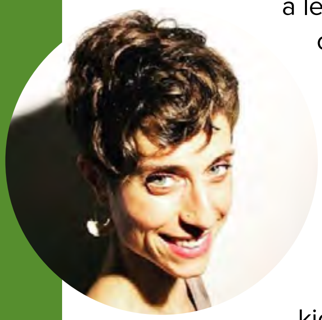
SurFACTS in Biomaterials

SUMMER 2021
VOLUME 26, ISSUE 2

INSIDE THIS ISSUE

PAGE 14 LOGO CONTEST!

From President Angela DiCiccio



2021 continues to serve as a lesson in letting go of expectations, breathing into the moment and innovating to optimize for now. With this spirit we are excited to kick off our second virtual Biointerface Workshop and Conference this September. We approached this year as an opportunity to polish the resources developed by our board and planning committees during last year's pivot and lay the foundation for what features we'd like to carry into 2022. Let's take this chance to continue to learn as a community, and keep what sticks as improvements but let go of what holds as a compromise.

This year Biointerface 2021 will again be a series of mini-sessions with an ongoing thread of conversation happening in our custom app and social media we pages! We hope you will join and use this space to intentionally network, strategically build connections with folks you may not have interfaced with in a while, and learn something new! Especially exciting is a growth opportunity for interaction with students via the pitch competition by adding a live session with Q&A opportunities at the end of our program. And speaking of a leader with vision, we are excited to announce the 2021 Excellence in Biomaterials Science Award winner, Dr. William Lee of AST Products and much more. Read a preview about his amazing work in this issue. Excited to tune in, get involved with an exhibit or learn more? Reach out and register at www.surfaces.org.

Thank you to those who attended and participated in our Open House in June, you can read more about our incredible speakers' journeys in this issue and if you missed them live, you can watch Tony Eisenhut, co-founder and CEO of Novasterilis and Michael Goglia, Elkem Silicones Healthcare Market Manager, discuss COVID-19 relief in our membership portal. If you would like to submit an article for a future issue, please reach out to us at info@surfaces.org.

Although we miss our community in person we hope you will join us virtually this year, share feedback on your experiences for how we can grow as a

Continued on page 2

From President Angela DiCiccio

continued from page 1

community next year, and look forward to seeing you in person Nov. 2–4, 2022 in Portland, Oregon. Mark your calendar!

Let's continue to focus on supporting each other and growing our support network. Surfaces in Biomaterials Foundation is here to support your efforts and bring everyone together as we continue to meet the needs during the pandemic and beyond.

A Multifaceted Approach to Develop and Optimize Surface Coatings for Diverse Medical Devices

Kevin Chen, Ph.D., Medical Surface Inc., Natick, MA 01760

Medical devices are very diverse—they come in different forms and shapes, and need different types of coatings for different purposes. For example, ocular devices usually have curved surfaces and are made of a variety of materials, including hydrophobic materials, which require a conformal hydrophilic coating that is also optically clear. In another example, implanted or wearable biosensors, such as glucose sensors, are miniature devices consisting of multiple layers of materials; they usually need biocompatible coatings as the outmost layer to minimize biofouling in the body, and permeability control coatings to allow the analyte to reach the sensing layer in a controlled rate, and minimize the permeation of non-analyte chemicals that could interfere with accurate sensing.

The diversity of medical devices brings additional challenges to coating development. If we try to apply the same coating technology regardless of the differences in the devices, the results are often not optimal. For example, a technology that is well suited for coating the outer surfaces of catheters may not be suitable for coating the inner surfaces of catheters, a coating that performs well on one type of biosensor may not work on another type of biosensor. Fortunately, there are a multitude of coating technologies that can be utilized to coat medical devices.

The most well-known coating technologies include dip coating (Figure 1a) and spray coating (Figure 1b). The principles of these coating technologies are simple but the techniques can be highly involved. For example, in dip coating, the withdrawal speed, the drying dynamics, the solvent evaporation rate and the viscosity of the solution are some of the critical parameters. The chemistries used in dip coating can involve UV curing or heat curing.

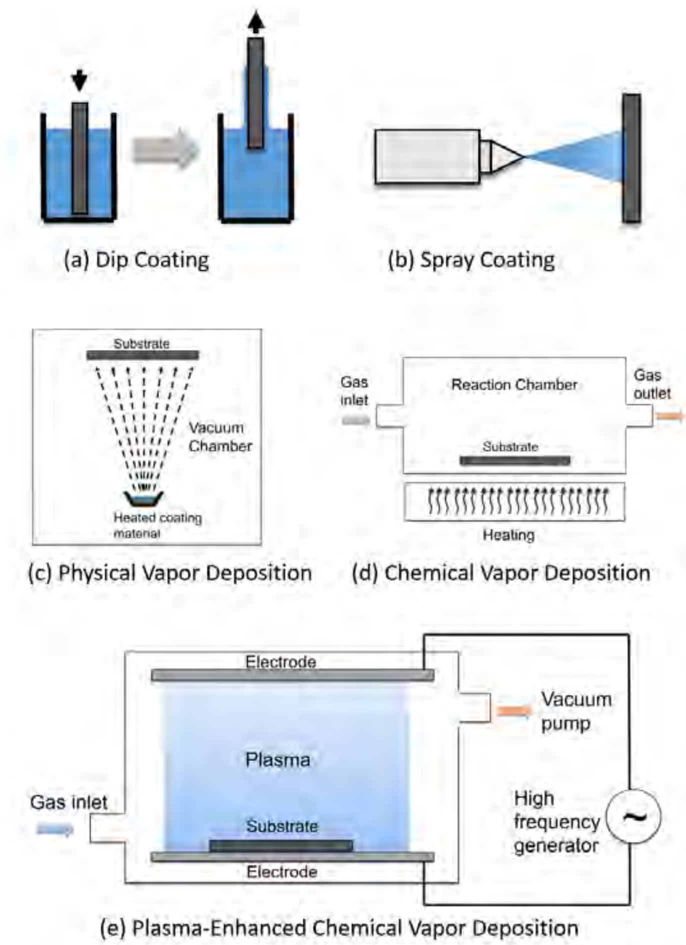


Figure 1: Schematic drawing of various coating technologies

In spray coating, there is a whole different set of critical parameters, such as the spray distance and the flow rate.

Another important category of coating technology is vapor deposition. This includes physical and chemical

Continued on page 3

vapor depositions. In physical vapor deposition (Figure 1c), no chemical reaction happens, the materials evaporate and deposit on the substrate; while in chemical vapor deposition (Figure 1d), the molecules in chemical vapors react to form a polymer coating on the substrate.

