

Advanced Coatings and Surface Technology Alert

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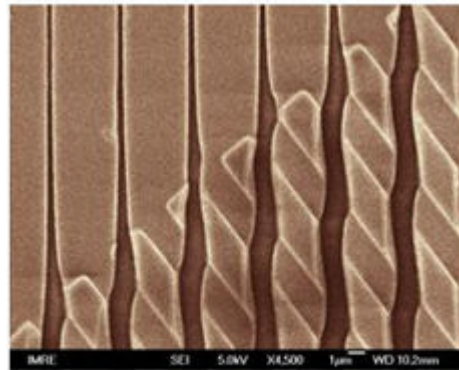
Emerging Technologies :: R&D Trends :: Technology Innovation :: Strategic Analysis

[TUNING ANISOTROPIC WETTABILITY OF POLYMERS VIA SEQUENTIAL IMPRINTING](#)
[MANUFACTURING TECHNOLOGIES FOR NANOCOMPOSITE CERAMIC STRUCTURAL MATERIALS AND COATINGS](#)
[NOVEL NANO-BASED MATERIAL SYSTEM TO IMPROVE SLURRY EROSION RESISTANCE FOR INDUSTRIAL OPERATIONS](#)
[NOVEL ANTIMICROBIAL SURFACE COATINGS FOR FOOD INDUSTRY](#)
[BIONI HYGIENIC COATINGS FOR BUILDING APPLICATIONS](#)

TUNING ANISOTROPIC WETTABILITY OF POLYMERS VIA SEQUENTIAL IMPRINTING

Thermal nanoimprint lithography (NIL) has been known to researchers as being a highly versatile technique for the fabrication of two-dimensional (2D) and three-dimensional (3D) surface structures. As such, a research team at the Institute of Materials Research and Engineering (IMRE) in Singapore has been carrying out research in the field of NIL for several years. The team's focus has been on developing and fine-tuning the NIL process in order to fabricate complex 3D structures, among such structures are the hierarchical 3D structures shown by many biological systems.

Their research has so far resulted in the capability to tailor engineer surface properties, specifically the surface wettability of polymers through surface structuring, while bypassing chemical treatments. Since complex hierarchical structures are not easily achievable using the conventional photolithography technologies, the researchers settled on thermal NIL technology as it had several advantages over competitive technologies such as; (1) maintaining the chemical nature of the polymer; (2) possibility of imprinting on a wide range of engineering materials; (3) nanoscale pattern resolution at relatively low-production costs; (4) ability to scale up fabrication to a large scale.



Hierarchical structure on polystyrene film
 Picture Credit: Hong Yee Low, IMRE

Thermal NIL technology is based on the thermomechanical deformation of a polymer film above the glass transition temperature (T_g) and at an applied pressure. In this case, hierarchical structures were created by the IMRE researchers via sequential imprinting (an extension of the thermal NIL process), which occurs when secondary and tertiary imprintings are carried out at temperatures below the T_g of a polymer. The IMRE researchers utilized the sequential imprinting technique to fabricate 2D and 3D structures on polystyrene (PS) and poly(methyl methacrylate) (PMMA) films, a process that occurred over a temperature range of 70 degrees C to 130 degrees C.

In this case, the researchers were able to perfect the NIL technique so as to result in anisotropic wettability tuning, meaning liquid droplets will only wet a polymer surface imprinted with such structure, and in one specific direction only. For example, by mimicking

the surface structure of a plant leaf, the IMRE researchers were able to increase the anisotropic wettability of PMMA from 6 degrees to 54 degrees and the wettability of PS from 8 degrees to 32 degrees, and were able to tune the water contact angle of PMMA and PS to nearly 120 degrees, all carried out without any chemical treatment.

The potential applications of tunable wettabilities are many-folds, as pretty much any application that requires the control of liquid flow may benefit from the development. In addition, the effect of wettability tuning can be applied to a wide range of polymers including thermoplastics and thermosets. Examples of applications that the IMRE researchers are exploring now are: (1) substrate for controlling cell proliferations, (2) substrate for controlling ink spreading in printing process and fluidic channels for "lab-on-chip" devices. Overall, the technique may find potential applications in fields such as antifouling, microfluidics, micro- or nanooptics, and so forth.

According to Hong Yee Low, the head of the research group, the most important advantage of the IMRE technique is the ability to use simple 2D patterned molds to obtain complex 3D structures. Nevertheless, there are still limitations to the technique, with the primary limitation being the ability to create surface structures over a large area. Presently, most nanoimprint equipment caters for 2 ft., 4 ft., and 8 ft. wafer sizes. As such, the IMRE technology is ready for application where the imprint area is a 2 in. wafer size, with the next phase being a scale-up to 8 in. wafer sizes. As the ability to perform roll-to-roll nanoimprinting is important for applications involving coating films, thus the IMRE researchers are also looking into the possibility of doing roll-roll-imprinting so as to bring the technology closer to commercialization.

