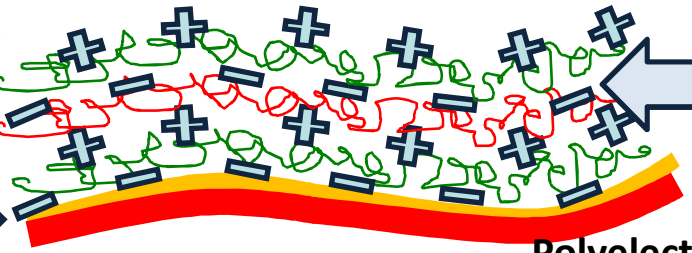
Multiscale surface functionalization of polyurethane materials will improve biocompatibility and reduce the risk of the coagulation system activation

MATERIALS

Scheme of PU surface functionalization by Ti(C,N)/DLC thin layer and polyelectrolyte multilayer film



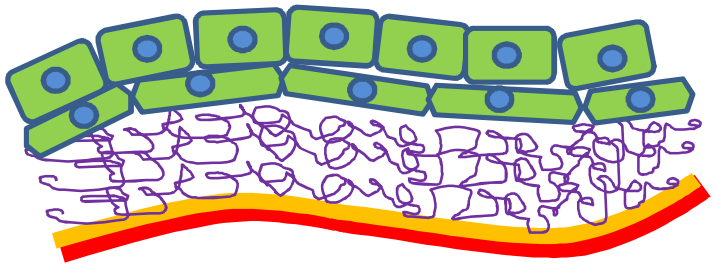
Ti(C,N)/DLC deposition



Polyelectrolytes deposition

Multiscale modification

- cross-linking
- protein adsorption
- nanoparticles incorporation
- microcapsules introduction



Tissue analog (scaffold + cells)

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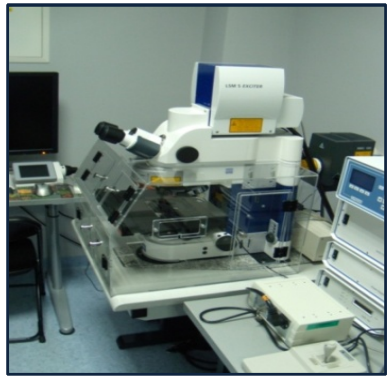
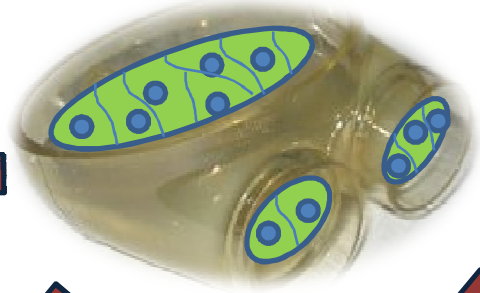
METHODS