One type of chemical vapor deposition has gained more and more attention. This is plasma enhanced chemical vapor deposition, or PEVCD (Figure 1e). The technology is sometimes referred to as plasma polymerization, as the polymer formation is induced by the plasma state. In this approach, the air in the reaction chamber is first evacuated by vacuum pumps, and then a chemical vapor is introduced into the chamber. A high frequency electrical signal is applied on the electrodes, inducing a plasma. Plasma is the fourth state of matter in which the molecules are ionized and produce a glowing light. The energized molecules react with each other and react with the substrate surface, the substrate surfaces are energized as well in the plasma. This reaction forms a polymer coating on the substrate. A lot of different type of hydrophilic or hydrophobic polymers can be formed using this powerful technique.

Equipped with a multitude of coating technologies, we can utilize a multifaceted approach (Figure 2) to develop and optimize surface coatings for diverse medical devices. Firstly, based on the desired functionalities of the coating, such as hydrophilicity or hydrophobicity, lubricity, biocompatibility, optical clarity, and permeability, we can select certain coating materials that will give rise to the desired properties. Secondly, based on the knowledge of material type of the devices to be coated, especially the surface energies and functional groups of the substrates, we can select certain chemistries for creating a strong adherence of the coating on the substrate surface. Thirdly, based on the geometries of the devices, such as simple plaques or tubes versus complex structures containing curved surfaces and corners, and whether external or internal surfaces need to be coated, we can select certain coating processes that are capable of creating a uniform coating on all the surfaces that need to be coated, and avoiding surfaces that do not need to be coated. Additionally, we need to take care that the coating chemistries and processes will not result in undesirable side effects to the devices. For example, a coating chemistry that results in haziness on the surfaces is not suitable for coating optical devices, a coating process that damages biomolecules such as enzymes is not suitable for coating biosensors that contains sensing enzymes.

Since each coating problem is very unique in characteristics,

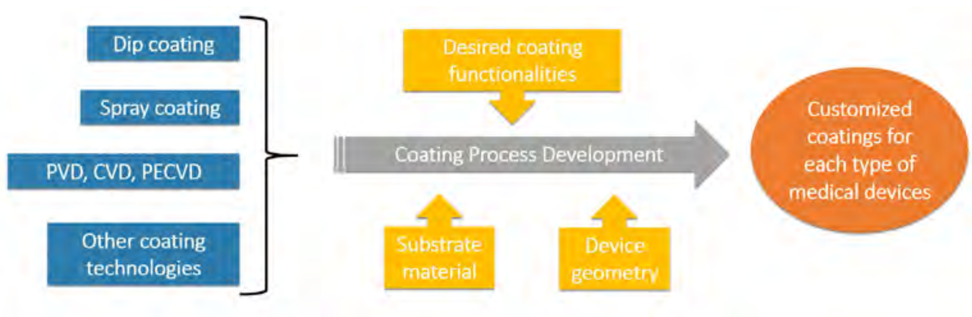


Figure 2

coating technologies need to be customized to solve a specific coating problem, and the coating processes need to be optimized for each type of medical devices. Based on the type of medical devices, the desired coating functionalities, the nature of substrate materials, and the geometries of the surfaces to be coated, we design the optimal approach to coating, using a combination of coating technologies. The followings are a few case studies that demonstrate our multifaceted approach.

Case study 1: Coating designed for hydrophilization of silicone and other hydrophobic substrates

Many medical devices use silicone and other hydrophobic materials, and need a hydrophilic coating to change the surface property. For example, silicone materials are widely used in medical devices due to many nice properties such as elasticity, biocompatibility, optical clarity and high oxygen permeation. Silicone surface is hydrophobic, while in many applications, such as in contact lenses, a hydrophilic surface is needed. It is difficult for a hydrophilic coating to adhere well on the silicone surface, as silicone substrates have low surface energy.

Plasma or corona treatments are very effective and have been the standard methods in making the silicone substrates hydrophilic. However, simple plasma / corona surface modification is not stable, as the hydrophobic group will migrate to the surface and make the surface

Continued on page 4

continued from page 3

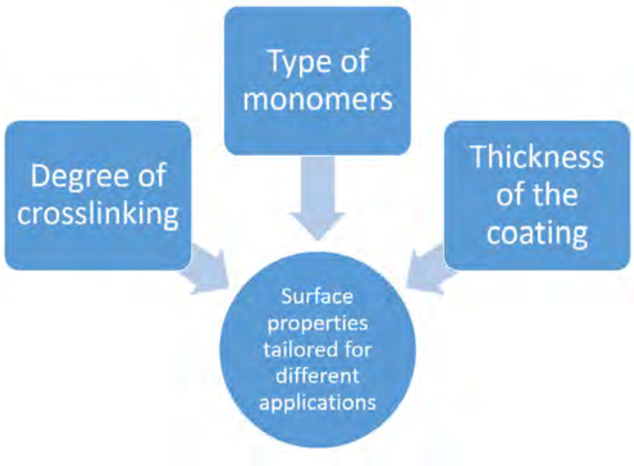


Figure 3

hydrophobic again. This phenomenon is known as hydrophobic recovery.

We have developed and optimized a PECVD method to create a durable, optically clear, hydrophilic coating for silicone substrates. In this approach, a polymer coating is grown and cross-linked on the surface during the PECVD process, this results in high durability. In the PECVD method, we are able to select the type of monomers for coating, and control the cross-linking density and coating thickness. By doing DOEs of these critical parameters, we are able to optimize the coating for a specific application (Figure 3).

Using the PECVD process, we are able to create a highly durable, optically transparent, hydrophilic coating (MediShield ™ Hydrophilic Coating) on silicone surface. The coatings have been used to make silicone contact lens surface water-like, prevent "tear breaking", and improve users' comfort level. Some of the characteristics of coating include (1) it is a one-step, solvent-free coating process; (2) it is a covalent, durable hydrophilic coating on hydrophobic materials; (3) it is an optically clear coating, no interference with light transmission through coated surfaces; (4) it is biocompatible; and (5) it has proven long term stability on silicone substrates (Figure 4).

Case study 2: Coating designed for reducing protein binding and cell attachment

For implantable / indwelling medical devices and biosensors, biofouling is a major problem that can lead to device malfunctioning, foreign body reaction, and infection. The biofouling process starts with protein binding to the surface, followed by cells attaching to the proteins on the surface. To mitigate biofouling, a hydrogel coating is used to resist protein binding, as protein binding is minimized, cell attachment is reduced as a result, and biofouling is therefore mitigated. This will allow the devices to work better and safer *in vivo*.