IMRE has more than 10 patent applications in the area of nanoimprint lithography, and the research team has already found a few industrial partners, although other opportunities for industrial collaborations are still welcomed.

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MANUFACTURING TECHNOLOGIES FOR NANOCOMPOSITE CERAMIC STRUCTURAL MATERIALS AND COATINGS

In the last few years, nanocomposite structural materials and coatings have been widely explored by several research groups at the laboratory scale. Due to their high-performance features, these nanocomposite materials have gained special interest now. Therefore, there is a need of engineering technologies for nanocomposite-based product development using nanopowders in the field of compounding, forming, and shaping under suitable thermal processing and sintering. In spite of several engineering studies on the properties of the materials, industrial product development and suitable manufacturing process are still underdeveloped. This is basically due to their extremely high hardness, toughness, and strength that most of these novel materials are not able to be precision machined at a reasonable cost. Therefore a net shape strategy in the manufacturing process chain is indispensable.

To overcome this challenge, Rainer Gadow, professor, University of Stuttgart, and his team have investigated a special feature in materials and developed a suitable manufacturing technology for composite materials with different sizes ranging from micrometer/submicrometer to nano level particles in the powder form. These powders are combined in dual or triple phase materials with unique mechanical, tribological, thermo physical, and electrophysical properties. The composite contains two strategic pillars in which one of the pillars is made of structural bulk materials based on sintered micro-nano composite

materials and the second consist of a layer of composites with high-performance coatings processed by special thermal spray techniques. The significance of this research work is that the newly developed manufacturing process has overcome several challenges experienced using this material in the industrial manufacturing scale. An extensive research led to the indepth understanding of full manufacturing chain including modelling and simulation of the processes and components for different applications. Currently the team is working on manufacturing robot-assisted computer controlled systems.

The materials composites that are developed by the researchers are found to possess potential in the fabrication of biomedical devices, which can be used in osteo- and endoprosthesis, artificial knee and ellbow, and various dental components. Due to their light weightedness ultrahigh-creep resistance at high temperatures, they can be used in the manufacture of structural components for extreme conditions in aerospace applications. Also oxide--nonoxide nanocomposites can be used for electrodischarge machining (EDM) of precision tools. In the next step of development, the researchers are concentrating more on developing ultralight weight nanostructured and sinterable carbon materials for engine components and special tribological applications such as in pumps.

According to Rainer, they have partnered with TTI GmbH, New Materials Technologies, Stuttgart, for technology transfer and industrialization. A recent patent has been issued on high-velocity suspension flame spraying (HVSFS), a process for supersonic fast nanocoating deposition of ceramics, metals, cermets, and bioglasses.

Industrialization of the advanced nano- and composite coatings for new engine components in motor engineering of light weight passenger cars, low-emission truck engines and high-performance racing engines of various types are in currently in progress. However, novel biomedical applications are expected to evolve at a slower pace due to certain procedural setbacks of the various international agencies. Further potential is seen in high-temperature structures for energy conversion systems including fuel cells and power plants and light weight thermo shock resistant low expansion devices for extra terrestrial telecommunication.

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NOVEL NANO-BASED MATERIAL SYSTEM TO IMPROVE SLURRY EROSION RESISTANCE FOR INDUSTRIAL OPERATIONS

Several deposition techniques have been employed to improve slurry erosion resistance in various industrial operations, but there was no significant improvement achieved until researchers from laser cladding services have developed a new technique to improve the performance.

Recently, Yarrapareddy, Laser Cladding Services Ltd., and his team have developed a new nano-based material system using laser-based direct metal deposition (LBDMD) process in order to improve slurry erosion resistance. This is achieved by investigating the resistance to the impingement of solid and liquid particles on the solid surfaces. The nano-based materials system hence developed, contains 5% tungsten carbide (WC) nanoparticles that are agglomerated with nickel-tungsten carbide 60 (Ni-Tung 60) by ball mill operation for slurry erosion resistant applications.

In this process, four material systems are used, which are deposited on 4140 grade steel

substrate coupons using the LBDMD MultiFab system. Three layers of each of the materials system are deposited on the substrate in order to process a sample with 30.4 mm × 25.4 mm × 7.7 mm dimension. These different sized samples with varying dimensions are deposited to suit for their testing under the different impingement angles. Similar deposition profile is used for all the material systems. These material systems are fabricated with a laser beam power of 350 watts to 380 watts and a 1-mm diameter laser spot. Higher laser power is used for the first layer, and lower values are used for the second and successive layers. The linear traverse speed used is 8 mm/s to 10 mm/s, and the powder delivery speed is 8 g/min to 10 g/min with argon as a powder carrier. Each layer is 0.43 mm in height and 1 mm in width. There is about a 40% overlap between the successive melting layers for all depositions in order to get the uniform surface of the built-up layer.

