LITERATURE REVIEW

Haiming Huang et al., (2019) investigated the potential distribution and work function of a graphene surface modified by various types of silanes by first principles quantum mechanical calculations to establish its surface hydrophobicity hierarchy. It is found that the work function relies on the electronegativity of atoms on silane. The localization feature of interaction between silane and the graphene surface is demonstrated by the electron density difference. The work function is demonstrated to be a critical quantity in understanding the surface polarizability and thereby the surface wetting properties. By performing contact angle measurements experimentally using water as the probe fluid, surfaces grafted with different silanes show hydrophobicity variation that is found to follow the reverse trend to that of the proposed surface polarizability obtained through the work function calculation. The work function-dependent contact angle can be fitted with a linear equation.

Sanjay S Latthe et al., (2019) has reported about many technologies . The remarkable non – wetting properties of lotus leaf has hugely occupied the minds of students, researchers and industrialists from last two decades. Due to high contact angle (>150°), water drops readily roll off the lotus leaf surface compiling dirt particles. This self – cleaning lotus effect has found huge attention in daily life. Many surfaces in day-to-day life eventually get contaminated due to the accumulation of dust/dirt or through air pollution. In this study, the suspension of hydrophobic silica nanoparticles was dip and/or spray coated on the body of motorcycle, building wall, mini boat, solar cell panel, window glass, cotton shirt, fabric shoes, paper (currency notes), metal, wood, sponges, plastic and marble. Every coated substrate exhibited superhydrophobicity with water contact angle nearly 160° and sliding angle less than 6°. The self-cleaning performance of the

superhydrophobic coating applied on various substrates was thoroughly evaluated.

Liquid mobility on super-wettable materials is of interest for enhanced heat transfer, self-cleaning, anti-fouling, anti-icing, water-harvesting, and oil–water separation. **Songnan Zhang et al., (2019)** has reviewed different mechanisms related to liquid mobility on super-wettable materials, encompassing some classical wetting theories and liquid transport behaviors observed on biological surfaces with special textures. Then, the different categories of liquid behaviors on super-wettability materials were summarized, focusing on recent progress on vertical motion (droplet self-propelling and bouncing), horizontal transportation (transportation on one-dimensional (1D) and two-dimensional (2D) materials), and interfacial penetration (oil–water penetration and water penetration). The latest applications in energy and the environment, followed by presenting the outlook and key challenges were also reviewed.

Sunisa Jindasuwan et al., (2019) developed hydrophobic based surface, which separates oil from water. Filter papers were coated to bear highly hydrophobic and oleophilic functionality that can allow only oils to pass through them. The coating solutions were prepared by mixing poly(methylhydro siloxane, PMHS) and fumed silica at different proportions. The properties of the treated filter papers were investigated by measuring water contact angle and surface free energy. The optimum coating solution was at the PMHS:fumed silica weight ratio of 1.25:1.00. The treated filter paper exhibited high hydrophobicity with water contact angle of 142.80 ± 0.36 degrees and surface free energy of 0.78 mJ/m^2. In addition, it exhibited high selective removal of diesel oil from water with oil absorption capacity of 2.3 g/g.

Superhydrophobic coatings (SHCs) are increasing every year, however, undesirable chemicals including organic solvents and fluorinated compounds were intensively used in the existing preparation methods, which seriously hinder

their large scale production and practical applications. Herein, a simple approach for preparation of totally waterborne, fluorine-free and durable SHCs has been reported by **Xia Zhao et al., (2019)**. The SHCs with high water contact angles (CA = 163.9°) and low sliding angles (SA = 3.7°) were prepared simply by sequentially spray-coating a polyurethane (PU) waterborne solution and the SiO_2@HD-POS waterborne suspension onto glass slides. The influences of SiO_2, HDTMS, reaction time and fabrication temperature on superhydrophobicity were investigated. The SHCs can withstand 80 m of reciprocating abrasion against A4 paper at 4.5 kPa and impacting of at least 50 g of sand microparticles with 30 cm release height. Moreover, the coatings also show exceptional thermostability in boiling water. The SHCs showed promising applications in various areas including oil/water separation and preventing scald, as the method is environmental benign and the coatings are applicable onto various substrates.

Hua Zhou et al., (2018) have reviewed the development of super-nonwettable (SNW) fabrics owing to their novel functions and enormous potential for applications in diverse fields. The key to practical applications of super-nonwettable fabrics is durability against various damages. Novel strategies have been developed to improve the durability of SNW fabrics. To mimic regeneration ability of natural SNW surfaces, self-healing was introduced. The article summarized the recent research progress in super nonwettable fabrics. It summarized commonly used SNW properties including superhydrophobic superoleophilic, superhydrophobic–superoleophobic (i.e., superamphiphobic), superoleophobic– superhydrophilic, and underwater superoleophobic fabrics. Strategies to fabricate durable SNW coatings on fabrics were discussed. Special attention was paid towards self-healing SNW fabrics. A perspective on the future development in this field was also explained.

Conservation strategies to limit the degradation of stone materials are being constantly developed. New materials are designed to confer hydrophobic properties and anti-graffiti protection to the treated surfaces. Hybrid nanocomposites, based on inorganic nano-particles added to an organic matrix,

have been recently proposed for treatments of stone surfaces, obtaining promising and innovative properties. **Mariateresa Lettieri et al., (2018)** showed an experimental product based on fluorine resin containing SiO_2 nano-particles, a commercial fluorine-based product and a silicon-based material were applied as protective coatings on two calcareous stones (compact and porous) widely employed in the Mediterranean region. All the studied products are expected to provide both water and anti-graffiti protection to both stones' surfaces. The rheological characterization of the liquid products, changes in color of the surfaces, and variations in water vapor permeability allowed the compatibility of the protective systems applied to stones to be evaluated. Water–stone contact angle measurements and water absorption by capillarity were used to control the action against water ingress. The oleophobicity was assessed by measuring the oil–stone contact angle. The experimental nano-filled product proved to be a suitable hydrophobic coating for compact and porous stones; furthermore, it provides high oleophobicity to the treated surfaces, as required for anti-graffiti systems.

S.Pendse et al., (2018) have reported hydrophobic modification of a high-performance broadband antireflective (AR) film comprising mesoporous MgF_2 nanoparticles. The MgF_2 film demonstrates high transmission ,> 99% (400-800 nm) and > 97% (300-1500 nm) and is hydrophilic with water contact angle of 27°. The films were hydrophobically modified with fluorosilane containing silica sol by simple dip coating process, which increases the water contact angle to 130° without affecting the transmittance. Hence, the prepared hybrid layer exhibited excellent anti-reflection in a broad wavelength range 98.8% (400-800 nm) and 97.03% (300-1500 nm), along with good water-repellence. Moreover, it was found that the layer is environmentally and mechanically stable indicating its suitability for solar and optical applications.

Concrete is an inherently multi-scale hydrophilic composite. Superhydrophobic surfaces have not been created solely by using chemical modification to reduce surface energy. A superhydrophobic concrete surface was fabricated by **Wei She**

et al., (2018) via direct spraying nano-silica gel functionalized by low surface-energy surfactants to simultaneously modified the inherent multi scale microstructure and surface chemical properties. The newly modified microstructures were characterized by scanning electron microscopy (SEM) and digital holographic microscopy (DHM) to facilitate an understanding of the effects of micro- and nanoscale topological features on the super-wetting properties. The superhydrophobic and self-breathing properties of the modified surface were confirmed by its large contact angle (CA = 162° ± 3°), small slide angle (SA = 5° ± 1°) and carbonation depth measurements. The chemical bonding between hydrophobic functional group grafted with nano-silica and cement hydration products, as well as the interface hydration of nano-silica in an alkaline environment, were estimated by Fourier transform infrared spectroscopy (FT-IR) and X-ray diffraction (XRD).

Xia Zhang et al., (2018) fabricated super-robust and non-fluorinated superhydrophobic free-standing items, through dispersing hydrophobic SiO_2 nanoparticles in a series of polymers. The mechanical and chemical strength can be greatly improved by increasing the fabrication pressure, and the materials are found to retain superhydrophobicity after a knife/file scratch test, a liquid nitrogen test, severe sand/water impacts, acidic/alkali corrosion and 2000 cm sandpaper abrasion. These materials achieved better abrasion resistance than commercial superhydrophobic coatings and a higher retention ratio after abrasion tests and hardness than those of bricks. Radar diagrams were used to generalize the results of the mechanical and chemical tests to compare the material performances of SiO_2/polymer blocks with those of bricks and commercial superhydrophobic coatings. The SiO_2/polymer blocks achieved much better overall performance. This simple method has great potential for making either small domestic items or structural materials with robust superhydrophobicity.

