Fabrication of Super Hydrophobic Surfaces on Aluminium Alloy AA6061

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Abstract
The superhydrophobicity, inspired by nature, is a property that describes the non-wetting characteristics of materials surfaces. It appeared due to surface roughness (micro-nanostructure) and the low surface energy coating. Two techniques to obtain superhydrophobic aluminum surfaces were explored in the present study. In the first technique, aluminum alloy surfaces were chemically etched with NaOH solution followed by passivation with stearic acid solution. The superhydrophobic aluminum alloy surfaces were obtained by minimum of 8 minutes of etching. In the second technique, the electrophoretic deposition (EPD) processes were employed to obtain superhydrophobicity by coating of functionalized ZnO nanoparticles on aluminum alloy surfaces. Both coated surfaces were analysed by optical profilometry, scanning electron microscope (SEM), X-ray diffraction (XRD), water contact angle as well as corrosion test. The corrosion resistance properties of the superhydrophobic surfaces are much higher than their as-received surfaces.

Keywords - *Super hydrophobic surfaces, aluminium alloy, AA6061*

I. INTRODUCTION

Composite material is a material made from two or more constituent materials with significantly different physical or chemical properties that, when combined, produce a material with characteristics different from the individual components. The individual components remain separate and distinct within the finished structure. Composite enable the design of unique materials which combine materials which are stronger, lighter, or less expensive when compared to traditional materials. The biggest advantage of modern composite materials is that they are light as well as strong.

A. Classification

Composites are classified by the geometry of the reinforcement — particulate, flake, and fibres — or by the type of matrix — polymer, metal, ceramic, and carbon.

B. Types of composites based on reinforcement shape

Particulate composites consist of particles immersed in matrices such as alloys and ceramics. They are usually isotropic because the particles are added randomly. Particulate composites have advantages such as improved strength, increased operating temperature, oxidation resistance, etc. Typical examples include use of aluminum particles in rubber; silicon carbide particles in aluminum; and gravels, and, and cement to make concrete.

Flake composites consist of flat reinforcements of matrices. Typical flake materials are glass, mica, aluminum, and silver. Flake composites provide advantages such as high out-of-plane flexural modulus, higher strength, and low cost. However, flakes cannot be oriented easily and only a limited number of materials are available for use.

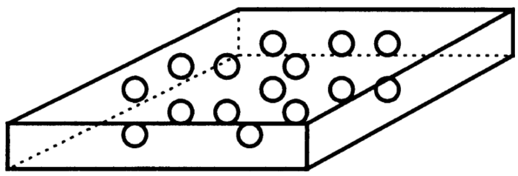

Fig.1: Particulate composites

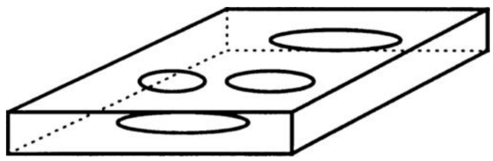

Fig.2: Flake composites

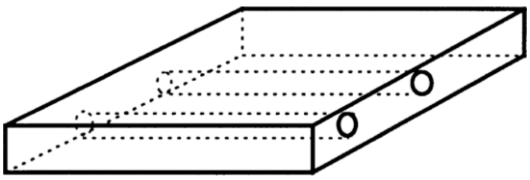

Fig.3: Fibre composites

Nano composites consist of materials that are of the scale of nanometres. The accepted range to be classified as a nanocomposite is that one of the constituents is less than 100 nm. At this scale, the 3properties of materials are different from those of the bulk material. Generally, advanced composite materials have constituents on the microscale. By having materials at the nanometre scale, most of the properties of the resulting composite material are better than the ones at the microscale. Not all properties of nanocomposites are better; in some cases, toughness and impact strength can decrease. Applications of nanocomposites include packaging applications for the military in which nanocomposite films show improvement in properties such as elastic modulus, and transmission rates for water vapor, heat distortion, and oxygen. Body side moulding of the 2004 Chevrolet Impala is made of olefin-based nanocomposites. This reduced the weight of the moulding by 7% and improved its surface quality. General Motors currently uses 540,000 lb of nanocomposite materials per year. Rubber containing just a few parts per million of metal conducts electricity in harsh conditions just like solid metal. Called Metal Rubber R, it is fabricated molecule by molecule by a process called electrostatic self-assembly. Awaited applications of the Metal Rubber include artificial muscles, smart clothes, flexible wires, and circuits for portable electronics. The manufacturing of this hydrogen system will require a series of machining. A milling machine is used in order to drill holes on the bottom of the vessel. This is where the tubes are going to be extended out of the container in order to connect the wires for the current. This will allow for the electricity to be outside of the vessel, while the highly flammable HHO gas is stored inside the container, making it safer.