One challenge of the hydrogel coating approach is the adherence of the hydrogel onto the device surfaces. Many medical devices contain materials with inert surfaces, therefore it is important to develop a strategy to create a tightly-adhered, antifouling, biocompatible coating on materials that are generally hard to adhere.

Our approach is to use PECVD method to create a functionalized surface (MediShield™ Biocompatible Coating) on inert substrates, allowing the covalent attachment of the antifouling hydrogel. We tested this coating strategy on a variety of substrate materials. Figure 5 shows the results of some representative materials, including polymers like polycarbonate, polyurethane and Nylon,

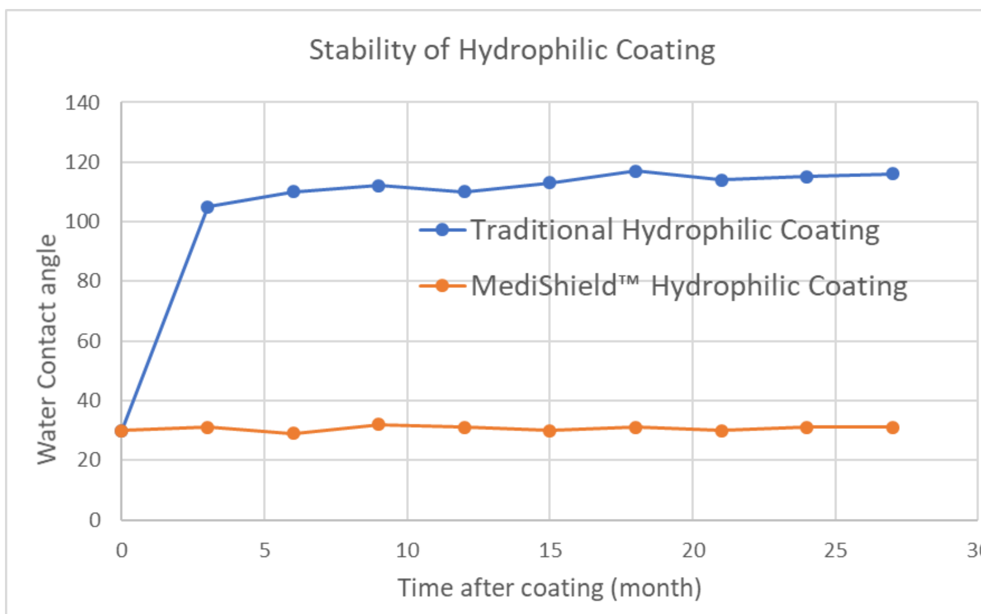


Figure 4

Continued on page 5

continued from page 4

and metals like stainless steel, titanium and platinum. Protein binding on uncoated and MediShield™ coated substrates is characterized by the IgG-HRP model system. The amount of IgG-HRP protein binding on the surface is quantitated by an ELISA type method using TMB colorimetry. For each material, including platinum, we are able to significantly reduce the amount of protein binding on the surface.

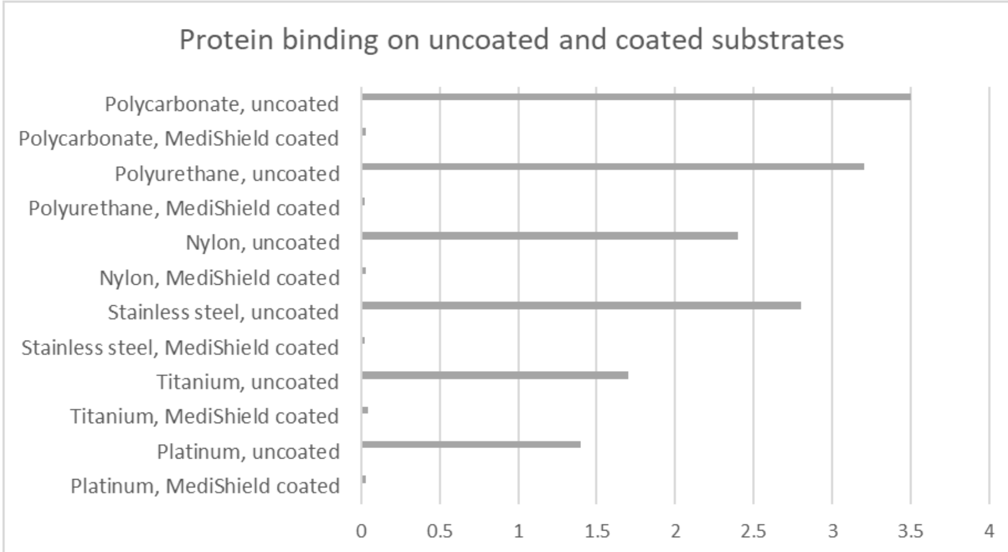


Figure 5

We have tested the MediShield™ Biocompatible Coating for the ability to resist cell attachment. In this experiment, uncoated and coated substrates are incubated with chondrocyte cell culture for two weeks. On the uncoated substrate, cells attached, grew and propagated on the surface. While on the coated substrate, cells did not attach, and the surface remained clean for the whole time (Figure 6).

We have also tested the MediShield™ Biocompatible Coating for the ability to resist bacterial adhesion. This

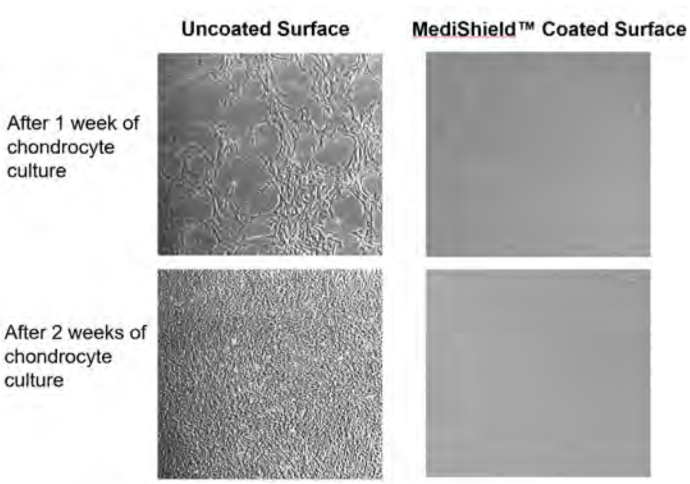


Figure 6

experiment is performed according to ISO 22196. Two types of bacteria were tested: S. aureus and E. coli. In both cases, no detectible bacteria were found to adhere on MediShield™ coated surface (Figure 7).

