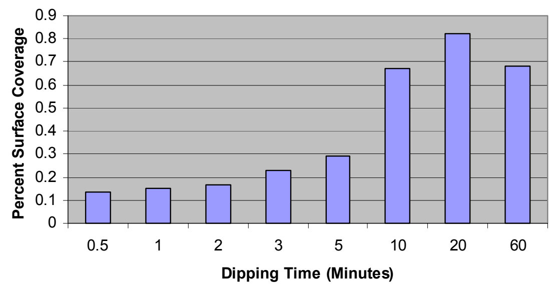
Surface Engineering of Cardiovascular Stents for Multimodal Imaging

Thomas Soike, Chenxia Guan, V. Prasad Shastri
Biomaterials, Drug Delivery and Tissue Engineering Laboratory; Department of Biomedical Engineering; Vanderbilt University, Nashville, TN 37232. *Prasad.Shastri@vanderbilt.edu

Statement of Purpose: Over one million stent procedures are performed annually. In roughly 30% of these cases the stents fail and the stent-supported artery constricts. In many instances, early intervention could have yielded more positive outcomes. Ability to extract information concerning the changes occurring in the tissue surrounding the stent is key. The objective of this work is develop a general methodology to engineer a stent surface through self-assembly strategies such that it amenable to imaging using MRI and CT modalities. Multi-modal imaging will provide physicians with additional information to better determine the performance of implanted stents.

Methods: Deposition of information was carried out using the layer-by-layer (LBL) polyelectrolyte assembly approach developed by Gero Decher (Science 1997, 277, 1232-1237.). We used a hybrid system composed of naturally occurring polysaccharides and polyionic polymers as our building blocks. 316L stainless steels foils (Goodfellow Corporation), 316L stainless steel and cobalt chromium stents, generously provided by Guidant Corporation (Santa Clara, CA) were used as model substrates. A typical surface modification process involves first dipping the substrate in the polysaccharide solution followed by sequential, alternating incubation in solutions bearing oppositely charged species. This process was typically repeated 4 times to yield a base surface modification layer. Additionally, depending on the design consideration, some of the layers included gold nanoshells, to improve contrast in the CT mode and supramolecular complexes of Gadolinium for MR imaging. Gold nanoshells (5 nm) and polystyrene nanoparticles (PS-NP) (300 nm) were studied as model particulate systems for incorporation on stent surfaces. Incorporation of these moieties and gadolinium was achieved by co-adsorption in presence of the major polyelectrolyte. The modified substrates were imaged using a field emission scanning electron microscope (Hitachi S4200). For the surface coverage experiments only PS-NP was employed due to its larger size. The surface area coverage was determined by analyzing the SEM images using Scion Image (NIHI), image analysis freeware, following which the system was optimized using an iterative approach.

Results/Discussion: In the LBL approach, alternating layers composed of charged moieties of opposite charge characteristics are assembled on a surface from solution. The strength of this approach lies in its simplicity and ability to impart information defined at a thickness of few nanometers. By appropriate choice of the co-adsorbent, nanoparticle of differencing charge and chemical characteristics cane be co-adsorbed and hence deposited onto the stent surface. Figure 1 shows the relationship between incubation (dipping) time and PS-NP surface coverage. Figure 2 shows a sample surface coated with gold nanoparticles with nearly 100% surface coverage. While the surface deposition of small gold nanoshells is interesting, the strength of the approach lies in the ability to modify, a material surface with large moieties such as the 200 nm PS-NP with near complete surface coverage (Figure 3). These nanoparticle-modified stents are currently being evaluated using CT and MR modalities.



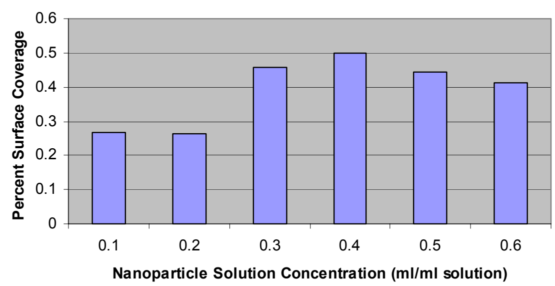


Figure 1 PS-NP surface coverage. 20 minute dipping times and 0.4 % nanoparticle solutions produced the most surface coverage.

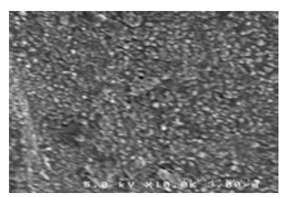


Figure 2: SEM image of a surface modified with gold nanoshells (10^4x)

Figure 3 SEM image of a surface modified with PS-NP 5000x

Conclusions: We have presented herein a novel approach to modify stent surface to make them amenable toward multi-modal imaging. This approach will open up new avenues to incorporate drug-delivery with imaging toward the development of the next generation drug eluting stents.