Confocal microscopy





SEM

Biomimetic cardivascular devices

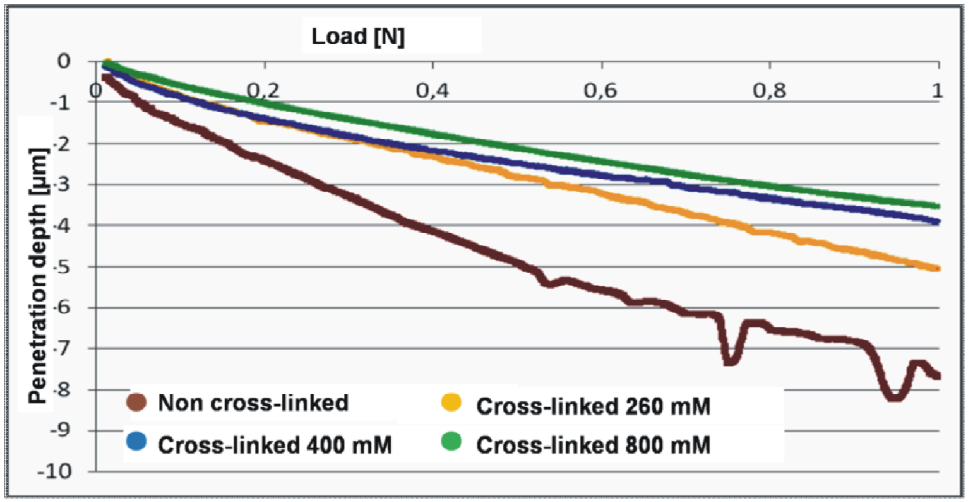
Aortic flow simulator

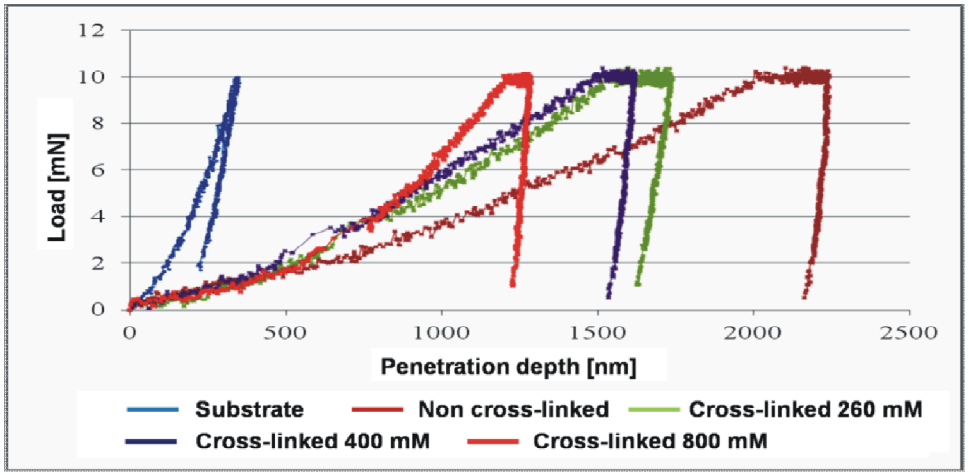
Radial flow chamber

Tensile testing machine

DS Calorimetry

RESULTS





Micro-hardness: results of scratch test (upper chart) and indentation test (chart below) of 12 bilayers poly-L-lysine/ hialuronic acid (PLL/HA) cross-linked and non-cross-linked films

- MicroCombi-Tester
- Berkovich's indenter
- Applied load:

