Section A-Research paper

Enhancement of self-cleaning properties of soda-lime glass coated with graphene

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ABSTRACT

Graphene-coated soda-lime glass was characterized by structural and optical investigation. The soda-lime glass with the graphene coating was formed by dip coating and graphene was synthesized using the Hummers modified method. The cycles for coatings were different (50&100 cycles). The structure, morphology, and optical characteristics of the synthesized samples were characterized by using XRD, FTIR, UV, SEM, and contact angle. Graphene particles were detected in the XRD spectrum. The FTIR spectroscopy technique is used to determine the functional group that seems to be present in the specimen. The morphology of the soda-lime glass coated with graphene was examined using SEM analysis. UV spectroscopy was utilized to measure the energy bandgap, and the bandgap for glass coated with graphene was slightly higher. The contact angle values of synthesized compounds were high compared with pure glass.

Keywords Graphene, Soda lime glass, dip coating, contact angle

1. Introduction

Nanotechnology has made significant strides in a number of industries, including pharmaceuticals, electronics, textiles, cosmetics, food, transportation, and building and construction. Nanotechnology is employed in certain building and car applications, such as self-cleaning windows [1]. Glass is the primary material used in both residential and commercial construction. [2] Glass is one of the most popular materials and has several uses, such as a construction material for buildings, a material for containers and vessels, and as windows in the automotive sector. Glass is desirable for a wide range of factors, including its transparency, chemical inertness, environmental friendliness, sustainability, strength, ease of availability, and relative affordability. Other readily accessible materials don't have these properties. Glass has always been utilized as window panes in the construction sector [3] Three varieties of glass are known. Glassware and household cookware are commonly produced from borosilicate glass. Optical fibres commonly make use of phosphates glass. Windows and lamps are constantly made of soda lime glass [4] In addition to the primary element silica, manufactured glass also contains significant amounts of a variety of metal oxides, primarily soda (Na_2O) and lime (CaO). Therefore, it is known as 'soda-lime-silica glass' or 'soda-lime glass' [5] Cleaning windows is one of the most dreaded and despised tasks. For high-rise buildings that have shabby exteriors and are perched high in the sky, window cleaning by hand is highly difficult and can lead to personal injury, time, money, and water waste. Self-cleaning coatings will be quite advantageous. Super-hydrophobic surfaces have potential use in self-cleaning building exteriors, window glass, automotive windshields, and waterproof materials. [6] Artificial amphiphilic surfaces with static contact angles above 150^0 and sliding angles below 10^0 have been effectively built using a variety of techniques in recent years. These interfaces were prompted by the lotus effect [7-8] The two types of self-cleaning coatings—hydrophobic and hydrophilic—clean surfaces in various ways based on how they respond to water. Since the latter sheets the rainwater that wipes the dirt from the surface using the suitable metal oxides, the earlier causes the droplets to slide and roll over the surfaces, keeping the dirt with them. [9] Glass coatings, commonly referred to as window glazes, are made by covering a standard piece of glass with a thin layer of another substance. These additional layers are so thin that it is simple to see through them. Less preceding

evidence exists to support solving this issue. however, the contact angle only slightly rises. Modified economical coatings with antibacterial, photocatalytic, and self-cleaning capabilities are receiving more attention today. Due to the thermal stability characteristics of TiO2. It is one of the materials that are most frequently employed in self-cleaning applications. Titanium dioxide (TiO2) is used for this in polymeric materials due to its affordable cost and photocatalytic abilities. [10-11] when using titanium dioxide to coat glass. the contact angle is 6.4, and when copper is added to titanium dioxide, the contact angle increases. Using graphene as a coating material is one approach to resolving this concern. because of its distinctive features

In recent years, researchers in material science and technology have focused intense attention on graphene-based nanomaterials. One of the most advanced carbonaceous materials, graphene Nanosheets have one or a few graphite layers. [12] When added to composite materials, graphene sheets exhibit notable advantages in their chemical and physical characteristics. Graphene-based composites have received the most attention compared to other composites because of their enormous surface area, outstanding characteristics, and ease of tuning. [13] Water is repelled by graphite and graphene, which are referred to as hydrophobic materials. It turns out that these materials are hydrophilic, or attracted to water, according to a recent study from the University of Pittsburgh. They suggest that after being exposed to air, graphene develops a thin coating of hydrocarbon on its surface, which contaminates it and turns it hydrophobic. Hydrocarbon is a substance made up entirely of hydrogen and carbon [14]. The development's objective is to endeavour to convert the glass' hydrophilic qualities to hydrophobic by increasing contact angle values. We choose to utilize graphene as the coating material on glass based on the aforementioned premise. because graphene is a substance that repels water. For improved outcomes, we employ the dip coating method for coating graphene on glass. [15]

2. Materials and methods

for one hour. After completion of stirring, use the dip coating units for coating the samples. The glass

The following chemicals were involved in the procedure: Graphite flakes, polyvinyl alcohol, 1-propanol, sodium nitrate($NaNO_3$), potassium permanganate($KMnO_4$), hydrogen peroxide (H_2O_2), and sulphuric acid (H_2SO_4). The compounds are all in their purest form.