Case study 3: Coating designed for increasing the lubricity of inner surface

For certain medical devices, a lubricious coating on the inner surface of a device is needed. One example of a device is the cartridge used for delivering intraocular lenses (IOL) during cataract surgery. The IOL needs to be squeezed through a narrowed tube, so that it can enter a small opening into the eye during the surgery. A lubricious coating is required on the inner surface of the tube to minimize the friction force during injection and prevent the IOL from being damaged due to high friction force.

For coating the inner surface of tubes, it is challenging to use UV chemistries since the UV light cannot reach the inside of the tube efficiently; similarly, it is challenging to use common plasma method to activate the inner surface of shallow tubing, as it is hard for the plasma to diffuse into the shallow tubing. Based on the types of substrate materials and geometries of the tubing, we have developed efficient methods to apply lubricious coating, using either a primer coating or a modified plasma coating setup that is specifically designed for coating the inner surface of tubing.

Figure 8 shows the comparison of injection friction force with or without lubricious coating. Without lubricious coating, a high friction force occurs during the injection of the IOL. This often results in the damage of the IOL. With lubricious coating, the friction force during injection is greatly reduced. The IOL is able to smoothly exist the delivery tubing without being damaged.

Continued on page 6

A Multifaceted Approach to Develop and Optimize Surface Coatings ...

continued from page 5

Case study 4: Coating designed for glucose sensors and other biosensors

Implanted or wearable biosensors, such as glucose sensors, need biocompatible coatings as the outmost layer to minimize biofouling in the body, and sometimes also need permeability control coatings to control the rate of permeation of different molecules. One example is glucose sensors used in continuous glucose monitoring (CGM) technologies.

CGM technologies have revolutionized diabetes care, allowing patients to monitor glucose level constantly without frequent finger pricks. The heart of CGM is a glucose sensor in constant contact with body fluids, allowing glucose level to be detected. In order to ensure accurate measurement, some glucose sensors require a glucose limiting membrane (GLM) coating that can regulate the influx of glucose to the sensing layer.

To create effective and controllable GLM coatings and coatings for controlling the permeation of other molecules, we use a selection of polymers that possess desired pore sizes and adjustable hydrophilicity. By fine-tuning the coating parameters, we have developed GLM coatings that are able to control the permeation of glucose and improve the accuracy of glucose sensing. Figure 9 shows the performance of our glucose sensor GLM coatings. Uncoated glucose sensor has limited linearity range due to the high glucose to oxygen ratio in the physiological environment. Our GLM coatings are able to restrict glucose and allow maximum oxygen diffusion toward the sensor. The level of glucose restriction can be controlled precisely in our coating process. As the GLM coating becomes more restrictive for glucose permeation (In Figure 9, GLM B is more restrictive than GLM A, and GLM C is more restrictive than GLM B), the linearity of the glucose detection becomes better.

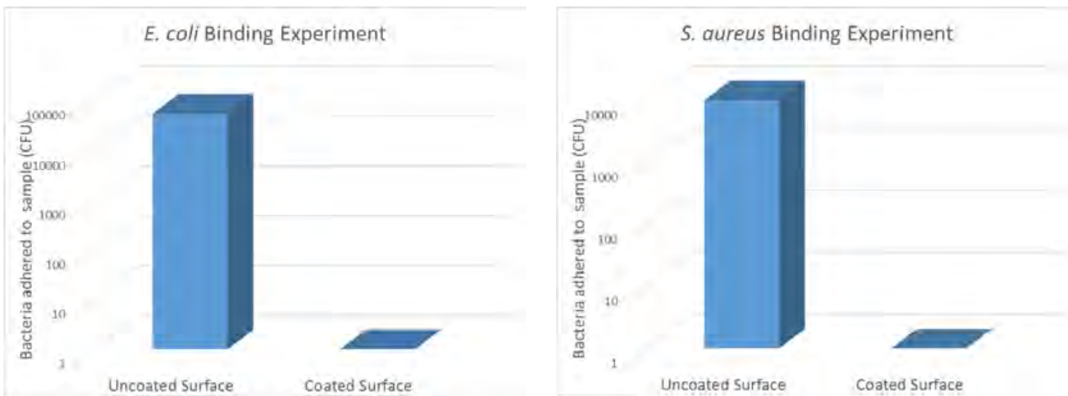


Figure 7

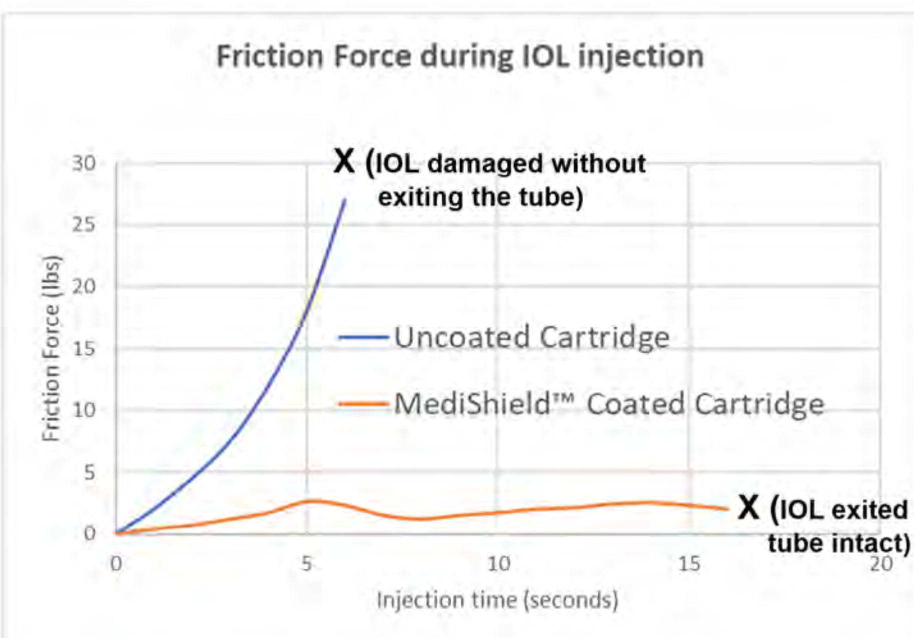


Figure 8

In addition to the GLM coatings, we have also developed biocompatible coatings for biosensors. The biocompatible coating layer does not restrict the permeability of glucose and other molecules, and is able to reduce protein binding and biofouling.