II. METHODOLOGY

A. Type of Matrix

1. Polymer Matrix Composites

A Polymer matrix composite (PMC) is a composite material composed of a variety of short or continuous fibres bound together by an organic polymer matrix. PMC are designed to transfer loads between fibres through the matrix. The most common advanced composites are polymer matrix composites (PMCs) consisting of a polymer (e.g., epoxy, polyester, urethane) reinforced by thin diameter fibres (e.g., graphite, aramids, boron). For example, graphite/epoxy composites are approximately five times stronger than steel on a weight for-weight basis. The reasons why they are the most common composites include their low cost, high strength, and simple manufacturing principles.

2. Metal Matrix Composites

Metal matrix composites (MMCs), as the name implies, have a metal matrix. Examples of matrices in such composites include aluminum, magnesium, and titanium. Typical fibres include carbon and silicon carbide. Metals are mainly reinforced to increase or decrease their properties to suit the needs of design. For example, the elastic stiffness and strength of metals can be increased and large coefficients of thermal expansion and thermal and electric conductivities of metals can be reduced, by the addition of fibres such as silicon carbide.

3. Ceramic Matrix Composites

Ceramic matrix composites (CMCs) have a ceramic matrix such as alumina calcium alumino silicate reinforced by fibres such as carbon or silicon carbide. Advantages of CMCs include high strength, hardness, high service temperature limits for ceramics, chemical inertness, and low density. However, ceramics by themselves have low fracture toughness. Under tensile or impact loading, they fail catastrophically. Reinforcing ceramics with fibres, such as silicon carbide or carbon, increases their fracture toughness because it causes gradual failure of the composite. This combination of a fibre and ceramic matrix makes CMCs more attractive for applications in which high mechanical properties and extreme service temperatures are desired.

4. Carbon–Carbon Composites

Carbon–carbon composites use carbon fibres in a carbon matrix. These composites are used in very high-temperature environments of up to 6000°F (3315°C), and are 20 times stronger and 30% lighter than graphite fibres Carbon is brittle and flaw sensitive like ceramics. Reinforcement of a carbon matrix allows the composite to fail gradually and also gives advantages such as ability to withstand high temperatures, low creep at high temperatures, low density, good tensile and compressive strengths, high fatigue resistance, high thermal conductivity, and high coefficient of friction. Drawbacks include high cost, low shear strength, and susceptibility to oxidations at high temperatures. Typical properties of carbon–carbon composites.

B. Need of Composite Project Formulation

There is unabated thirst for new materials with improved desired properties. All the desired properties are difficult to find in a single material. For example, a Material which needs high fatigue life may not be cost effective. The list of the desired properties, depending upon the requirement of the application, is given below.

- Strength
- Stiffness
- Toughness
- High corrosion resistance
- High wear resistance
- High chemical resistance
- Reduced weight
- High fatigue life
- Thermal insulation or conductivity

C. Types of Aluminum Alloys

1000 Series

The 1000 series alloys are comprising of Aluminum 99 percent or high purity. This series has excellent corrosion resistance, excellent workability, as well as high thermal and electrical conductivity. The 1000 series is commonly used for transmission and power grids. Common alloy designations in this series are 1350 for electrical applications and 1100 for food packaging trays.