- scratch test: 0.01-1N
- indentation test: 10mN

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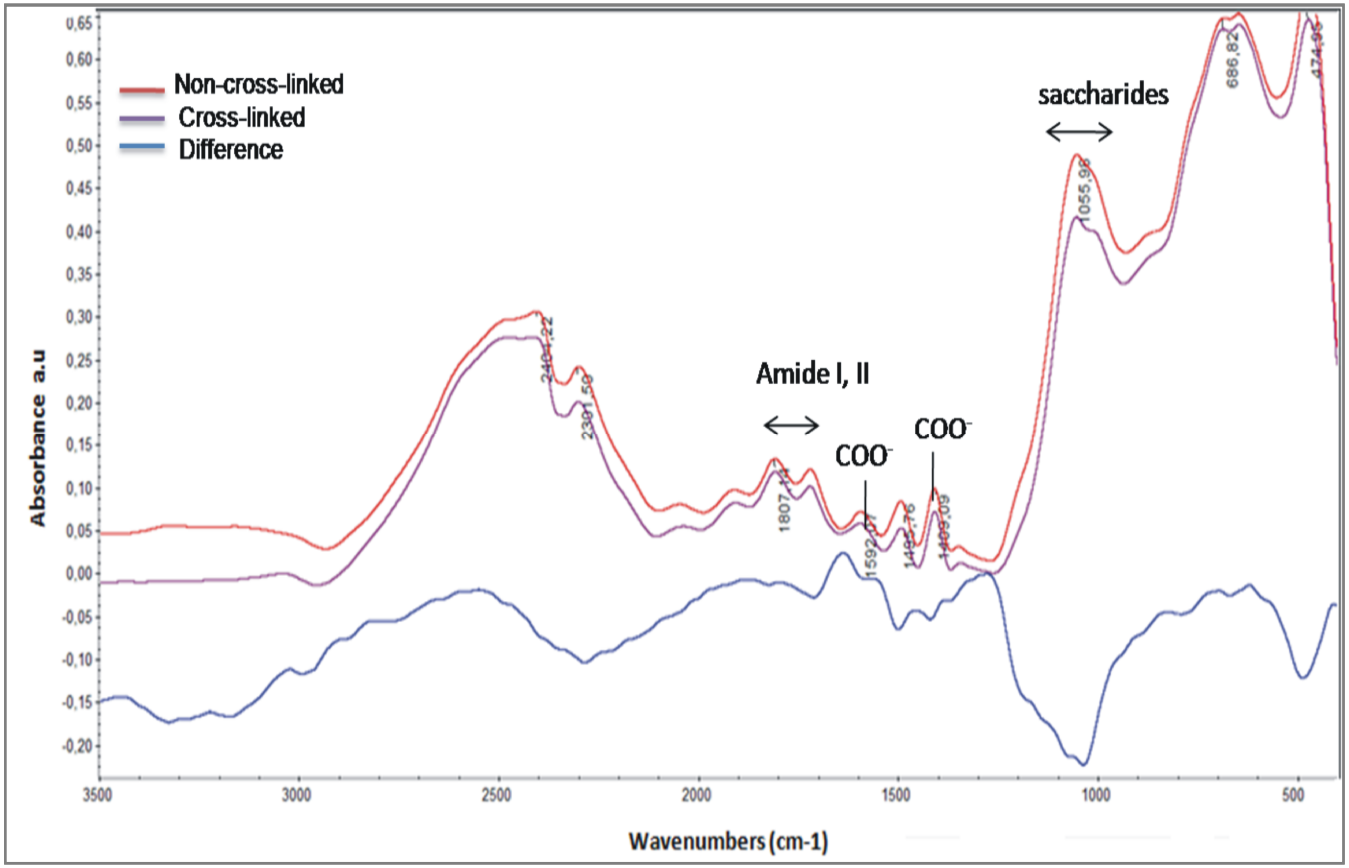
RESULTS



Internal structure analysis of PLL/HA 12 bilayers by Fourier Transform Infrared Spectroscopy (FTIR) method - comparison between non-cross linked and cross-linked films

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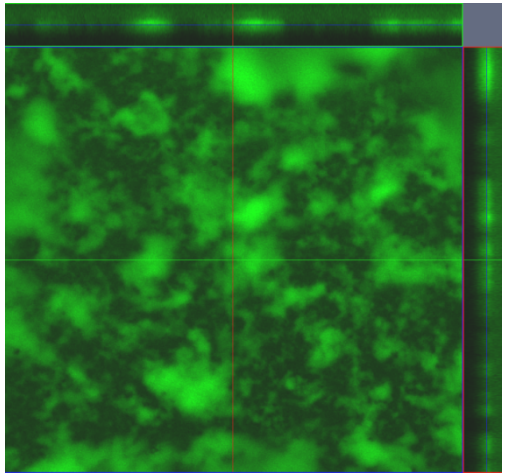
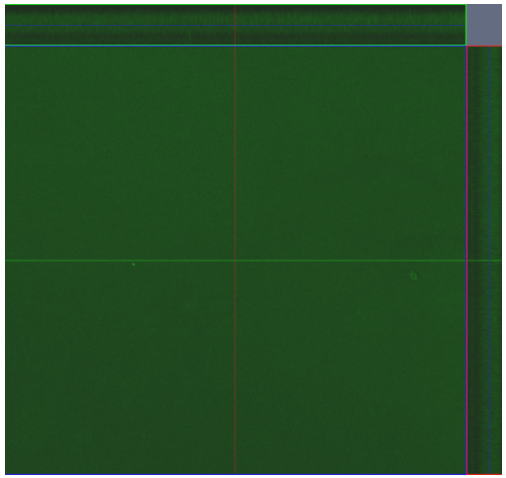
non cross-linked