Zhengwei Song et al., (2018) prepared super-hydrophobic coating on AZ31B Mg alloy. Electroless Ni-P coating as the inner layer was deposited on the AZ31

substrate via an electroless planting process, and Cu was electroplated as the intermediate layer. Then, the electroplating Ni method was employed to form the micro/nano structure, and the super-hydrophobic coating was prepared after the composite coating modified by stearic acid. The modified coating exhibited super-hydrophobic properties with a static water contact angle of 155°. Potentiodynamic polarization and electrochemical impedance spectroscopy (EIS) tests were conducted in 3.5 wt.% NaCl solution at room temperature. The test results indicated that the corrosion resistance of AZ31 was improved significantly by this superhydrophobic coating. The super-hydrophobic samples had much more corrosion resistance in comparison with freshly prepared samples.

In this study, **Zhengyong Huang et al., (2018)** has developed a facial one-step approach to prepare durable super-hydrophobic coatings on glass surfaces. The hydrophobic characteristics, corrosive liquid resistance, and mechanical durability of the super-hydrophobic surface are presented. The as-prepared super-hydrophobic surface exhibits a water contact angle (WCA) of 157.2° and contact angle hysteresis of 2.3°. Mico/nano hierarchical structures and elements of silicon and fluorine were observed on super-hydrophobic surfaces. The adhesion strength and hardness of the surface are determined to be 1st level and 4H, respectively. The coating is, thus, capable of maintaining super-hydrophobic state after sand grinding with a load of 200 g and wear distances of 700 mm. The rough surface retained after severe mechanical abrasion observed by atomic force microscope (AFM) microscopically proved the durable origin of the super-hydrophobic coating. Results demonstrate the feasibility of production of the durable super-hydrophobic coating via enhancing its adhesion strength and surface hardness.

Chun- Wei Yao et al., (2017) have studied about the artificial hydrophobic coatings in an effort to understand the effects of structured micro- and nano-scale features on droplet motion and self-cleaning mechanism. The micro-textured surfaces consist of a combination of hydrophilic and hydrophobic materials, designed, fabricated and characterized to know how the surface

properties and morphology affect enhanced self-cleaning mechanism. The study focused on the effect of surface vibration on droplet shedding at different inclined angles on micro-textured surfaces. The experimental results showed that the droplets under the influence of surface vibration depict different contour morphologies, vibrating at different resonance frequencies and the sliding angle can be reduced.

Silica was deposited on the soot film pre-coated glass via chemical vapour deposition by **Feng Zhang et al., (2017)**. Through calcination at 500°C with the assistance of O_2 airflow, the soot film was removed and a novel robust fibered-silica network film, was then decorated onto the glass substrate. On modification of the film with fluorosilane, the surface water contact angle (WCA) was 166° and sliding angle (SA) was 1° which behaved as a good self-cleaning film.The average transmittance was found to be 88% in visible wavelength. The fibered-silica coating showed a strong tolerance for heavy water droplets, acid/alkali corrosion, salt solution immersion and thermal treatment.

Superhydrophobic surface possessing exceptional stretchability, robustness and non-fluorination is highly desirable applications ranging from wearable devices to artificial skins. **Jie Ju et al., (2017)** have reported multi-performance superhydrophobic surface achieved through incorporating hydrophilic micro-sized particles with pre-stretched silicone elastomer. It was demonstrated that the as-prepared fluorine-free surface could preserve the superhydrophobicity under repeated stretching – relaxing cycles. The most important was that the surface's superhydrophobicity was well maintained afer severe rubbing process, indicates the wear-resistance. The noevel superhydrophobic surface integrates multiple key properties such as., stretchability, robustness and non-fluorination, which provides wide range of applications in biomedicine, energy and electronics.

Both surface morphology and surface energy of solid surface conclude its wettability, either in Wenzel's hydrophobic or Cassie–Baxter's superhydrophobic wetting state. **Popat G. Pawar et al., (2017)** have developed superhydrophobic

silica coatings by spin deposition technique from a mixture of hydrophobically modified silica particles and polystyrene. To enhance the adherency of the coating on the substrate and also to improve the durability of the coating, polymer is utilized in the coating solution. The durability of the super-hydrophobic coating was confirmed by resistency towards water jet impact. The consequence of number of spin deposited layers on the wettability of the coatings was precisely studied. The static and dynamic water contact angle of 158° and 9° were achieved on the coating surface. Freely rolling spherical water drops on the non-wettable solid surface are favourable for the self-cleaning effect and so the prepared superhydrophobic coatings revealed superior self-cleaning performance. An anti-corrosion performance of the superhydrophobic coating was also confirmed using electrochemical corrosion experiments in 3.5% NaCl solution with long immersion time.

Smart coatings are innovative coatings that can react spontaneously, due to inbuilt stimuli responsive mechanisms. The functionality obtained from these class of coatings at the metal solution interface in aggressive environments has led to advances in anticorrosion studies and applications. The review article by **Sarah B. Ulaeto et al., (2017)** emphasized the effects of corrosion sensing, self-healing, anti-fouling, and self-cleaning coatings for corrosion inhibition of metallic materials. However, in keeping with the theme, novel coating designs with anticorrosive characteristics that outweigh the limitations in the use of conventional coatings have been discussed. The presence of highquality nanoparticles in coating formulations has outweighed the effects of the microparticles. These have triggered unprecedented functionalities in the smart coatings. The smart coatings respond to single/multiple external stimuli such as light, dirt, pH changes, temperature, aggressive liquids, bio-foulant, impact, fatigue etc; and have demonstrated outstanding, barrier properties with scratch resistance, in-situ healing, superhydrophobicity, superoleophilicity, high optical transmission, thermal stability, and resistance to strong acids etc., resulting in extended service life of the coatings and the protected metallic materials. The

utilization of smart coatings in complex, real-time conditions, effectively controls the triggers of metallic degradation, structural failures, and resource depletion.

The degradation of corrosion preventative coatings contribute to high cost and time requirement for maintaining structures in harsh environment. **X. Sun et al., (2017)** have worked to quantify the barrier properties and corrosion resistance of two novel highly hydrophobic polysiloxane formulations and the legacy silicone alkyd topcoat was used on the topside of Navy's ship, all with haze gray pigmentation. With FTIR-ATR and EIS measurements of the pristine coatings, both the polysiloxane showed improved barrier characteristics (lower water diffusion coefficient and capacitance) than the silicone. The results were confirmed with 3-month-long immersion corrosion test, 1K and 2K (Polysiloxane coatings) had comparable degradation characteristic and remained highly hydrophobic.

Reusable polyvinylidene fluoride (PVDF) membranes with inclusions of expanded graphite (EG) were developed by **Zhao-Xia Huang et al., (2017)** via electrospinning methodology for water harvesting studies. Scanning electron microscopy (SEM) was used to perform morphological studies and demonstrated that the inclusions of EG slightly increased the diameters of the electrospun fibers. Static water contact angle was measured to evaluate wetting phenomena. Hydrophobic surfaces were obtained for both samples with and without EG inclusions, while the composite membrane was found to have relatively high water contact angle. A setup was used to evaluate the water-retaining performance of electrospun composite samples. An improvement of 63.4% in water harvesting efficiency was obtained when EG was included. The morphology and wettability of membranes containing EG after water harvesting experiments remained the same as before. And the results suggested that the composite membranes were reusable.

A facile method for the fabrication of organic coating with superhydrophobic surface on copper substrate was presented by **Zhengqing Yang et al., (2017).** Liquid-phase exfoliated fluorographene (FG) nanosheets, a low-surface-energy material with different sizes and shapes, were spatially stuck on the surface of epoxy resin coating to build rough surface with random micro/nano structure. The built coating system displayed superior protection performances due to its self-cleaning function, mechanical abrasion resistance and chemical stability both in acidic and alkaline aqueous solutions. It not only provides a facile process for superhydrophobic modification of organic coating, but also introduces a new and effective strategy to protect materials by synergistically coupling the protection function of both superhydrophobic surface and organic coating, used for large-scale manufacturing of superhydrophobic organic coating in industrial applications.