2000 Series

In the 2000 series, copper is used as the principle alloying element and can be strengthened significantly through solution heat-treating. These alloys possess a good combination of high strength and toughness, but do not have the levels of atmospheric corrosion resistances many other aluminum alloys. These alloys are usually painted or clad for such exposures. They're generally clad with a high-purity alloy or a 6000 series alloy to greatly resist corrosion. Alloy 2024 is the widely known aircraft alloy.

3000 Series

Manganese is the major alloying element in this series, often with a smaller amount of magnesium added. Only a limited percentage of manganese can be effectively added to aluminum. 3003 is a popular alloy for general purpose because it has moderate strength and good workability and may be used in applications such as heat exchangers and cooking utensils. Alloy 3004 and its modifications are used in the bodies of aluminum beverage cans.

4000 Series

4000 Series alloys are combined with silicon, which can be added insufficient quantities to lower the melting point of aluminum, without producing brittleness. The 4000 series produce excellent welding wire and brazing alloys where a lower melting point is required. Alloys is one of the most widely used filler alloy for welding 6000 series alloys for structural and automotive applications.

5000 Series

Magnesium is the primary alloying agent in the 5000 series and is one of the most effective and widely used alloying elements for aluminum alloys in this series possess moderate to high strength characteristics, as well as good weldability and resistance to corrosion in the marine environment. Aluminum-magnesium alloys are widely used in building and construction, storage tanks, pressure vessels and marine application. Example of common alloy application include: 5052 in electronics, 5083 in marine applications, anodized 5005 sheets for architectural applications and 5182 makes the aluminum beverage can lid.

6000 Series

The 6000 series are versatile, heat treatable, high formable, and have moderately high strength coupled with excellent corrosion resistance. Alloys in this series contain silicon and magnesium in order to form magnesium silicate within the alloy. Extrusion products from the 6000 series are the first choice for architectural and structural applications. Alloy 6061 is the most widely used alloy in this series and is often used in truck and marine frames.

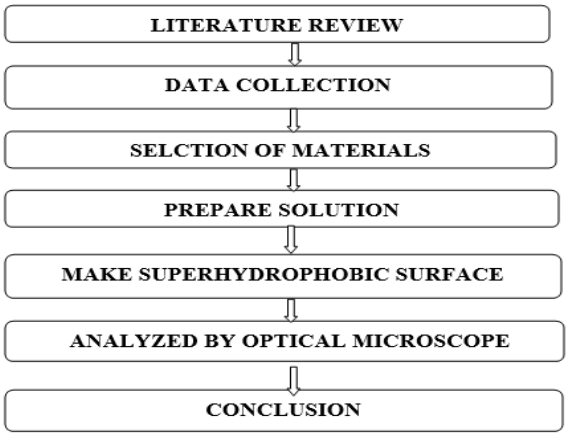

Fig 4: Methodology

III. COATING METHODS

A. Chemical vapor deposition

Chemical vapor deposition (CVD) is a chemical process used to produce high quality, high-performance, solid materials. The process is often used in the semiconductor industry to produce thin films. In typical CVD, the wafer (substrate) is exposed to one or more volatile precursors, which react and/or decompose on the substrate surface to produce the desired deposit. Frequently, volatile by-products are also produced, which are removed by gas flow through the reaction chamber.

B. Physical vapor deposition

Physical vapor deposition (PVD) describes a variety of vacuum deposition methods which can be used to produce thin films and coatings. PVD is characterized by a process in which the material goes from a condensed phase to a vapor phase and then back to a thin film condensed phase. The most common PVD processes are sputtering and evaporation. PVD is used in the manufacture of items which require thin films for mechanical, optical, chemical or electronic functions.

C. Roll-to-roll coating processes

In the field of electronic devices, Roll-to-roll processing, also known as web processing, reel-to-reel processing or R2R, is the process of creating electronic devices on a roll of flexible plastic or metal foil. In other fields predating this use, it can refer to any process of applying coatings, printing, or performing other processes starting with a roll of a flexible material and re-reeling after the process to create an output roll. These processes, and others such as sheeting, can be grouped together under the general term converting.