In summary, the case studies show that there is no universal coating approach for a diverse range of medical devices. A multifaceted coating development approach allows us to successfully develop highly customized optimal coatings for various medical devices. Focusing on the characteristics of each type of medical devices allows us to optimize the coating for the devices.

The 31st Annual BioInterface Workshop & Symposium Virtual September 2021

During our event you will be enriched by the science and the **high quality of interaction that is fostered by the unique blend of industry, academic, regulatory and clinical attendees.** There will be opportunities to connect, share and learn on our Surfaces in Biomaterials app.

Registration will give you access to all sessions throughout the month of September.

Event Highlights

- Workshop: Medical device pioneers
- Seven Technical Sessions
    - Tissue engineering, clinical translation, host-biomaterials interactions and surface modifications
    - Biomedical implants
    - Additive manufacturing commercialization strategies
    - Bioinspired solutions to clinical problems
    - Ophthalmic / Ocular
    - Analytical characterization of medical devices
    - Drug delivery
- Student pitch competition
- Virtual Exhibit hall

Visit https://www.surfaces.org/BioInterface-2021 for the complete program (updated regularly). Register online—full registration is $100 for members and $150 for nonmembers.

Thanks to our Sponsors!

GOLD SPONSORS

Medtronic

GORE

SILVER SPONSOR

plasmatreat

Coatings: A publication to complement the resources you gain from attending BioInterface

Coatings is an international, peer-reviewed and open access journal devoted to the science and engineering of coatings, thin and thick films, surfaces and interfaces, which is published by MDPI online monthly. Check out this website to have a general view of our journal: https://www.mdpi.com/journal/coatings

Nanostructured Titanium Surfaces for Improved Hemocompatibility

Vignesh K Manivasagam[1], Roberta M Sabino2, and Ketul C Popat1,[2,3]

1. Department of Mechanical Engineering, Colorado State University, Fort Collins, CO 2. School of Advanced Materials Discovery, Colorado State University, Fort Collins, CO 3. School of Biomedical Engineering, Colorado State University, Fort Collins, CO

The use of implantable blood-contacting devices has increased in recent years and the need to improve the efficiency of these devices is at its pinnacle [1]. Blood-contacting implants are prone to thrombosis due to improper interactions with blood proteins, platelets, and cells [2]. The initial event that happens when medical device surfaces come in contact with blood is the adsorption of blood plasma proteins, such as fibrinogen and albumin, which can lead to a complex series of reactions, also called coagulation cascade [3]. The coagulation cascade is then responsible for the platelet adhesion and activation on the foreign surface. Once activated, platelets start to form a platelet-immune complex, which provokes leucocyte attachment to the surface, ultimately leading to thrombus formation and failure of the device [4]. To prevent this problem, patients need to take anticoagulant medications, which can cause serious bleeding effects. Therefore, researchers have been trying to develop hemocompatible surfaces that are able to prevent blood clotting.

Studies have shown that blood protein adsorption, platelet adhesion, and activation, and leukocyte complex formation can be averted by modifying the surface morphology, chemistry, wettability, and mechanical properties. For instance, hydrophilic surfaces tend to reduce protein adsorption due to the stronger water-surface interaction [5]. Previous studies have shown promising results where nanostructured surfaces have led to better hemocompatibility when compared to nontextured surfaces [6]. Titanium and its alloys have been widely used in blood-contacting devices, such as cardiovascular stents, prosthetic heart valves, and circulatory assist devices due to their outstanding biocompatibility and mechanical properties [7]. However, even titanium-based surfaces can cause the complications above mentioned when in contact with blood.

In this study, hydrothermal treatment with sodium hydroxide and hydrochloric acid was used to develop three unique surface morphologies on titanium [8]. Hydrothermal treatment is a simple technique, where the substrates are immersed in the working solution and placed inside a hot oven for the desired amount of duration [9]. This process has the capacity for scalability due to the ease of setup and cost. The experiment parameters such as treatment duration,

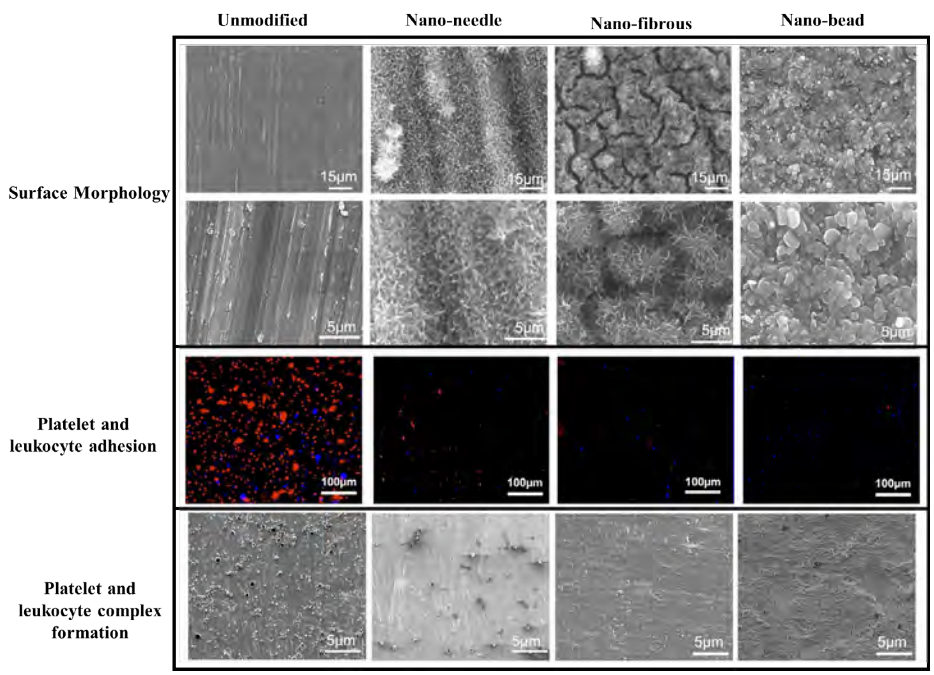


Figure 1: Morphology of different nanostructured surfaces can be seen in the SEM images. Platelets (Red) and leukocyte (blue) adhesion can be seen on the different surfaces in the fluorescence images. Activated platelet (dendrite formation), leucocyte adhesion and platelet-leukocyte complex formation on different surfaces can be seen in the SEM images [8].

solution concentration, and temperature were varied to develop different surface morphologies. These surfaces were further characterized for wettability, morphology, chemistry, and crystallinity. The results showed that there is a significant difference in surface morphology on the surfaces, with nano-needle, nano-fibrous and nano-bead structures developed after the different treatments (Figure 1). Wettability on these three unique surfaces was significantly different, the advancing contact angle was

Continued on page 9

Nanostructured Titanium Surfaces for Improved Hemocompatibility

continued from page 8

32°,13°, and 64° for nano-needle, nano-fibrous, and nano-bead, respectively. This is due to the difference in surface morphology and chemistry. The nanofibrous surface was the most hydrophilic surface.