Athanasios Milionis et al., (2016) have studied about the mechanical wear robustness and long-term durability of superhydrophobic surfaces. It is found that superhydrophobic surfaces has limited behavior and hence there is restriction in their usage in commercial and industrial applications. The progress on fabrication, design and understanding the mechanically durable superhydrophobic surfaces were summarized. Various types of mechanical wear ranging from substrate adhesion, tangential surface abrasion and dynamic impact to ultrasonic processing underwater were reviewed. Of all these, the most successful approach to produce robust surfaces that can maintain their non-wetting state after the wear or abrasive action were discussed.

Chao-Ching Chang et al., (2016) have synthesized colloidal silica nanoparticles from tetraethoxysiliane via a sol–gel process. The surface was modified by 3-(trimethoxysilyl) propyl methacrylate (MSMA) and 1,1,1,3,3,3-hexamethyldisilazane (HMDS). MSMA acted both as a C=C provider and a coupling agent, whereas HMDS was used to prevent particle aggregation and engender hydrophobicity. The modified silica particles ($HMSiO_2$) were UV-cured together with the crosslinking agent, dipentaerythritol hexa-acrylate (DPHA) to

form coatings on poly(methyl methacrylate) (PMMA) substrates. Dynamic light scattering of the synthesized sols indicated that the average size of $HMSiO_2$ was 10 nm, consistent with that obtained from TEM imaging. FTIR spectroscopic analyses demonstrated chemical attachment of HMDS to the silica particles. The cured coatings were characterized in terms of water contact angle, light transmittance, hardness, abrasion resistance, and surface morphology. It was found that hydrophobicity of the coatings increased while light transmittance and hardness decreased with increasing HMDS content. DPHA played the role of providing mechanical strength and adherence; however, the coatings became lightly hazy when the weight ratio of DPHA/silica fell in the range 0.3–0.7. In the optimal case, a hard coating (4H) with water contact angle of 108° and transmittance of ~100% (vs PMMA) had been obtained at the DPHA content of 10 wt%.

Chaoyou Tao et al., (2016) has reported the preparation of antireflective coating (AR) with superhydrophobicity and ultralow refractive indices (as low as 1.08) from sols containing hexamethyldisilazane (HMDS)- functionalized hollow silica particles via sol-gel process. With the increase in HMDS content , the water contact angle increased from 15° to 156° ,which ensured the coatings with superior water repellency property. The HMDS- functionalized HSNs-based layer produced a fair anti-reflection effect consisting of more than a 4% increase in optical transmittance. Such coatings have potential applications in the field of electronics and optical devices.

Superhydrophobic surfaces has great promise for applications that range from self-cleaning windows to anti-icing air-crafts. **Hasan H. Ipekci et al., (2016)** has fabricated spray-coating of nanoparticles functionalized with low energy molecules , which can meet all such requirement except the mechanical robustness of the coating. By engineering the polymer matrix, the mechanical robustness can be improved. Hydroxyl-terminated polystyrene (PS-OH) serves as a matrix for dispersing silica nanoparticles functionalized with fluorinated

silanes. The films were fabricated with Hydroxyl- ends of the PS-OH , which facilitate chemical and physical interactions with the substrate through grafting of polymer chains to form brushes and showed high surface roughness with water contact angle (θ) greater than 170°. The coatings had retained their superhydrophobicity behavior (contact angle >150° and sliding angle < 10°) upon abrasion with sand grains at impact velocities lower than 10km/h. The current study has allowed the fabrication of superhydrophobic coating which transmitted 85% of the visible light that passes through the bare glass slide.

Recent progress to construct super-antiwetting coating on cellulose-based substrates has been discussed by **Hui Liu et al., (2016).** Applications relating to artificial superhydrophobic surfaces with special wettability and controlled adhesion , e.g., oil-water separation, self-cleaning, anisotropic wetting for microfluidic devices. In addition to the mentioned anti-wetting properties, attention is paid for coating durability, other incorporated functionalites such as UV shielding, photocatalytic self-cleaning, and self-healing applications.

Lotus-inspired super-hydrophobic coatings are usually mechanically weak and lack durability, this hinders their practical application. To overcome this, **Nan Wang et al., (2016)** has designed mechanically durable superhydrophobic coating, which retains water repellent properties after multiple cycles of abrasion, blade scratching, tape-peeling, repeated deformation, a series of environmental tests and recycling. Depending on its superhydrophobicity under oil, two highly efficient systems were developed for oil purification – stirring and inverted cone system. Water drops converge on the coated surface that was in oil through velocity- controlled stirring or to design a inverted cone superhydrophobic surface under oil to collect water drops spontaneously. The designed coating can be used in practical applications as durable superhydrophobic coating that functions either in air or oil.

Qianqian Li et al., (2016) have synthesized a fluorinated polymeric sol-gel precursor (PFT) by co-polymerization of 2,3,4,5,5,5-hexafluoro-2,4-bis(trifluorinated methyl) pentyl methacrylate (FMA) and 3-methacryloxypropyltrimethoxysilane (TSMA) to replace long chain fluorinated alkylsilanes. The fluorinated silica sol is prepared by introducing PFT as co-precursor of tetraethylorthosilicate (TEOS) in the sol-gel process with ammonium hydroxide as catalyst, the glass substrates were coated by dip-coating method. The effects of PFT concentration on the chemical structure of the formed fluorinated silica, the surface chemical composition, surface morphology, wetting and self-cleaning properties . X-ray powder diffraction (XRD), Fourier transform infrared spectroscopy (FTIR), X-ray photoelectron spectrophotometer (XPS), Scanning electron microscopy (SEM), and Water contact angle measurements (WCA) have been analysed. The size and size distribution of fluorinated silica particles are found greatly depend on the concentration of PFT, plays a crucial role in the surface morphology of the corresponding fluorinated coatings. The low surface energy and multi-scaled microstructures, lead to the formation of the superhydrophobic coatings with bio-mimicking self-cleaning property similar to lotus leaves.

A new method was employed by **Xiaojiang Liu et al., (2016)** for the construction of rough morphology and the chemical modification, known as self-modification. Candle soot acted as an intermediate to create rough, superhydrophilic and transparent surfaces on glass trough with calcination of polydimethylsiloxane (PDMS) at 550°C. Subsequently, a novel chemical vapour deposition (CVD) modification was conducted by heating PDMS at330°C in air to give the surfaces a water contact angle (WCA) of 170°± 0.5° and a sliding angle (SA) of 0°.This CVD modification found to be a valuable way of modification because of its simple operation, low cost and short time consumption. Results indicate that the high temperature calcination and the moderate temperature CVD modification drastically improve the stability of the surperhydrophobic surfaces through controlling the morphology and the surface chemical composition. The as-prepared glass surfaces are capable of bearing heavy rains, keeping the sight

clear in the rain and being used at a high temperature (<400°C) or in water. Besides, superhydrophobic fiberglass mesh was prepared and which has been applied in oil–water separation.

The functional properties such as anti-fogging, anti-icing and self-cleaning. **Xin Yang et al., (2016)** had controlled the surface topography and chemical composition via one-step method through hydrolysis and condensation of TEOS to form silica sol-gel films. With proportionate amount of water, TEOS and basic catalyst, the hydrophilic and hydrophobic chemical groups on the silica particle surface were controlled. The contact angle of 7.7 ±1.5° to 121.6 ±1.8° were exhibited. Through the heat-treatment, the wettability of the silica film could change from hydrophobicity to superhydrophilicity with the time-temperature equivalence principle. Raising the temperature and extending the time were equivalent to breaking of chemical bond, which results in wettability change of silica films.

The study involves a novel method of combining both low and high surface energy SiO_2 nanoparticles. **Xinghua Wu et al., (2016)** have employed such particles to prepare superhydrophobic and superoleophobic coating by sol-gel method.The hydrophobicity and oleophobicity of the coatings were analyzed by various liquid droplets with surface energy ranging from 72.4 to 29.5 mJ /m^2. To check the mechanical strength , Pencil scratch test, cross-cut tape adhesion test, nano-indentation and PosiTest Pull-off adhesion test were done. It was observed that with the molar ratio at 2:4 between the low and high surface energy has given rise to the best superoleophobicity and mechanical properties. Such coatings hold good promise for self-cleaning and ant-icing applications under mechanically erosive/abrasive environment.