D. Sol-gel process

In materials science, the sol-gel process is a method for producing solid materials from small molecules. The method is used for the fabrication of metal oxides, especially the oxides of silicon and titanium. The process involves conversion of monomers into a colloidal solution (sol) that acts as the precursor for an integrated network (or gel) of either discrete particles or network polymers.

E. Spray coating

Spray coating is a technique where a device sprays a coating through the air onto a surface. The most common types employ compressed gas usually air to atomize and direct the paint particles. Spray guns evolved from airbrushes, and the two are usually distinguished by their size and the size of the spray pattern they produce. Airbrushes are hand-held and used instead of a brush for detailed work such as photo retouching, Air gun spraying uses equipment that is generally larger. It is typically used for covering large surfaces with an even coating of liquid. Spray guns can be either automated or hand-held and have interchangeable heads to allow for different spray patterns.

F. Problem Definition

The ice formation on airframe structures is a major cause for flight crashes due to natural calamities. The ice on structural skin are sometimes hard and not easily removed, that will require more surface treatment while maintenance. The inflight icing will severely affect the flight performance characteristics, leads to increase in drag and weight, decrease in lift, alter in pitching control. To overcome this more thrust and controls has to be used and this may consume more amount of fuel than usual.

There are several conventional ice removing methods (anti icing and de-icing techniques) were employed in aircraft during flight to minimize the icing effects, in accordance with the type of ice formed or location of the ice formation. Even though there are several parts are not protected by this ice removing equipment, which mostly affect the flight operation. The major drawback of this ice removing methods such as electro thermal method is it may causes thermal stresses in the skin and require high care during maintenance. Pneumatic Boot deploying is another ice removing method which may affect the aircraft’s pitching during its deployment and require more power. The Wing Weeping method and bleed air method are harmful to the structural skin due to their highly reactive chemicals and hot gases. But all this technique was used only for a short time during the flight, so they cause less harm to the aircraft.

Passive coating method is one effective method of ice removal in aircraft. The coating material has to be selected with less reactivity to the aircraft’s surfaces. Super hydrophobicity techniques were incorporated into the coat’s property by biomimetic. This will enhance the surfaces with water (super cooled liquid) repellent and self-cleaning characteristics. In addition to this the surface roughness has to be increased in microscopic level, which make higher contact angles with the water and surface, and this will cause the water droplets to roll off from the surfaces. This is one effective method in which the ice forming possibilities on aircraft is minimum. The coating should be prepared in such a way that it can able to handle weather effects and at the same time can sustain the aerodynamic loads without making any disturbances in the flow over aircraft. Another important criterion for the coating is it should be less reactive, easily maintainable, durable, and reliable over time.

IV. SUPERHYDROPHOBIC

Ultra-hydrophobic (or super hydrophobic) surfaces are highly hydrophobic, i.e., extremely difficult to wet. The contact angles of a water droplet exceed 150°.This is also referred to as the lotus effect, after the super hydrophobic leaves of the lotus plant. A droplet impacting on these kinds of surfaces can fully rebound like an elastic ball.

The Lotus effect is based on this principle. Inspired by it, a lot of functional superhydrophobic surfaces were prepared. Water striders are insects that live on the surface film of water, and their bodies are effectively unwettable due to specialized pubescence referred to as hydrofuge; many of the body surfaces are covered with specialized "hair piles", composed of tiny hairs spaced so closely that there are more than one thousand micro hairs per mm, resulting in a hydrophobic surface. Similar hydrofuge surfaces are known in other insects, including aquatic insects that spend most of their lives submerged, with hydrophobic hairs preventing entry of water into the respiratory system.