2.1 Synthesis of Graphene Nanoparticles

Graphene oxide was prepared from graphite powder by a modified Hummers method. In our synthesis of 2gm of graphite, flakes were added to 60 ml of H_2 SO_4. The mixture was kept below 20°C using an ice bath. The entire setup was kept in a magnetic stirrer and allowed to mix. After 30 minutes, 1.5 gm of $NaNO_3$ is added pinch by pinch and stirred well. After 2 hours, 8gm of $KMnO_4$ was added to the mixture, and 50ml of deionized water was mixed drop by drop. Finally, mix 3ml of H_2O_2 with the 125ml of deionized water and the mixture was added drop by drop to stop the reaction and at last. A graphene oxide solution was obtained. To extract unexploited graphite, the resultant sample was centrifuged for 20 minutes at 8000 rpm at 25 °C. It was then cleaned several times with deionized water and ethanol, dried for 90 °C, and the resulting graphene oxide nanoparticles were collected. The graphene oxide nanoparticles which are obtained in the first step were carried out for the reduction process and the reduction process is carried out in three ways, via the Chemical, Thermal, and Photo reduction process. In this work, we have used the thermal reduction process. The graphene oxide nanoparticles were heated up to 350°C using a hotplate for nearly 6 to 8 hours and finally, we get the resultant graphene Nano sheets. [16]

2.2 Preparation of graphene-coated soda lime glass

Glass slides were washed with double distilled water and ethanol. The thickness of the glass plate is 1.35mm. Glass slides are dipped in ethanol solution and the beaker is kept in an ultrasonicator for sonication with heat for one hour. Finally, glass slides dried in an oven at 105^0C for 30 minutes. 20 ml of propanol was mixed with 0.5 g of graphene. 0.5g of PVA was mixed with 20 ml of double distilled water. Both solutions were stirred at 400 rpm for 18 hours. Mixed both solutions and stirred

was coated with a dip of coating speed 3000m/s for 20 secs and dry the glass for 5sec with a heating temperature of 80^0 C. finally the glass slides were kept in the oven at 100^0C for 24 hours. The coating cycles were 50 &100. [17]