A simple and time-saving approach for preparing self cleaning superhydrophobic silica coatings using a dip-coating technique have been reported by **Annaso B. Gurav et al., (2015)** in the study. Commercially available silica particles were

modified with methyl groups using methyltrichlorosilane as a modifying agent. By adopting a multi layer deposition process, a superhydrophobic silica coating with a water contact angle of 153˚±2˚ and roll-off angle of 8˚ ± 1˚ was obtained. The prepared silica coating exhibited excellent self-cleaning performance; moreover, it was able to maintain superhydrophobicity under the impact of a waterjet. This method could be an effective strategy for fabricating self cleaning superhydrophobic surfaces for promising industrial applications.

Monolayer and bilayer coatings were deposited on Polypropylene (PP) surface by sol-gel process at room temperature by **Cristian Petcu et al., (2015).** The monolayer coatings consist of Tetraethylorthosilicate (TEOS) and different co-precursors such as phenyltriethoxysilane (PhTES), Octylmethyldimethoxysilane (OMDMS), and Dodecyltriethoxysilane (DOTES). Bilayer coating consist of a layer as prepared for monolayer, followed by second layer obtained from fluorinated silica nanoparticles dispersion. By the presence of C-F bonds along with network Si-O-Si vibrational mode, the fluorinated group has been confirmed.The water contact angle for bilayer coated polypropylene are higher, on comparing with pristine (PP) and monolayer coated substrate and varies as a function of the hydrophobic functional groups of the silica co-precursors : phenyl< octyl< dodecyl. The fluorooctyl functions lead to a significant decrease in the surface energy values for bilayer coating, with very small values of polar component.

The formulation and characterization of erosion-resistant self-cleaning coatings were reported by **Divya Kumar et al., (2015).** Hydroxyl-terminated polydimethylsiloxane (PDMS) was added to tetraethylorthosilicate (TEOS) based sol-gel network as a functional additive. The coatings showed static contact angle of 112° and sliding angle of 1°. Spectrophotometric measurements were used to quantify the self-cleaning efficiencies after subjecting the samples to artificial dirt spray and water cleaning. The mechanical properties and the

durability were studied. The concept of self-cleaning coatings were successfully demonstrated without forming superhydrophobic surfaces.

Divya Kumar et al., (2015) have reported about self-cleaning coatings with excellent water-repellence and good mechanical properties are in high demand. However, producing such coatings with resistance to mechanical abrasion and environmental weathering remains a key challenge. Mechanically robust coatings based on tetraethylorthosilicate (TEOS) and glycidoxypropyltriethoxysilane (Glymo) have been prepared using a sol–gel method. The combination of the blended matrix produced coatings with good adhesion to substrates and improved mechanical properties. Fluoroalkylsilane (FAS) and silica fillers were introduced to increase the hydrophobicity of the coating. It was found that the water contact angle (CA) of these coatings increases from 115° to 164° upon decreasing filler size from 1–5 μm to 10–20 nm. The sliding angle (SA) for coatings with 15 wt.% loading of 10–20 nm silica is around 2°. UV weathering does not show significant effect on the properties of the coatings. Mechanical properties and performances including hardness, Young's modulus, coating adhesion and abrasion resistance were systematically analyzed. In the current work, a simple self-cleaning test, which measures the extent of dirt accumulation and subsequent removal by water spray, was performed. The coatings with 15 wt.% loading of 10–20 nm silica particles show the best self-cleaning performance both before and after mechanical abrasion. The developed coating process is simple and can be easily scaled-up for large surfaces that require self-cleaning function.

Optically transparent superhydrophobic silica-based films were obtained by means of sol-gel processing and self-assembly (SA) .**H.M.Shang et al., (2015)** have developed films with desired surface roughness by tuning the micro-structures of the sol-gels through the control of hydrolysis and condensation process. Modification of surface chemistry was done by introducing a monolayer through surface condensation reaction, which are obtained by dip-coating . The resultant coating has optical transparency higher than 90% and reflection lower

than 10 %.The advancing and receding contant angle is 165°/115°. Such coatings have applications where anti-reflection, optical transparency and super-hydrophobicity. In addition, such films can be made in to room temperature involving no expensive equipment and readily coated on various substrates.

A novel and facile passivation process for a perovskite solar cell is reported by **Insung Hwang et al.,(2015)** The most critical demerit of a perovskite solar cell is the poor stability in ambient atmosphere, which have been rectified by simple passivation process using a hydrophobic polymer layer. The hydrophobic polymer (Teflon) is deposited on the top of a perovksite solar cell by spin-coating technique.With the hydrophobic passivation, the perovskite solar cell shows negligible degradation after 30 day storage in ambient atmosphere. X-ray diffraction, light absorption spectrum and quartz crystal microbalance were used to prove the suppressed degradation of the perovskite film. This simple and effective passivation process suggests new kind of approach to enhance stability of perovskite solar cells to moisture.

John T Simpson et al., (2015) has reviewed about superhydrophobic materials and coatings. For the past few years, oxide/polymer-superhydrophobic surfaces and coatings were used with exceptional water repellency. The article attempted to explain the basic fundamentals and properties of hydrophobic, super-hydrophobic surface and coatings. Such surfaces and coatings can fundamentally change how water interacts with surfaces and it can legitimately said that this technology has the potential to literally change the world.

Leila Shams Solaree et al., (2015) aimed in the study of generation of hydrophobic silica coatings on glass substrates using tetraethoxysilane and phenyltriethoxysilane using sol-gel method. Water contact angle, SEM, FTIR, AFM techniques were used to characterize the surface. The concentrations of the silanes were investigated and optimized to obtain the best hydrophobic coating/surface.

Transparent hydrophobic silica coatings were produced by surface silylation method using tetraethylorthosilicate (TEOS) as a precursor and phenyltriethoxysilane (PhTES) and isooctyltrimethoxysilane (iso-OTMS) as silylating agents. The article reported by **Maedeh Ramezani et al., (2015)** explained about the influence of different organosilanes on the hydrophobic properties and surface modification of the films. Silica alcosol was prepared by maintaining the molar ratio of TEOS:H_2O:EtOH constant at 1:6.35:30.3 and varying the percentage of hydrophobic agents from 0 to 8 vol%. The iso-OTMS-modified film showed the higher contact angle (140°) in comparison with the PhTES-modified film. Silica films were characterized by the field-emission scanning electron microscopy (FE-SEM), atomic force microscopy, Fourier transform infrared spectroscopy, percentage of optical transmission, static contact angle measurement and thermal stability by TG-DTA analysis. FE-SEM images showed that the better coverage of nanoparticles in iso-OTMS-modified film caused the higher contact angle than that of PhTES-modified film.

Eventhough there are many viable approaches to induce hydrophobicity, superhydrophobicity surface could be fabricated only by the combination of surface chemistry modification and roughness enhancement. **Mehmet Hancer et al.,(2015)** has reported the surface roughness was enhanced by 12 nm SiO_2 nanoparticles which were chemically modified using self-assembled monolayer of perfluorodecyltrichlorosilane. The particles rendered hydrophobic, then successfully dispersed into polysilicon (silsesquioxane) matrix at varying concentrations from 0.5 to 4 %. In order to achieve polymer thin film nanocomposites, the nanoparticles dispersed polymer suspension was then spray coated on glass and aluminium coupons. It was found that the water contact angle exceeded 178° (super-hydrophobic) with low hysteresis and bouncing water droplet behavior. Taber abrasion testing was applied in order to gain insights into the abrasion resistance of nanocomposite film. The superhydrophobic nanocomposite film coated substrates was stimulated by ice formation at -20°C.

Zein, a widely used biopolymer has unique uniform film forming abilities. **P.Gizem Gezer et al.,(2015)** has developed a facile technique to change the water affinity of zein film surface achieved by simple solvent casting technique onto Polydimethylsilohexane (PDMS) substrate that was exposed to oxygen plasma. The water contact angle of zein surfaces is as low as 20° (Hydrophilic). Atomic force microscopy, Optical absorbance and light microscopy were used to study the film characterization and its surface topography. Hydrophilic zein surfaces has high surface roughness value, compared to the hydrophobic ones. Th effect introduced by sand paper and gratings does not have the same effect as surface chemistry. It was demonstrated that the zein films surface properties can be controlled by its ability to self-assemble depending on the substrate.