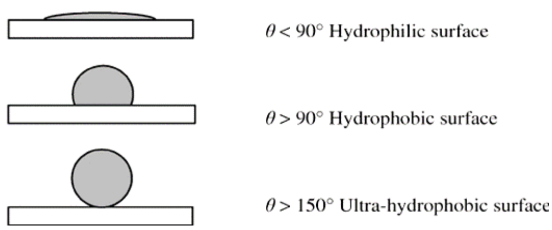

Fig 5: Superhydrobic surface

A. Application

A primary purpose of hydrophobic coatings such as Silicone is to act as a barrier against water commonly seen in automobiles. It is widely used in aerospace industry for providing anti-icing coating on the surface of the aero plane. Self-cleaning, Low adhesion and Drag reduction in nature. Hydrophobic self-cleaning glasses are installed in traffic sensors control unit. The development of super hydrophobic and self-cleaning surfaces is important for basic research as well as various applications, such as Anti-biofouling paints for boats, Anti-sticking of snow for antennas and windows, Self-cleaning windshields for automobiles, metal refining, stain resistant textiles, anti-soiling architectural coatings, dust-free coatings on building glasses, anti-condensation, and so on.

B. *Material Properties*

AA6061is a precipitation hardened aluminium alloy, containing magnesium and silicon as its major alloying elements. Originally called "Alloy 61S", it was developed in 1935. It has good mechanical properties, exhibits good weldability, and is very commonly extruded. It is one of the most common alloys of aluminium for general-purpose use. It is commonly available in pre-tempered grades such as 6061-O (annealed), tempered grades such as 6061-T6 (solutionized and artificially aged) and 6061-T651 (solutionized, stress-relieved stretched and artificially aged).

Table 1: Chemical composition

S.NO	ALLOY	PERCENTAGE (%)
1	Aluminum	95.85–98.56%
2	Silicon	0.4-0.8%
3	Iron	0.7%
4	Copper	0.15-0.40%
5	Magnesium	0.8-1.2%
6	Chromium	0.04-0.35%
7	Zinc	0.25%
8	Titanium	0.15%
9	Other elements	0.05-0.15%

C. *Optical Microscope*

The optical microscope, often referred to as light microscope, is a type of microscope which uses visible light and a system of lenses to magnify images of small samples. Optical microscopes are the oldest design of microscope and were possibly invented in their present compound form in the 17th century. Basically, optical microscopes are the oldest design of microscopes can be very simple, although there are many complex Design which aim to improve resolution and sample contrast

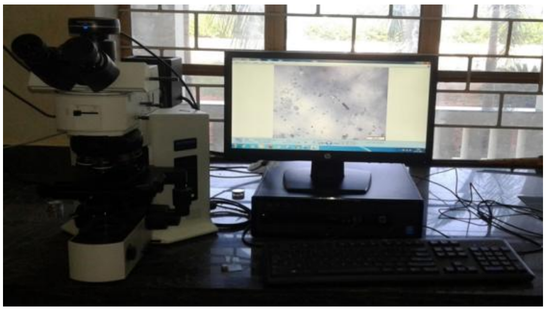

Fig 6: Optical Microscope set-up

The image from an optical microscope can be captured by normal light-sensitive cameras to generate a micrograph. Originally images were captured by photographic film but modern developments in CMOS and charge-coupled device (CCD) cameras allow the capture of digital images. Purely digital microscopes are now available which use a CCD camera to examine a sample, showing the resulting image directly on a computer screen without the need for eyepieces.