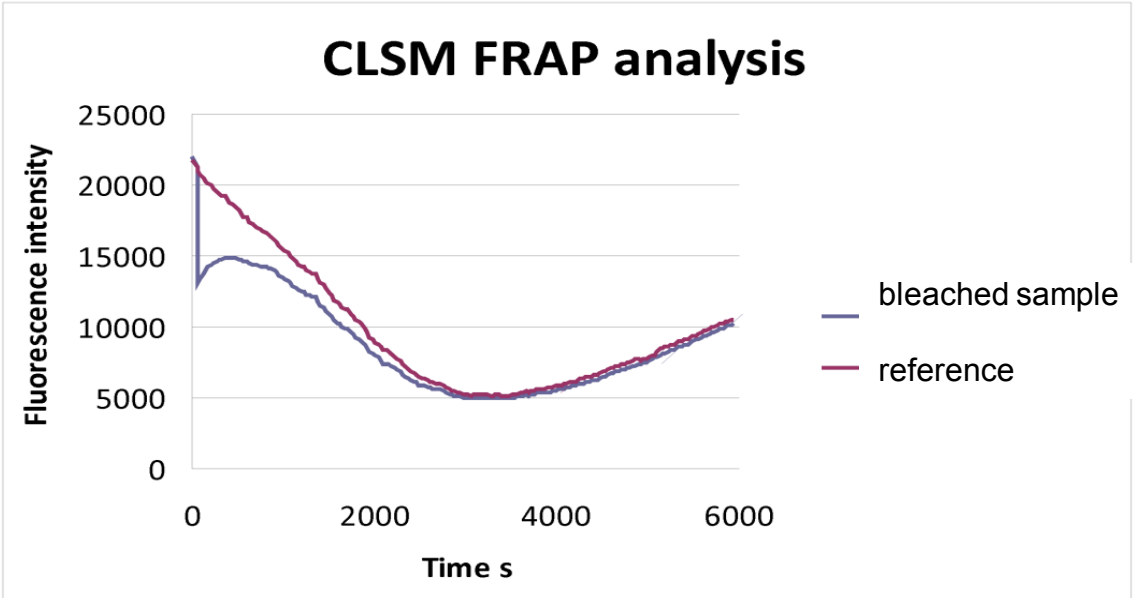


cross-linked



Diffusion process analysis – comparison between cross-linked and non-cross-linked films

- LSM Exciter 5 confocal microscope
- Method: time-lapse and Fluorescence Recovery after Photobleaching (FRAP)
- Fluorescence source: FITC labeled PLL layer