Hemocompatibility was evaluated after studying protein (fibrinogen and albumin) adsorption, platelet and leukocyte adhesion and activation, and whole blood clotting assay. The results indicated that the nanofibrous surface, despite being the most hydrophilic surface, adhered less protein and platelet (Figure 1). This is mainly because of the surface morphology since the fibrous surface has less surface area of contact for the proteins to adhere. Nano-needle and nano-bead surfaces showed similar fibrinogen adhesion and it was higher than the nanofibrous surface adhesion due to their increased surface area available for adhesion. A similar trend of lower platelet adhesion and activation was seen on the nanofibrous surface. Studies have shown that lower fibrinogen on the surface can reduce platelet adhesion and activation [10]. Nano-needle and nano-bead surfaces had higher platelet adhesion due to the increased fibrinogen adhesion assisting platelets to adhere. In agreement with these results, the whole blood clotting results showed less clotted blood on the nanofibrous surface compared to nano-needle, nano-bead, and unmodified titanium surfaces. Thus, this study shows that surface wettability is essential to understand the interaction of blood with the implant. However, the surface morphology plays a major role in dictating protein, platelet, and leukocyte adhesion and activation.

Figure 1: Morphology of different nanostructured surfaces can be seen in the SEM images. Platelets (Red) and leukocyte (blue) adhesion can be seen on the different surfaces in the fluorescence images. Activated platelet (dendrite formation), leucocyte adhesion and platelet-leukocyte complex formation on different surfaces can be seen in the SEM images [8].

References

[1] I.H. Jaffer, J.I. Weitz, The blood compatibility challenge. Part 1: Blood-contacting medical devices: The scope of the problem, Acta Biomater. 94 (2019) 2–10. doi:10.1016/j.actbio.2019.06.021.

[2] R.M. Sabino, K. Kauk, S. Movafaghi, A. Kota, K.C. Popat, Interaction of blood plasma proteins with superhemophobic titania nanotube surfaces, Nanomedicine Nanotechnology, Biol. Med. 21 (2019) 102046. doi:10.1016/j.nano.2019.102046.

[3] R.M. Sabino, K. Kauk, L.Y.C. Madruga, M.J. Kipper, A.F. Martins, K.C. Popat, Enhanced hemocompatibility and antibacterial activity on titania nanotubes with tanfloc/heparin polyelectrolyte multilayers, J. Biomed. Mater. Res. - Part A. 108 (2020) 992–1005. doi:10.1002/jbm.a.36876.

[4] K. Bartlet, S. Movafaghi, A. Kota, K.C. Popat, Superhemophobic titania nanotube array surfaces for blood contacting medical devices, RSC Adv. 7 (2017) 35466–35476. doi:10.1039/C7RA03373G.

[5] L.-C. Xu, J.W. Bauer, C.A. Siedlecki, Proteins, platelets, and blood coagulation at biomaterial interfaces, Colloids Surfaces B Biointerfaces. 124 (2014) 49–68. doi:10.1016/j.colsurfb.2014.09.040.

[6] V. Leszczak, K.C. Popat, Improved in Vitro Blood Compatibility of Polycaprolactone Nanowire Surfaces, (n.d.). doi:10.1021/am503508r.

[7] A.M. Khorasani, M. Goldberg, E.H. Doeven, G. Littlefair, Titanium in biomedical applications—properties and fabrication: A review, J. Biomater. Tissue Eng. 5 (2015) 593–619. doi:10.1166/jbt.2015.1361.

[8] V.K. Manivasagam, K.C. Popat, In Vitro Investigation of Hemocompatibility of Hydrothermally Treated Titanium and Titanium Alloy Surfaces, ACS Omega. (2020) acsomega.0c00281. doi:10.1021/acsomega.0c00281.

[9] J. Vishnu, V. K Manivasagam, V. Gopal, C. Bartomeu Garcia, P. Hameed, G. Manivasagam, T.J. Webster, Hydrothermal treatment of etched titanium: A potential surface nano-modification technique for enhanced biocompatibility, Nanomedicine Nanotechnology, Biol. Med. 20 (2019) 102016. doi:10.1016/j.nano.2019.102016.

[10] L.C. Xu, J.W. Bauer, C.A. Siedlecki, Proteins, platelets, and blood coagulation at biomaterial interfaces, Colloids Surfaces B Biointerfaces. 124 (2014) 49–68. doi:10.1016/j.colsurfb.2014.09.040.

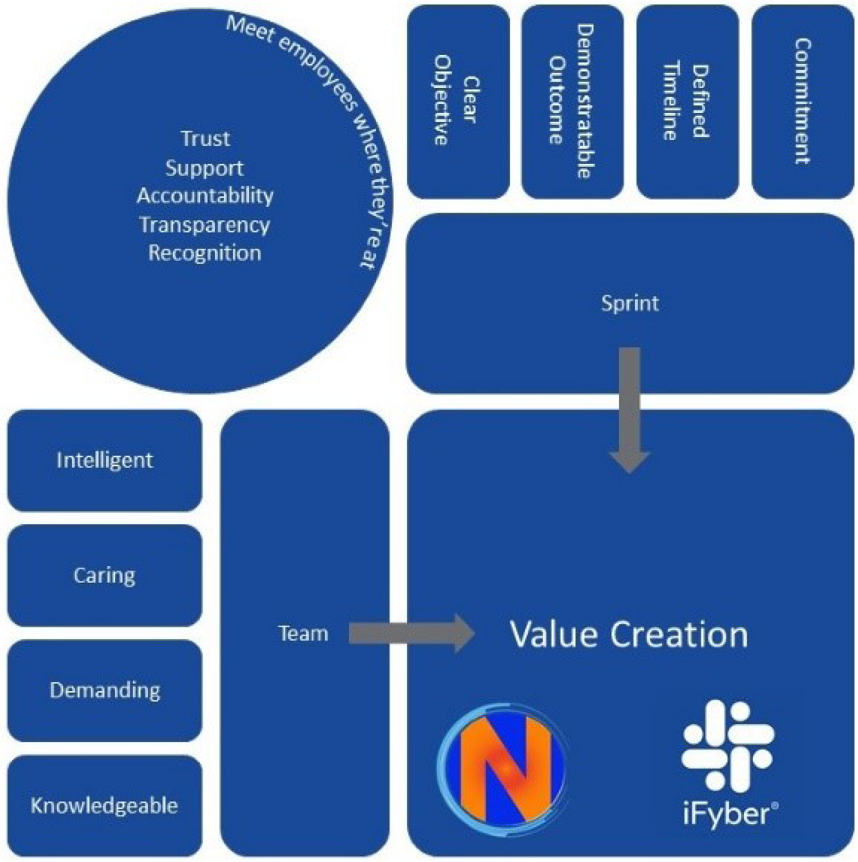
NovaSterilis/iFyber: 'Back to Better'