A new strategy to induce superhydrophobicity by introducing hierarchical structure into PVDF film. Nanofibrous composite films were prepared by **Rasoul Moradi et al., (2015)** via electrospinning of PVDF and PVDF/Graphene blend. Mechanical properties were studied using stress-strain test. The incorporation of graphene to PVDF, has changed the morphology, enhanced the surface roughness, which improved the hydrophobicity by inducing a morophological hierarchy. With the contact angle of 160°, superhydrophobicity can be achieved by PVDF/Graphene electrospun nanocomposite film.

Shanhu Liu et al., (2015) have reported a novel way to prepare raspberry like superhydrophobic silica coatings for self-cleaning applications. The hydrophobic silica particles were obtained by simple condensation of fluoroalkoxysilane (17FTMS) in ethanol at room temperature. These silica particles were embedded into the sol–gel processed silica matrix and deposited on glass plates. On this coating surface, water drops exhibited a contact angle of 152˚ and rolls off the surface at sliding angle of 10°. This extremely low sliding angle was employed to self-clean the superhydrophobic coating, where dirt particles accumulated on the surface of superhydrophobic coating was efficiently cleaned by quickly sliding water drops.The stability of the micro structure as well as the wetting properties

of the coating surface were investigated by scratch resistance and water stream impact test. The superhydrophobic coatings endured against the scratch of applied force of ~150 mN. Such one pot synthesis of raspberry-like superhydrophobic silica coatings may open new avenue in the sublime field of superhydrophobic research.

On contact with dusty superhydrophobic surface , moving spherical water drops collect the dust particles and eventually flow off the surface. **Shanhu Liu et al., (2015)** has fabricated transparent and self-cleaning superhydrophobic coating via sol-gel processing of long-chain fluoroalkylsilane. The coated surface exhibited rough, wrinkled , hill-like morphology similar to the micro-structure of the lotus leaf, which is responsible for superhydrophobicity , which allowed the water droplets to take round shape with contact angle of 169°. The water droplets abruptly roll off the coated surface at less than 5° of tilting . The dust-repellent (self-cleaning) property, plastron stability and durability against water-jet impact were examined on the superhydrophobic coatings.

Organic-Inorganic polyvinyledene fluoride (PVDF)/SiO_2 hybrid membranes were prepared by **Xin Huang et al.,(2015)** via phase inversion by TEOS sol-gel process and to concentrate fennel oil in herbal water extract. On introducing SiO_2 nanoparticles to PVDF, the thermal and mechanical properties were improved. The crystalline structure of PVDF changed from β phase to α phase when TEOS content surpassed 20%. It was found that the hydrophilicity, permeation, rejection, porosity and mean pore size of the hybrid membranes are increased with ascending TEOS contents. The concentration process of fennel oil in herbal water extract through the hybrid membranes was conducted and proved that the separation performance was improved effectively.

The roughening or structuring of inherently hydrophobic surfaces to possess microscopic and nanoscopic features can transform them to exhibit

superhydrophobicity. The use of impacting particulate sprays here eschews specialized reagents and equipments; is simple, inexpensive, and rapid to implement; creates highly repeatable outcomes; and permits selective region transformation via simple masking. As explained by **Chun Yat Lau et al., (2014),** With PTFE, the contact angle transforms from 90° to 150°, in which SEM examination reveals erosivewear mechanisms that are dependent on the impingement angle. The process tends to cause the sampleto bulge upwards from the treated surface due to elongation there, and can be mitigated by using lower impingement angles in the particulate spray. A finite element model created enables this characteristic to be related to the action of locked-in surface traction forces. The use of adhesive bonding to a rigid base is shown to be an alternative method to reduce the bulging. A second finite model developed allows knowledge of the right adhesive needed for this. In developing substrates for biochemical analysis, the approach offers very small possibilities for unintended synergistic interactions.

Wetting of rough surfaces has attracted great scientific interests in recent decades.Super-hydrophobic surfaces possess extraordinary water repelling properties due to their low surface energy and specific nanometer, micrometer-scale roughness with variety of potential applications ranging from self-cleaning surfaces to micro-fluidic devices as noted by **Hannu Teisala et al., (2014)** In the past few years, cellulose-based materials have established themselves among the most frequently used substrates for superhydrophobic coating. Various approaches to fabricate such coatings were discussed.In addition to anti-wetting properties, coating durability and other incorporated functionalities, such as gas permeability, transparency, UV-shielding, photoactivity, and self-healing properties were given attention.Cellulose- based materials range from water and stain-repellaent, self-cleaning, and breathable clothing to cheap and disposable lab-on-chip devices made from renewable sources with reduced material consumption.

The formation of a sol from wet-deposited aqueous potassium silicate solution as a novel route for the generation of highly performing large-area anti-reflective (AR) surfaces for solar energy conversion. Compared to alternative technologies, the present approach enables processing at very low cost. The mechanism of coating formation and consolidation was evaluated by **Karsten H. Nielsen et al., (2014)** . A typical size of ~20-40 nm of the colloids was established already at deposition stage without significant growth in the later process. Potassium species are removed in a subsequent washing procedure, leaving only a minor amount of residual potassium at the interface between coating and substrate in an otherwise nonporous silica layer. Physically and chemically bound water species was drived out of the coating in a final annealing step. In this way, an AR layer of nonporous silica with a thickness of ~100-150 nm was easily created. The AR effect is caused by two-beam interference at this layer, enabling an absolute transmission increase of 3.6% at a wavelength of 550nm and a relative transmission increase of 3.1%over the spectral range of 400-1100 nm for a single-side coating on solar glass for c-Si as well as thin-film modules.

The importance of self-cleaning materials and coatings has been reviews by **Prathapan Ragesh et al., (2014)**. Self-cleaning coatings has become an integral part because of their utility in various applications such as windows, solar panels, cements and paints. The fabrication of hydrophilic, hydrophobic, oleophobic, amphiphobic and multifunctional coatings and their synthesis routes have been discussed. The fundamentals of self-cleaning attributes such as water contact angle, surface energy and contact angle hysteresis were studied.

Hydrophobic antireflective coatings with low refractive index were prepared via base/acid – catalyzed two-step gel process using TEOS (Tetraethylorthosilicate) and MTES (Methyltriethoxysilane) as precursors were prepared by **Shuang Cai et al., (2014) .** The base-catalyzed hydrolysis of TEOS lead to the formation of sol with spherical silica particles. The acid- catalyzed MTES hydrolysis and condensation at the surface of the initial silica particles, which enlarges the silica particle size from 12.9 to 35.0 nm. With dip-coating process, the hybrid sol gives

an anti-reflective coating with a refractive index of 1.15. The water contact angle was increased from 22.4° to 108.7° ,as the MTES content increases, affords an excellent hydrphobicity. The core-shell particle growth mechanism of the hybrid sol was proposed and the relationship between the microstructure of silica sols and the properties of AR coatings were investigated.

S.R.Kunst et al., (2014) studied the corrosion resistance of hybrid films. Siloxane –Poly (methyl methacrylate) PMMA hybrid films were coated on Tin plate via sol-gel method obtained by hydrolysis and polycondensation of 3-(trimethoxysilylpropyl) methacrylate (TMSM) between organic (PMMA) and inorganic (siloxane) using benzoyl peroxide (BPO) as a thermic initiator. The effect of TEOS on the protective properties were evaluated. The hydrophobicity and morphology were determined by contact angle measurements and SEM. It was found from the result that the siloxane- PMMA hybrid films modified with acetic acids are promising anti- corrosive coatings, which can act as an efficient diffusion barrier, protecting tin plates against corrosion. The thickness were increased and irregular surface coverage on addition of TEOS.

The silica aerogel was prepared by **Azadeh Tadjarodi et al., (2013)** by acid-base sol-gel polymerization of tetraethylorthosilicate precursor followed by ambient pressure drying. Fourier Transform infrared (FTIR), Thermo-gravimetric and differential thermal analysis (TG/DTA), X-ray diffractometer (XRD), E-DAX, Brunauer-Emmitt-Teller (BET) and Scanning electron microscopy were characterized for the silica aerogels. The obtained results show that silica aerogel was light and crack-free solid with very low bulk density 0.027g/cm^3, high specific surface area 655.58 m^2/g and large pore volume of 0.4831cm^3/g. The size of the particles were calculated by Microstructure measurement program and Minitab statistical software.

The interest in superhydrophobic surfaces has grown exponentially over recent decades. Since the lotus leaf dual hierarchical structure was discovered, researchers have investigated the foundations of self-cleaning behavior which

was reviewed by **Elena Celia et al., (2013).** Generally, surface micro/nanostructuring combined with low surface energy of materials lead to extreme anti-wetting properties. Besides the thirst for knowledge, scientists have been driven by the many possible industrial applications of superhydrophobic materials in several fields. Many methods and techniques have been developed to fabricate superhydrophobic surfaces, and the current article aimed to review the recent progresses in preparing manmade superhydrophobic surfaces.