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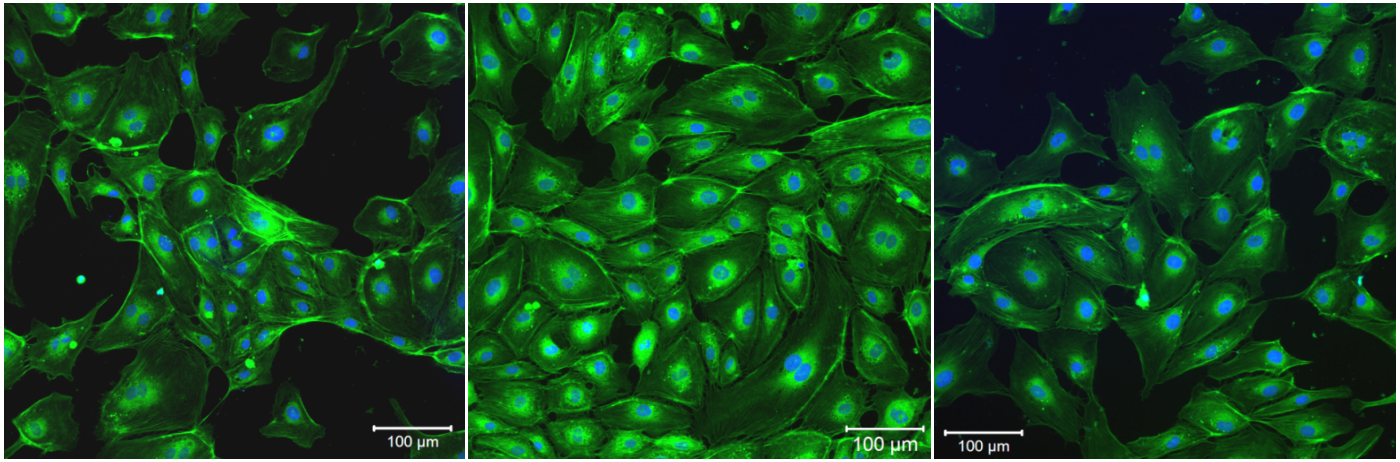
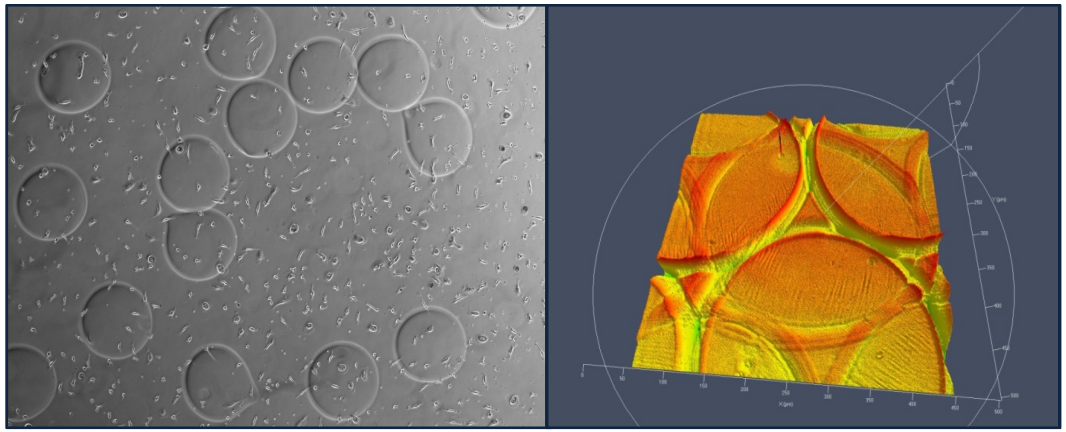


260 mM EDC/NHS **400 mM EDC/ NHS** **800 mM EDC/NHS**

Human Umbilical Vein Endothelial Cells (HUVEC) growth kinetics and morphology - dependence on scaffold rigidity. Confocal microscopy images - staining of cells nuclei (DAPI – blue), cytoskeleton (Alexa Fluor® 488 phalloidin – green)

HUVEC proliferation on PLL/HA films + alginate microcapsules as growth factors carriers