V. RESULT AND DISCUSSION

D. *Morphology Analyse*

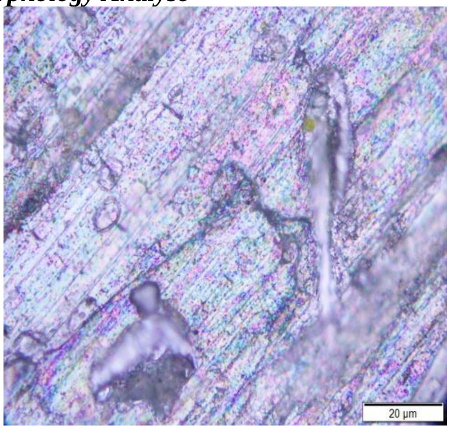

Fig.7: Non-Coated AA6601-1

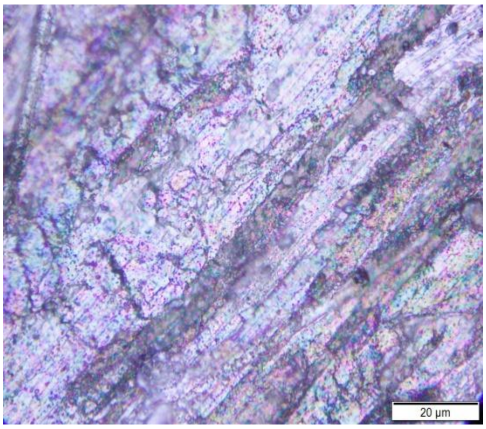

Fig.8: Non-Coated AA6601-2

The above images shown on the surface of non-morphology images. The non-coated aluminum alloy 6061 was analysed by optical microscope. The surface is possible to the high wet condition. So, modify the aluminum alloy 6061 surface for non-wet condition. There are several methods available for surface coating. The above optical images are explaining the surface wet condition. They surface are bubbles, that is shown in above fig.so coating technique are used to the reduce the bubbles and wet surface of the Aluminum alloy.

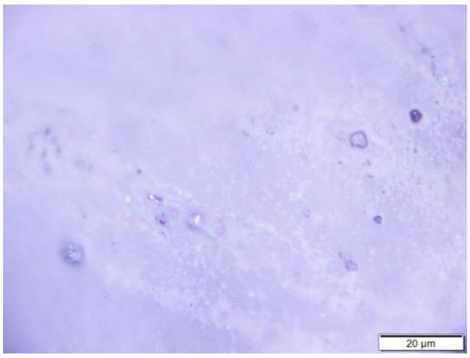

Fig.9: Coated AA6601-1

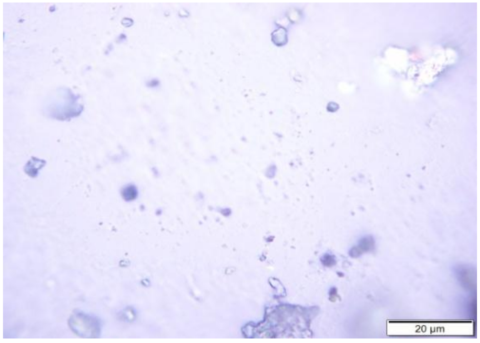

Fig.10: Coated AA6601-2

The above surface morphology of the sprayed film shows moderately homogeneous and continuous grains with the existence of few voids illustrated by the white spots on the Fig.6 and Fig.7 The measurements acquired by the surface profilometry indicated that the thickness of the deposited film was found to 20µm. the above morphology helps to the reduce the wet 5% to 45%. which the morphological irregularities previously stated in the characterization of the optical microscope. to the results obtained by the spray method. The spherical crystal grains are uniformly distributed. which may be due to the thickness because when the latter augment it causes an increase and clarification of the peaks, but the films homogeneity and morphology are better and the crystallite size looks bigger compared to the sprayed ones. Therefore, we can say that the spraying method allows us to obtain a good crystalline structure but on the other hand the surface homogeneity of the deposited films is poorer.

VI. CONCLUSION

In this work, we proposed a simple method to fabricate mechanically stable coated. Thin films of silicone were successfully deposited by spray coating techniques. We noticed that the structural and optical properties were slightly changed but the morphological and nonlinear optical properties were more affected by the change of the elaboration method. The contact angle between the liquid droplet and the surface were varied to evaluate the factors involved in the spreading of water over the surfaces at low contact angle and repelling of water from the surface at higher contact angle(>150°) were studied.

Therefore, a surface with higher contact angle has to be prepared for minimizing the ice formation. Completed the study of different bare and coated Aluminum samples. The Aluminum alloy 6061 was etched and sprayed with a colloidal solution of silicone. The morphology was analysed via optical microscope. It is reduced to the ice formation. Studying the properties of various material and their behaviour, when interacted with our working environment. Experimental Testing of the surface coated model in an icing Tunnel has to be done for visualizing the flow over the coated model of the Mechanical behaviour of the coated surface like abrasion, corrosion, wear, expanding have to be tested for the coatings, durability and reliability while in operation. Comparing the experimental results against the analytical result.

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