When asked to write this article, we were told to focus on something new and interesting. Our most interesting project over the past year was the transformation of our business. This isn't a normal SurFACTS article, but we hope you find it thought provoking.

NovaSterilis and iFyber have a successful history of collaborating on sterilization projects. NovaSterilis providing supercritical CO2 sterilization and iFyber performing pre-clinical CRO assessments at the interface of chemistry, biology, and materials science. We were set to merge on March 31, 2020. In the blink of an eye, the landscape changed. We completed the merger, but nothing else was as we imagined in 2020.

We have spent a great deal of time over the past 16 months analyzing how our business would survive in the turbulence of the COVID-19 pandemic. Our original goal was to find a path that would allow us to return to normal. By June 2020 we realized that the future could be better, so we coined the phrase "back-to-better." Below are some highlights of the 12-month journey to better.

By mid-March, PPE supply issues were occurring globally. On March 18 we performed proof-of-concept sterilization testing on N95 respirators. Our original intent was to simply publish a whitepaper on a current event. We did not believe that reprocessing a $0.40 disposable mask was viable long-term. In the end we were right, but we did not appreciate the magnitude of what our world was about to experience.



We were approached to help evaluate ethylene oxide (EtO) reprocessing of N95 respirators for Weill Cornell Medicine. It struck us that if people were so desperate that they thought EtO was a viable solution regardless of the health risks, we had to act. We were faced with a challenge and an opportunity: NovaSterilis didn't have the people, experience, or application knowledge necessary to meet the need. We are an industrial sterilization supplier, not a healthcare sterilization supplier.

Although the merger had not yet closed, NovaSterilis and iFyber came together the weekend of March 22 and operationally reinvented ourselves. We embedded a team of six from iFyber into NovaSterilis and set out to file an Emergency Use Authorization (EUA) for decontamination of N95 respirators. We would need to run tests and gather data in short order and most of what we needed to do was new to us (e.g., NIOSH, TSI Porta Count, and SARS-CoV-2 viral testing). Despite these challenges, we successfully submitted an EUA application on April 11, just 24 days from proof-of-concept testing.

In parallel with the regulatory effort, our engineering team readied four Nova2200s for installation in New York City (a four-month effort completed in one month). Our team was on the ground at NYC hospitals from April–June, to ensure a smooth installation and training heightening our commitment to the cause.

Continued on page 11

Medical Grade Silicone for Implantable Drug Delivery: How Silicone Interacts with API

Silicone has proven to be an effective excipient for active pharmaceutical ingredients (API) for implantable drug delivery, offering a number of well-established advantages—so well-established that it's been the material of choice for many implantable devices for more than 60 years.

One of the reasons silicone is chosen so often as the best excipient for implantable devices is its ability to form a permeable matrix structure when cured—this creates space for API to inhabit and gradually pass through to the delivery point.

Methods for silicone to interact with API

There are a number of options available to the industry when it comes to biocompatible silicones. An important consideration before a manufacturer selects materials based on the features that they require, is which method will be used to treat the silicone in order for it to interact with the API.

Whether you are choosing a full blending method prior to cure, curing the silicone to act as a reservoir, or using a solvent-API solution to impregnate a cured componen—each method has its own impact on the integrity of the silicone and present different challenges for the development process. With this in mind, how can manufacturers choose the best silicone material for their implantable drug delivery devices?

HCR, LSR or Adhesive?

High Consistency Rubber/Heat Cured Rubber (HCR) has a claylike consistency in its raw state, giving it a stronger green strength that enables the holding of a shape while heat is being applied to cure the material. Typically, advantages include higher tensile strength, elongation, and tear strength. When using HCRs, manufacturers can use the extrusion process in order to make tubes or profiles and this continuous process also allows for automated cutting that can produce large quantities of simple parts quickly.

Continued on page 12

NovaSterilis/iFyber: 'Back to Better'

continued from page 10

This experience created significant long-term value for all our stakeholders through disruptive thinking. Although the disruption included invention, it was not the primary value creator. Operational implementation, project management, supply chain management, and user experience were all equal contributors to the success.

Disruptive thinking requires adrenaline. Adrenaline is best used in short sprints, which in the context of business can be measured in days and weeks but not months. Sprints are not a new concept—they have been used in the software industry for years. The Value Creation Sprint concept was necessary for our business to operate successfully in 2020 because during this turbulent time we needed a clear objective, a defined period of execution, and a demonstrable outcome.

Our customer satisfaction and success are dependent on the quality of our team. We have always strived to hire caring, demanding, and knowledgeable people who have complimentary intelligences throughout our company. Our back-to-better path has been built by a team that believed, vendors that bought in to our mission, customers that needed the outcome, and a regulatory body that understood the current and future value of our technology. As we move through 2021 and beyond, finding Value Creation Sprints that fit these elements is critical for our team to be successful.

What has this transformation done for NovaSterilis and iFyber in just one year? NovaSterilis has grown in prominence, which has led to more public presentations, development partnerships, R&D test units leased, and commercial systems sold. The impact on iFyber has been more significant with the launch of a new business service—regulatory/quality consulting, and a new product—Embedded Value Creation Teams.

The NovaSterilis/iFyber corporate culture is forever changed—we have authored a new operations strategy that has revamped our organization chart. We are committed to meeting our team members where they are at in their lives, which has reduced stress and increased satisfaction. There is no taking away the brutality of the pandemic, but from it, we are excited to have found back-to-better!