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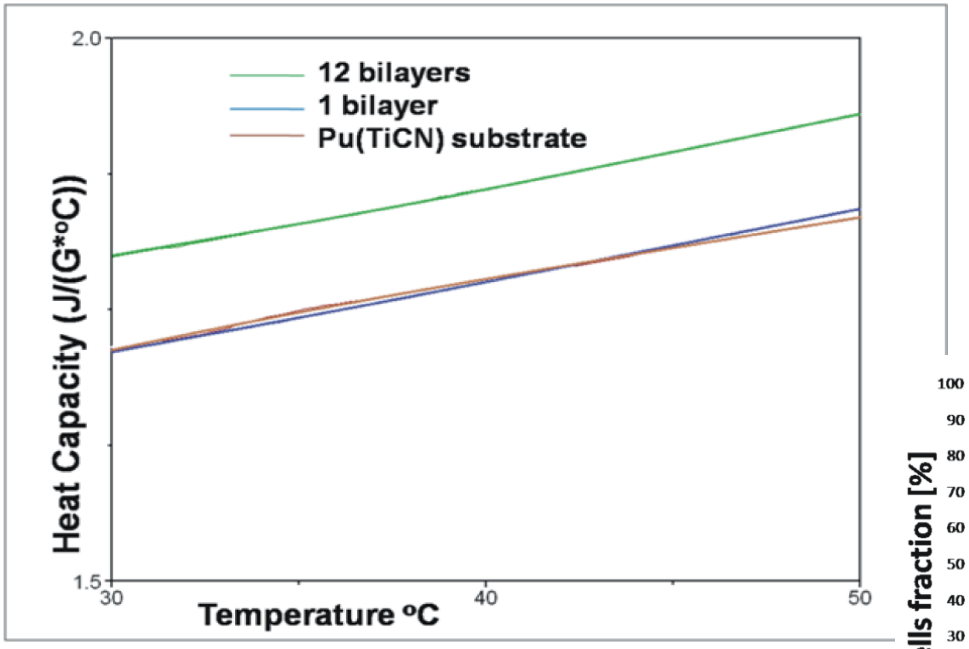
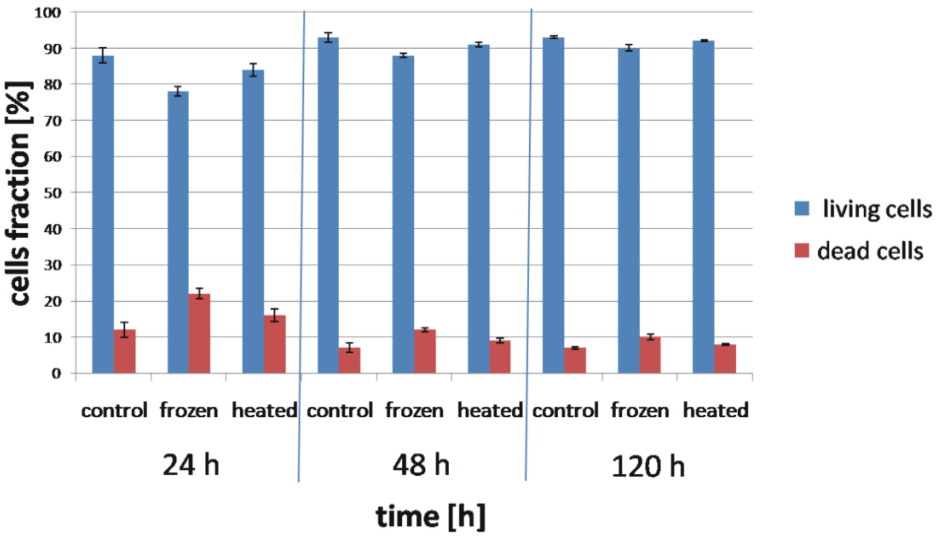


Calorimetric (DSC) determination of changes in porous coating heat capacity – comparison between polyelectrolytes with different thickness (chart above)

Results of HUVEC growth kinetics assessment on 400 mM EDC cross-linked 12 PLL/HA bilayers – comparison of various temperature treatment effects (-50 to +50 °C) (chart below)



SUMMARY

• Poly-L-lysine (PLL) and hyaluronic acid (HA) were applied due to be a promising materials for the cardiovascular implants surface modification.

• Scaffolds were cross-linked chemically and the optimal rigidity for endothelial cells growth was determined. The obtained result indicates that concentration of 400 mM EDC/ 200 mM NHS seems to be the best choice.

• Micro-hardness studies have shown that cross-linking of coatings caused a significant increase in their mechanical properties. Hardness of cross-linked compared to non-cross-linked films increases from 75 to 275 MPa and the Young's modulus from 11 to 26 GPa.

• Thermal analysis indicates on stability of porous coatings in range between -50 to +50 ^{o}C, which will be significant for their storage and application. There were no changes observed in scaffolds potential to endothelialization after thermal alterations.

• Modifications like protein adsorption (fibronectin), and alginate microcapsules introduction were performed. The preliminary results indicated on enhancement of HUVECs proliferation by the fibronectin and effectiveness of applied growth factors microcapsules delivery system.

• Further modifications and searching for a new type materials for multilayer coatings fabrication by LbL method will be the main interest of the future research.