Water repellency can be evaluated by Dynamic water contact angle (above 0°C). **Golrokh Heydari et al.,(2013)** worked to overcome the issue of wetting properties of supercooled water at sub zero temperature by determining the temperature-dependent dynamic contact angle of microliter-sized waterdroplets on smooth hydrophobic and superhydrophobic surface with similar surface chemistry. The data showed the work of adhesion of water in the temperature interval from 25°C to below -10°C affect surface topography. A marked decrease in contact angle of superhydrophobic surface with decrease in temperature. In contrast , no significant wetting transition is observed on smooth hydrophobic surface. The freezing temperature and freezing delay time were determined for water droplets resting on a range of surfaces with similar chemistry but different topography, including smooth and rough surfaces in Wenzel state or Cassie-Baxter state.

Fabrication of large-area anti-reflective coatings (ARC's) on glass substrates by using a cost-efficient and simple approach, especially for applications in photovoltaics, remains a challenge. The study proposes electrospinning as a technique to fabricate porous SiO_2 ARC's on large area glass substrates ($20x20cm^2$) by **Hemant Kumar Raut et al.,(2013).** The existing electrospinning setup is modified to enable large-area glass coatings and electrospinning process parameters are optimized to achieve sub-wavelength ARC's. The post-sintered SiO_2 ARC's is thoroughly characterized for the film morphology and optical properties. The transmittance for one-side and both-sides coated glass is found to be 94.3% and 96% respectively. The anti-reflective glass is incorporated

in solar modules to determine the increase in short circuit current. The increase in short circuit current is found to be 3%.electrospinning as a fabrication technique has potential in offering accost effective solution for synthesizing ARC's on large area substrates for photovoltaic applications.

With its lightweight and recyclability properties, Polypropylene is one of the most used polymer. Due to its poor characteristics of surface energy and lack of polar functional groups, it needs to overcome adhesion processes as explained by **M. Pantoja et al., (2013)** To improve the adhesion behavior of polypropylene by combining atmospheric pressure plasma surface activation and silane adhesion promoter. Hydrolysis and condensation of Tetraethoxysilane are followed through infrared spectroscopy by attenuated total reflectance in order to set the coating conditions. The results showed that the ability of plasma treatment to create active oxydised functional groups on the polypropylene surface. Shear strength of single-lap bonding of polypropylene with polyurethane adhesive suffers a significant improvement when the silane coating is applied on plasma activated samples. The stability of the solution was tested upto 30 days yielded diminished, acceptable adhesion strength values.

Hydrophobicity and superhydrophobicity have been considered to promote ice-phobicity.

Polystyrene and Tetraethylorthosilicate (TEOS) colloidal solution was synthesized by **No-kuk Park et al.,(2013)** for the formation of an anti-reflective layer over glass substrate. Macro pores were formed in the silicon oxide layer due to the decomposition of PS spheres. The size of macro pores is 167 nm, which is well matched with the size of PS-spherical beads. TEOS-PS mixture solution was not stable due to its gelation by the hydrolysis of TEOS. Therefore the macroporous silica layer on a glass substrate can be coated with the TEOS-PS-IPA system for anti-reflection in this study.

Hybrid films of siloxane-poly(methyl methacrylate) (PMMA) were used in materials such as galvanized steel alloys.In this context **Sandra Raquel Kunst**

et al., (2013) had coated the galvanized steel with hybrid film of PMMA and mixture of alkoxides 3-(trimethoxysilyl propyl) methacrylate (TMSM) and Tetraethoxysilane (TEOS). The films were applied dip-coating and cured for 3 hours at a temperature of 160°C. The hydrophobicity and the morphological studies were determined.The mechanical behavior was evaluated by tribology trials of attrition. With the presence of TEOS, the silanol content was raised and the results obtained for the T4AN01 film showed higher thickness. EIS showed that this film displayed the best performance.

The study by **Shing-Dar Wang et al., (2013)** aimed to fabricate superhydrophobic antireflective coating which can be deposited on the covering of a solar cell system. The antireflective coatings were synthesized on glass subatrates with an average transmittance of 96% by layer-by-layer deposition of polyelectrolyte. The sol-gel was prepared by hydrolyzing tetraethoxysilane, reacting it with Hexadimethyldisilazane, aged at 20°C for 96h.Later, it was used to spin-coat a superhydrophobic film with contact angle 163° and transmittance of ~91%.On the top of the AR coating in a glass substrate, the super-hydrophobic sol gel was coated by spin-coating technique. The average transmittance, advancing contact angle and contact angle hysteresis of the coated sol-gel aged for 96h or 168h were 94.5 ± 0.7%, 154.0°± 1.5°, and 15.4°± 0.3° or 96.4 ± 0.2%, 158.4°± 4.4 and 1.8 °±0.3° respectively.

Wettability of solid surfaces is an important property, which depends on both the surface chemistry and surface roughness. The current article by **V.G. Parale et al., (2013)** described room temperature synthesis of dip coated water repellent silica coatings on glass substrates using phenyltrimethoxysilane (PTMS) as a co-precursor with two-step sol–gel process. Silica sol was prepared by keeping the molar ratio of tetraethylorthosilicate precursor, methanol solvent, acidic water (0.001 M oxalic acid) and basic water (12 M NH_4OH) constant at 1:11.03:0.17:0.58 respectively, throughout the experiments and the weight percentage of PTMS was varied from 0 to 15 %. It was found that with an increase in wt% of PTMS, the roughness and hydrophobicity of the films

increased. However, the optical transmission decreased from 93 % to 82 % in the visible range. The hydrophobic silica films retained their hydrophobicity up to a temperature of 386°C and above this temperature the films were hydrophilic. The hydrophobic silica thin films were characterized by taking into consideration the surface roughness studies, Fourier transform infrared spectroscopy, percentage of optical transmission, scanning electron microscopy, thermogravimetric– differential thermal analysis and contact angle measurements.

Xiaoyu Li et al., (2013) have fabricated high performance broadband antireflective (AR) and water-repellent coatings on glass substrates by assembly of silica nanoparticles and polyelectrolytes via the layer-by-layer (LbL) assembly technique, followed by calcination and hydrophobic modification. A porous poly(diallyladimethylammonium chloride) (PDDA)/20 nm SiO_2 nanoparticles (S-20) multilayer coating with AR property was prepared first. The maximum transmittance is as high as 99.0%, while that of the glass substrate is only 91.3%. After calcination and hydrophobic modification, the coating became water-repellent while maintaining the good AR property. Such water repellent AR coatings can improve the short-circuit current of solar cells as much as 6.6% in comparison with glass substrates without the coatings. Scanning electron microscopy (SEM) was used to observe the morphology and thickness of coatings. Transmission spectra and reflection spectra were characterized by UV–Vis spectrophotometer. The surface wettability was studied by a contact angle/interface system.

A facile, inexpensive, and general approach was explored for the fabrication of transparent silica/organic silicon hybrid sol, which could form transparent hydrophobic coatings on different substrates conveniently. The sol was prepared by **Fang Wang et al., (2012)** by using hexamethyldisilazane (HMDS) as a surface-modifying agent and the source of base catalyst required for the hydrolysis of tetraethoxysilane (TEOS). The resulting silica-based coatings on

glass slide have shown an optical transmission over the visible range up to 89% (in reference to 100% transmission defined by a plain glass substrate) and high thermal stability. The water contact angle of the film reached 152˚. The transparent hydrophobic silica-based hybrid sol has potential applications in creating outdoor building glass, protecting paper files from moisture and preventing metals from corrosion.

Decorative , hydrophobic coatings were generated using sols synthesized by **R. Subasri et al., (2012)** from hydrolysis and condensation of methyltriethoxy silane, tetraethoxy silane and 1H,1H,2H,2H- perfluorooctyltriethoxy silane, with nanosized and sub-micron sized inorganic black pigments particles. The coatings were densified at 250°C using near infrared radiation and conventional curing method. Thickness, roughness, contact angles and adhesion were characterized for densified coatings. It was found that the properties of near-infrared radiation cured pigmented coatings were compared to conventionally cured coatings. Both the coatings exhibited improved hydrophobicity with contact angle 130° to 145°, when compared to the unpigmented counterparts, which showed contact angle of 93° to 97°.The improved hydrophobicity was explained with the roughness of the coatings.