Excellence in Biomaterials Science Award by the Surfaces in Biomaterials Foundation Winner: Dr. William Lee

At a young age Dr. William Lee remembers his grandmother complaining that of her 12 children and 50 plus grandchildren, none had become a doctor. This memory resonated with him for years which led him to earning his B.Eng. and M.Eng. in Chemical engineering, and his Ph.D. in chemistry and biotechnology from the University of Tokyo, Japan, and going on to having a successful career in biomedical and chemical engineering field. While Dr. William Lee is not practicing medicine or a family physician like perhaps his grandmother had envisioned, he is still able to honor his grandmother's memory through his accomplishments and contributions to the biomedical field.

Dr. Lee is this year's recipient of the Excellence in Biomaterials Science Award by the Surfaces in Biomaterials Foundation (formerly known as the Excellence in Surface Science Award). He rightfully earned this award with his significant contributions to the biomaterials science field with his extensive 30 years of experience in surface treatment technology, and product design and development as an engineer, executive and entrepreneur.

Dr. Lee is the VP of R&D and Regulatory Affairs at AST Products, Inc. and the president of ICARES Medicus, Inc. (Taiwan). Prior to AST Products, Dr. Lee had his working experiences at the Japan Atomic Energy Research Institute, Harvard Medical School/Massachusetts General Hospital, Japan's largest venture capital firm, JAFCO, and a startup company that he founded, eMembrane, Inc.

eMembrane, Inc was founded almost 21 years ago during a time that Dr. Lee was struggling to put meals on the table, but because of his perseverance his company continues to thrive. When asked about his personal and

professional life goals, he answered, "Professionally, I would like to set the path of our companies to reach its 100th year. Personally, continue to do what I like and never have any regrets until the last second I leave this world; to be the only 'me' in this world." There are no truer words to live by. Dr. Lee is constantly working on his next piece to this puzzle called life and "learning about the real-world problems and innovations" through

Continued on page 13

Medical Grade Silicone for Implantable Drug Delivery

ontinued from page 11

Liquid Silicone Rubbers (LSRs) are designed for molding applications, most commonly injection molding. For implantable drug delivery devices, LSRs can be full standalone devices or combined with other substrates via over-molding. The main advantage LSRs offer is the capability for the widest range of component design potential due to the ability to flow into much smaller geometries than HCRs and the fact that injection molding can be fully automated. Additionally, mixing API into LSRs is simpler, without the necessity for creating a masterbatch.

Adhesives serve more as a complementary addition to implantable drug-device substrates. They perform multiple roles, including bonding elements together and being able to elute an API. They can be deposited extremely accurately using manual or automated dispensers, making them ideal for a cure-in-place drug delivery element, as well as ensuring that the correct amount of silicone eluting an API is placed where it is needed.

Elkem Silicones works closely with customers in various industries across the globe to provide innovative silicone solutions. Our team has developed a full range of HCRs, LSRs, and Adhesives to meet the strict requirements for implantable drug delivery devices.

Discover our innovative solutions for drug delivery and other medical grade silicones backed by Elkem's Silbione™ brand for high quality, clean manufacturing, and biocompatibility support. Contact us through our website or call 866-474-6342.

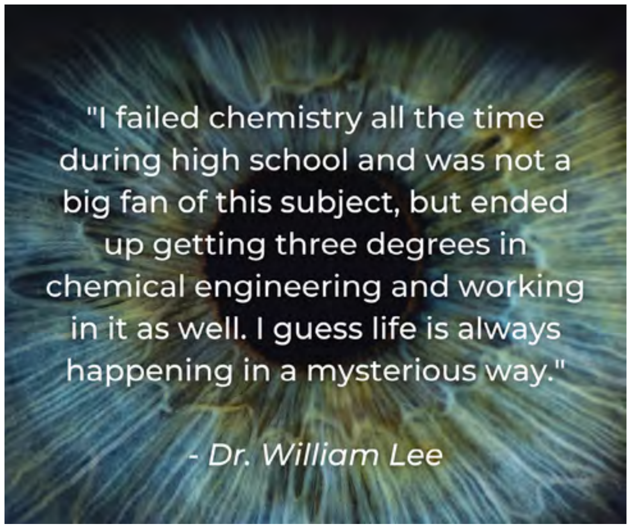
Excellence in Biomaterials Science Award by the Surfaces in Biomaterials Foundation Winner: Dr. William Lee

continued from page 12

his membership with the Society of Biomaterials.

Dr. Lee has stayed true to himself through it all and kept his personal goal in the foremost of his mind. “When I applied for a post-doctoral training in the U.S. after my Ph.D. degree at the University of Tokyo in Japan, the last letter (the sixty-sixth) was the only one that got me in to Harvard Medical School/ Massachusetts General Hospital to do research in gene therapy, which is a totally different subject than what I had been done at my Bachelor’s, Master’s and Ph.D. studies. I guess my perseverance or stubbornness worked like a charm that time.”

Dr. Lee’s perseverance and stubbornness made it possible to achieve these accomplishments in a fraction of a lifetime. He led a team to obtain 20 CE-marking approvals and four FDA- 510(k) clearances for medical devices. He is the sole inventor of the LubriMATRIX™ surface treatment technology that has been applied onto more than 5 million intraocular lens (IOL) injectors annually to enable safe and precise delivery of the IOL into the cataract patient’s eye, and was awarded the 2020 Heroes of Chemistry Award by the American Chemical Society (ACS) for such contribution to improve the lives of people worldwide. He was also an awardee for the 2018 GOOD DESIGN® Award by The Chicago Athenaeum Museum of Architecture and Design and the 2008 North America Technology Innovation of the Year Award by Frost & Sullivan. Not to mention, he is fluent in seven languages including English, Japanese, Mandarin and Malay, and a serial Japanese calligraphy awardee in Japan for the last continuous seven years annually.



Congratulations, once again to Dr. William Lee for all of your achievements and this year’s Excellence in Biomaterials Science Award by the Surfaces in Biomaterials Foundation!

Follow the Surfaces in Biomaterials Foundation on Social Media!

Like us on Facebook: click here

Visit our LinkedIn page here

Follow us on Twitter: click here

Surfaces in *Biomaterials* Foundation

LOGO CONTEST!

Submit a sketch of your logo idea!

Submission deadline: Oct. 1
Email to: info@surfaces.org

We'll launch the new logo in 2022!

Twitter
@SurfacesIBF

Facebook
@Surfacesdotorg

LinkedIn
@company/surfaces-in-biomaterials-foundation

SurFACTS in Biomaterials is the official publication of the Foundation and is dedicated to serving industrial engineers, research scientists, and academicians working on the field of biomaterials, biomedical devices, or diagnostic research.

Surfaces in *Biomaterials* Foundation

Thank You to OUR MEMBERS