The performance tests on slurry erosion on the LBDMD processed depositions at different impingement angles were done using the abrasive water jet erosion testing machine. From these tests the amount of material removed, depth of penetration, and profile of the formed crater are computed as a function of the abrasive water jet impingement angles. The nano-based materials system exhibited better performance for slurry erosion resistance than the monolithic Ni-Tung 60 depositions on 4140 steels. In order to understand the role of the WC-nano particles' influence on slurry erosion resistance and to understand the characteristic features of erosion surfaces, subsurfaces, and the erosion mechanism, different advanced characterization tools are used.

The developed nanomaterials using the novel LBDMD technique has shown 25% erosion improvement. Eswar said, "the researchers have started with an idea of developing functionally graded materials and then moved onto to the nano-based materials and at present the idea behind this work is to improve the service life of the oil drilling crossover tools and oil drilling components". The potential application areas of these coatings include oil industry, energy and power companies, military and aerospace industries.

According to Eswar, this work was sponsored by National Science Foundation, and Halliburton Energy Services. His present company, Laser Cladding Services, works toward developing and commercializing this technology and materials and improve the process control and process optimization for this kind of materials for different industries.

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NOVEL ANTIMICROBIAL SURFACE COATINGS FOR FOOD INDUSTRY

Originally antimicrobial surface coatings were developed to curb the growth of organisms on moist surfaces. Researchers from the Microbial Food Safety Research Unit based in Wyndmoor, Pennsylvania, are currently researching on antimicrobial surface coatings to evaluate their ability to control microbial growth and prevent biofilm formation. The significant aspect of these novel surface coatings is that they help in preventing the development of biofilms in industrial/medical applications, and they have been widely incorporated into many consumer products as well as in medical devices.

The researchers are at the forefront of identifying potential solutions to the current challenge of commercial end use of the coated materials by industries that includes the food industry on food contact surfaces and nonfood contact surfaces.

This research is likely to lead to the development of coated materials that can potentially be used by the food industry to prevent the growth of pathogens and biofilm formation on food- and nonfood-contact surfaces. Further, the researchers are investigating the synergistic

antimicrobial effects of several other coating materials.

The significance of this research work is to develop coating systems for food contact and nonfood-contact surfaces that will enable protection against microbial contamination. The proposed research work will draw on complementary activities of microbial adhesion and the antimicrobial mechanisms of materials such as silver ion-exchanged glass, silver, copper, and other heavy metal zeolite matrices. These materials are safe for human contact and are very effective against a broad spectrum of microorganisms. There is a need to quantify the antimicrobial efficacy of these materials to provide data needed to focus continued development on the most promising technologies and applications, including use by the food industry. Future work will include optimizing and demonstrating the microbial cleaning characteristics of coating compositions for commercial applications involving various substrates (glass, metals, ceramics, polymers, and painted surfaces).

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BIONI HYGIENIC COATINGS FOR BUILDING APPLICATIONS

Researchers at the Fraunhofer-Institut Chemische Technologie (ICT), Germany, have worked on the aspect of synthesizing and characterizing certain types of nanoparticles that has got to play promising roles in certain selected applications in buildings. Researchers have found that using nanotechnology that combines chemical and intrinsic particle properties good volume, surface, and quantum effects could be attained. Researchers have taken particles of size ranging between 5 nm to 50 nm into considerations for the study.

Problems related to buildings such as the growth of fungi, having an easy to clean surface are issues that needs to be addressed. Fungi growth in buildings is found to cause severe allergic problems leading to a large number of respiratory complaints. Although the use of silver to bring about a biocide effect is well known, the concept of combining nanotechnology with the biocidal property of silver has been found to have better effects. Easy to clean surfaces could be produced by combining silicon dioxide (SiO_2) nano particles with polymer binders for tuning surface structure and energy.

Some of the nano applications in buildings selected by the researchers include biocide surface-treatment of walls and ceilings with nano-silver, easy to clean surfaces, scratch resistant coatings, functional surfaces with adapted heat reflection properties, electric conductive floors, and flame protected surfaces.

The advantage of their nano-silver concept is that good antimicrobial antiviral and antiallergic performance could be reached avoiding human-toxic components. Since vapor pressure of silver (Ag) is not significant, a sustainable solution is found to be possible. In combination with a polymer binder concept the researchers guarantee for nano-safety. Similar technologies can not take advantage of a synergetic concept. Since they can reduce the silver content to a minimum, no change in color in the products will happen.

The researchers have placed a basic patent in Germany and several international application patents and their budget for research and development is about €26 Mio per year.

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[GO BACK TO TABLE OF CONTENTS](#)

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