Sanjay Subhash Latthe et al.,(2012) has reviewed hydrophobic and superhydrophobic surfaces. Such water repellency surfaces are seen plants, insects and birds feather which booms for the development of biomimetrics (i.e) development of nanomaterials, nanodevices with its mimic nature. Such superhydrophobic surfaces can make water to bounce or roll off the surface which is due to the surface roughness. The article provides the overview of recent progress in synthesis, characterization, theoretical modeling and applications of superhydrophobic surfaces. The development of various techniques and the difficulties related to implementation of such surfaces were discussed.

The article by **Violeta Purcar et al., (2012)** reported the synthesis of hydrophobic and antireflective coatings by sol–gel process at room temperature (25°C), using tetraethylorthosilicate (TEOS) as a precursor and methyltriethoxysilane (MTES), phenyltriethoxysilane (PTES), vinyltriethoxysilane (VTES), and octyltriethoxysilane (OTES) as surface modifying agents. The silica sol was prepared by keeping the molar ratio of TEOS:RTES at 1:1, in acidic conditions with ethanol and 0.1 M HCl. All the hybrid systems were enriched with titanium(IV) isopropoxide as the cross-linking agent. With the introduction of hydrophobic organic group, it was observed that the obtained silica films become hydrophobic. Higher value of static water contact angle (107±3°) was obtained for the silica film prepared with TEOS+OTES. Under optimal synthesis condition, we obtained antireflection coatings, exhibiting a low reflection in the visible range.

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Akira Nakajima.,(2011) has reviewed hydrophobic surfaces.Technologies related to hydrophobic coatings have been applied to various industrial items for droplet formation and removal from solid surfaces. For such surfaces, excellent water-shedding properties and droplet control in a desired direction are not easily attained merely by reducing their surface energies, but also requires design and control of nanolevel surface structure with appropriate chemical composition. Various hydrophobic surfaces were developed and their static hydrophobicity have been studied. The paper presented a review of recent studies investigating the study of design of hydrophobic surfaces of liquid droplet control and on dynamic hydrophobicity.

Chien-Hung Chen et al.,(2011) have reported that sol-gel Sio2 anti-reflection coating (AR) on solar glass, known to increase the current output. To improve its mechanical durability, the amorphous Sio_2 can be replaced with zeolite (microporous aluminosilicate crystalline material) . With aggregate zeolite nanoparticles and zeolite precursors, scratch resistant AR coating is prepared by dip coating. Nanoidenter measurements show BEA zeolite films have 1.5 GPa indent hardness and elastic modulus of 35 GPa. The prepared AR coating shows

a self-cleaning effect with water contact angle close to zero, which can be made into super-hydrophobic surface on treating with Hexamethyldisilazane (HMDS).

Anti-reflective (AR) coatings with high transmittance and enhanced abrasion-resistance were developed by **Haiping Ye et al., (2011)** with base/acid catalysed sol-gel process using tetraethylorthosilicate (TEOS) as precursor. The experimental results reveal that the acid-catalyzed silica was covalently bonded to base-catalyzed silica particles, which increased the abrasion-resistance. Hexamethyldisiloxane (HDMS) was further used to improve the hydrophobicity of AR coatings. The water contact angle for pure silica AR coatings and HDMS treated AR coatings were 21.3° and 72.5°, in which there is a significant change in hydrophobicity. The existence of $–Si(CH_3)_3$, after HMDS treatment, were replaced by hydroxyl group, $-OSi(CH_3)_3$ is revealed by FT-IR and provides an excellent environmental resistance with HDMS.

Lianghong Yan et al., (2011) reported a simple method of preparing hydro-oleophobic antireflective films . FAS (Fluoroalkylsilane) modified SiO_2 was obtained by base catalyzed hydrolysis and condensation of tetraethoxysilane by dip-coating. The films have tested with contact angle measurement and it was found that the water contact angle is 136° and oil (peanut) contact angle is 93° . The surface chemical modification of hydro-oleophobic films were confirmed by Fourier Transform infrared spectroscopy (FTIR) . Additional absorption bands were obtained at 1100 cm^{-1} corresponding to C-F bond for FAS and TEOS based films.The highest optical transmittance of the hydro-oleophobic films were found to be 99.5%. The laser-damage threshold of as-deposited films were measured at 351 nm wavelength (1 ns) by Nd:YAG lasers, for which the threshold was as high as 22.6 J/cm^2 .

Extremely lightweight plates made of an engineered PMMA-based composite material loaded with hollow glass micro-sized spheres, nano-sized silica particles and aluminum hydroxide prismatic microflakes were realized by cast moulding. Their interesting bulk mechanical properties were combined to properly tailored

surface topography compatible with the achievement of a super hydrophobic behavior after the deposition of a specifically designed hydrophobic coating. With this aim, **Paola Pareo et al., (2011)** has synthesized two different species of fluromethacrylic polymers functionalized with methoxysilane anchoring groups to be covalently grafted onto the surface protruding inorganic fillers. By modulating the feed composition of the reacting monomers, it was possible to combine the hydrophobic character of the polymer with a high adhesion strength to the substrate and hence this maximized the water contact angle (upto 157˚) and durability of the easy-to-clean effect (upto 2000h long outdoor exposure).

The review article by **V. Anand Ganesh et al., (2011)** summarized about the key areas of self-cleaning coatings, primarily focusing on various materials that are widely used in recent research and also in commercial applications. The scope of this article orbits around hydrophobic and hydrophilic coatings, their working mechanism, fabrication techniques that enable the development of such coatings, various functions like Anti-icing, Electrowetting, Surface switchability and the areas where self cleaning technology can be implemented. Different characterization techniques and material testing feasibilities were also analyzed and discussed. Though several companies have commercialized a few products based on self-cleaning coating technology, much potential still remains in this field.

A double-layer broadband antireflective and scratch-resistant coating with hydrophobic surface is fabricated by **Xiaoguang Li et al.,(2011)** via sol-gel process with acid and base catalyzed silica as precursor solutions. The coating has dense and porous-silica films of which the refractive indices are high and low, realizing a step-index gradient structure with glass as substrate. The average transmittance of BK7 glass coated found to increase by 99.5% , range of 500 - 850 nm with the AR property to maximize the amplification yield of the laser disk amplifiers used in high power laser system. Trimethylchlorosilane is employed to modify the coating surface to improves the optical stability by

resisting moisture. These treatments can ensure that this broadband AR coating is durable for its real application.

A super-hydrophobic and super-oleophilic silica film on stainless steel meshes were obtained by simple sol-gel method using tetraethozysilicane (TEOS) and methyltriethosilane (MTES) as precursors. **Hao Yung et al., (2010)** have prepared surfaces with super hydrophobic and super-oleophilic properties, which were achieved owing to the hierarchical structure of the silica film with methyl groups terminated domains constructed on the mesh. The effects of the particle size, molar ratio of MTES, TEOS, and molar concentration of TEOS and aging of the silica sol on the hydrophobicity of the silica film were discussed. On increasing the dimensional size of the silica particles, molar ratio of MTES/TEOS, molar concentration of TEOS and aging period, the hydrophobicity of the silica film can be enhanced, as it increases the surface roughness or coverage of the methyl groups. Besides, diiodomethane droplet can spread out on the silica film within 6.71 s for the capillary force and intrinsic oleophilicity of the methyl groups.

Jyoti L. Gurav et al., (2010) have reviewed that the silica aerogels have drawn interest both in science and technology because of their low bulk density (95% of their volume is air) , hydrophobicity, low thermal conductivity, high surface area and optical transparency. With sol-gel process, the aerogels were synthesized. Supercritical drying is more common, however , recent developed methods allow removal of the liquid at atmospheric pressure after the chemical modification of the inner surface of the gel, leaving the porous silica network filled with air. These properties lead to the synthesis of silica aerogels by sol-gel method, as well as the drying techniques and applications in the current industrial development and scientific research.

Wettability of solid surfaces is a crucial concern in our daily life as well as in engineering and science. The work by **Sanjay S. Latthe et al., (2010)** described the room temperature synthesis of adherent and porous superhydrophobic silica films on glass substrates using methyltriethoxysilane (MTES) as hydrophobic

reagent by sol–gel process. The coating sol was prepared by keeping the molar ratio of tetraethoxysilane (TEOS), methanol (MeOH), water (H_2O) is 1:22.09:6.25, respectively, with 0.01 M NH_4F catalyst throughout the experiments and the MTES/TEOS molar ratio (M) was varied from 0 to 0.43. The static water contact angle as high as 160˚ and water sliding angle as low as 3˚ was obtained for silica film prepared from M = 0.43. The surface morphological study showed the porous structure with pore sizes ranging from 250 to 300 nm. The superhydrophobic silica films retained their superhydrophobicity up to a temperature of 290˚C and above this temperature the films were superhydrophilic. The prepared silica films were characterized by Scanning Electron Microscopy (SEM), Atomic Force Microscopy (AFM), Fourier Transform Infrared (FT-IR) spectroscopy, percentage of optical transmission, humidity test and static and dynamic water contact angle measurements.

A superhydrophobic poly (methyl methacrylate) (PMMA)/silver thiolate composite has been fabricated by **Xianghui Xu et al., (2010)** via simple spraying method. On Comparing with the intrinsically hydrophilic pure PMMA, the as-prepared PMMA/silver thiolate composite coating displayed a superhydrophobic property. And the UV-Vis spectra displayed a notable absorption of light in the ultraviolet range (UVA light), which made the composite potential material for ultraviolet absorption applications.

The hydrophilicity of Poly(vinyldene fluoride) PVDF was first improved by in situ polymerization of polar monomer in PVDF solution, explained by **Xuejuan Zhao et al., (2010)** Methyl methacrylate was adopted as the reaction monomer and the polymerization occurred in a solution of PVDF in N,N- dimethylformamide. Blend of PVDF/PMMA was obtained after in-situ polymerization. The contact angle of in-situ blend and blend were measured and compared. The measurement indicated that in-situ polymerization have stronger modifying effect on the hydrophilicity of PVDF than solution blending.

Bharathi Bai J Basu et al., (2009) has developed superhydrophobic surface by embedding hydrophobically modified fumed silica (HMFS) particles in

polyvinyledene fluoride (PVDF) matrix.The water contact angle on PVDF-HMFS hybrid composite coating depends on its content and nature of silica particles. The contact angle gets enhanced to 117° to 168° on increasing the silica concentration in PVDF matrix between 33.3% to 71.4% and the sliding angle decreased 90° to <1°. An irregular rough surface structure composed of microcavities and nanofilaments was found to be responsible for the superhydrophobicity examined using Scanning electron microscopy. The method is simple and cost- effective and used for preparing self-cleaning superhydrophobic coating on large areas of different substrates.

Changhong Su et al., (2009) have fabricated both highly hydrophobic and oleophilic foam by coating inner surface of polyurethane (PU) foam with a super-hydrophobic film. The contact angle of the foam was large as 152.2˚ for water, and 0˚for kerosene. The foam can absorb kerosene-water mixture and be regenerated easily. The foam may be used to reclaim oil from polluted natural water area resulted from shipwreck or leakage.

The article provides a review of superhydrophobicity and related phenomena (superoleophobicity, omniphobicity, self-cleaning) induced by surface micro- and nanostructuring. **Michael Nosonovsky et al., (2009)** has used the classical approaches (Young, Wenzel, and Cassie-Baxter models) to superhydrophobicty for contact angle. The issues beyond the above mentioned theories were discussed such as, mulitscale effects, 1D vs 2D interactions, the effects of contact line, size of roughness details, curvature and CA hysteresis. Potential applications such as energy transition, antifouling, and environment-friendly manufacturing were discussed.

A superhydrophobic coating with an anti-corrosive property has been fabricated on aluminium foil by sol-gel with Polystyrene spheres (PS) by **Qian Feng Xu et al., (2009)** The size of PS on the surface structure has effect on superhydrophobicity of the surface. When the size of PS is 200 nm, the coating

shows high static contact angle (i.e) larger than 150° and large adhesive force with the substrate. With the size of 500 nm, the contact angle is 160°.The water droplet can roll off the substrate easily. The coated aluminium foil found to possess good chemical stability and anti-corrosive property. The CA remains unchanged even after exposure to air for one-year or immersion in acid solution for 5 hours.

Silicon dioxide films were prepared on p-type Si (100) substrates by sol electrophoretic deposition (EPD) using tetraethylorthosilicate (TEOS) at low temperature. **Sa-Kyun Rha et al., (2009)** has estimated the characteristics of SiO_2 films , such as composition, surface morphology, wet etch rate and breakdown voltage . With the increase in the TEOS quantity , the growth rate of the film increased linearly, was saturated at approximately 200 nm on hydrophilic Si surface after more than 6 days. The growth rate of the EPD SiO_2 films on the hydrophobic Si surface was much lower than hydrophilic Si surface.

Different organic/inorganic compositions and deposition methods were used by **Rosa Taurino et al., (2008)** to prepare superhydrophobic surface with the help of metal alkoxides and sol-gel process. In order to acquire superhydrophobicity ,both surface roughness and composition were adjusted to obtain very high contact angles and low contact angle hysteresis.Multilayer samples with a fluorinated organic-inorganic top layer showed water contact angle of about 157° with low hysteresis (2°). The Water drops rolled off the surface at a tilt angle as low as 4°.

The Optical and structural properties of Antireflective coatings (AR) deposited from hydrolyzed TEOS sol have been characterized and explained by **A.Beganskiene et al., (2007).** The influence of various parameters for the formation of colloidal silica anti-reflective coatings by the dip-coating has been investigated. UV-Visible spectroscopy, laser ellipsometry and Atomic force microscopy were used to characterize the silica films. Using Optimal sol-gel

processing condition, (dipping rate – 40mm/min, coating time – 20s, temperature – 20°C) , the colloidal silica coatings were obtained and characterized and compared with the uncoated glass substrate. The reflectance of the AR coatings were increased with the temperature. The laser damage threshold of as deposited films was measured at 1064nm (1H) and 335nm (3H) wavelength using Nd:YAG lasers. And it was found that, threshold exceeded 15.22 J/cm^2 at 1064nm and 26.82 J/cm^2 at 355nm.

Ailan Qu et al., (2007) have reviewed about the superhydrophobic surface originated from quinicunx-shaped composite articles was obtained by utilizing the encapsulation and graft of silica particles to control the surface chemistry and morphology of the hybrid film. The composite particles make the surface of film from composite interface with irregular binary structure to trap air between the substrate surface and the liquid droplets which plays an essential role in obtaining high water contact angle and low water contact angle hysteresis. The water contact angle on the hybrid film was determined to be 154 ± 2˚and the contact angle hysteresis is less than 5˚. This is expected to be a simple and practical method for preparing self-cleaning hydrophobic surfaces on large area.

The article by **Neil J. Shirtcliffe et al., (2007)** describes a method for the production of thin films of porous, hydrophobic sol-gel materials that can be made hydrophilic if treated in certain ways. The materials become hydrophilic when heated above critical temperature, which can be varied by changing their composition. As water cannot penetrate into the hydrophobic material due to hydrophobicity of the pore walls, the bulk material floats on water. When made the transition from super hydrophobicity to imbibition as an indicator for maximum temperature reached, for concentration of surfactant or for measuring ethanol concentration in water.

Qingjun Wang et al., (2007) described a simple method for fabricating both highly hydrophobic and oleophilic meshes by coating thin fluoro-containing films. The static contact angle of such meshes was greater than 150˚ for water and close to 0˚ for kerosene, xylene and toluene. These meshes can separate water

from oil effectively without resorting to any extra power or chemical agent. Moreover, they exhibited stable water resisting, anti chemical erosion and anti hot aging properties. It promises as a candidate for the separation of oil and water.

Super-hydrophobic film is commonly prepared from hydrophobic materials. Poly (methyl methacrylate) (PMMA) is considered as a hydrophilic polymer (intrinsic contact angle below 90˚) with the water contact angle (CA) of ~68˚. However, a super hydrophobic PMMA film with CA of ~154˚was obtained by treating polystyrene (PS) and PMMA blended film in a warm selective solvent, cyclohexane, as explained by **Ying Ma et al., (2007).** The surface was characterized by scanning electron microscopy (SEM), X-ray photoelectron spectroscopy (XPS) and Fourier Transform infrared spectroscopy (FT-IR). The results showed that the conversion from the hydrophilic surface to a super hydrophobic one is due to the cooperation of the micro, nano structure and the side group reorientation in the PMMA chains at the topmost.