3. Results and discussion

3.1 XRD analysis

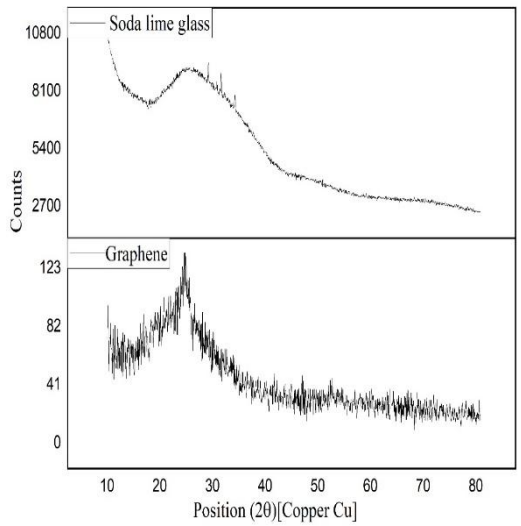

Fig1- XRD pattern of graphene and soda-lime glass

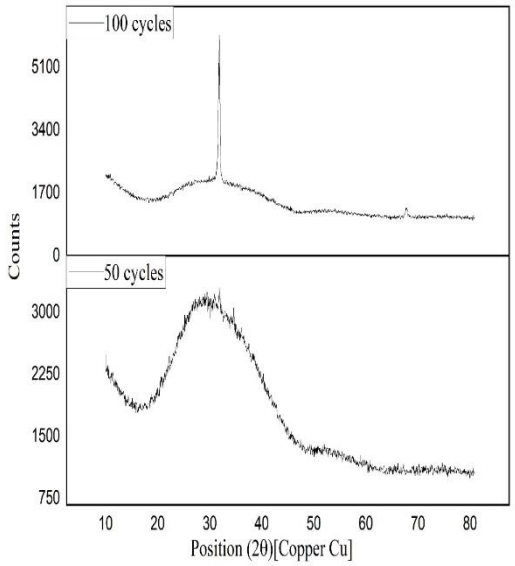

Fig-2 XRD pattern of 50 &100 cycles of graphene-coated glass

The XRD pattern of graphene and soda lime glass is shown in fig 1. Pure graphene has a diffraction peak at 24.7°, which corresponds to its highly ordered layer structure and interlayer d-spacing of 8.527A°. it shows due to thermal reduction the graphene is completely oxidized. [16&18] The XRD pattern for a pure glass substrate was obtained. The spectra were seen as intense, sharp peaks as a result of thermal treatments. It illustrates that the prominent, sharp peak of the glass pattern at 2=5° and 23.76^0 is due to the high Si component in the glass material. As would be expected for an amorphous structure, there are no peaks are associated to any crystalline phases in the XRD pattern, mostly a broad diffraction peak. [19] The XRD pattern of graphene-coated glass for shown in figure 2. In 50 cycles, the X-ray diffraction peak at 25.7^0 corresponds to the characteristic peak of graphene thin films. There is a weekend broad peak that appears. Because the glass slide for kept in the oven for one hour. In 100 cycles, the sharp peak appears at 26^0 which corresponds to graphene. The sharp peak appears due to the coating glass being kept in the oven for 24 hours. Due to the temperature, the graphene's sharp peak appears. The additional peaks were not detected because a very small amount of PVA is used. [20]

3.2 FTIR analysis

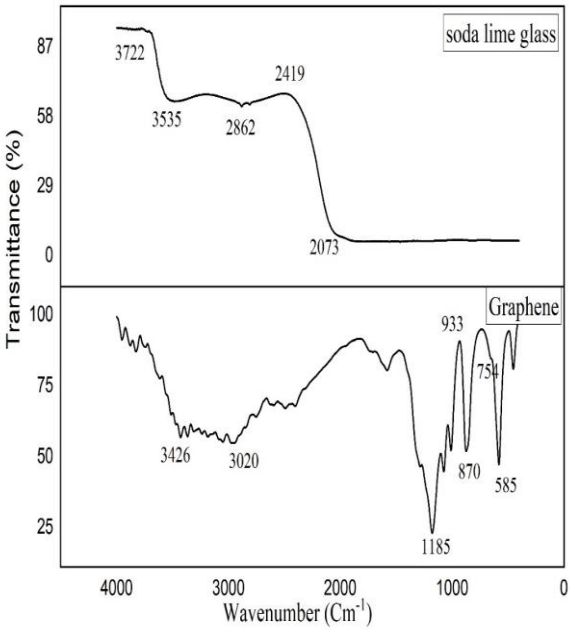

Fig 3 FTIR pattern for graphene and soda lime glass

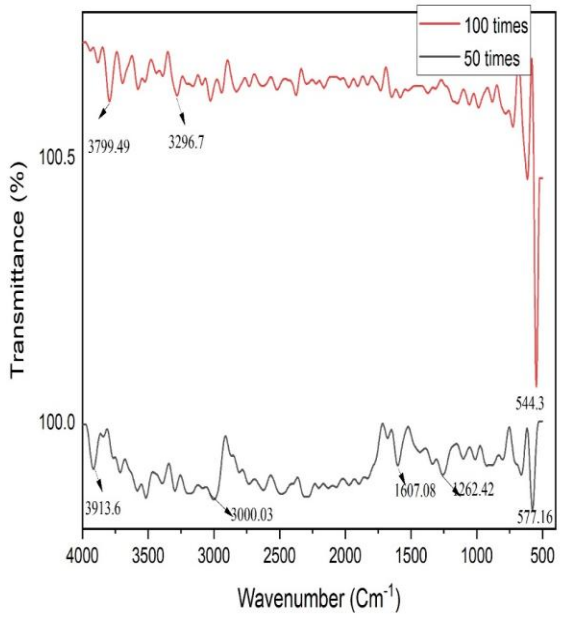

Fig 4 FTIR pattern 50 & 100 cycles of graphene-coated soda lime glass

The FTIR spectra of graphene and soda-lime glass was shown in Figure 3. The band at 3426 cm^{-1} has a carboxyl group bonded to it that was formed by water molecules. Carbon in peak 1185 cm-1 corresponds to the C-O-C stretching vibrations band caused by graphene. The oxygen reacts with the graphene. [21] the peak at 3722 cm^{-1} corresponding to the water O-H stretching band. The FT-IR spectra vibrations in the actual glass are well-defined for the infrared active modes identified at 3535 cm^{-1} and 2862 cm^{-1}. The broad bands are caused by different mixtures of mechanical scattering of samples related to the Si-OH group. The hydroxyl groups of O-H are responsible for the traditional broadband at 3535 cm^{-1}, which is caused by stretching vibrations. [22] A band that may be seen around 2921 cm^{-1} is proof that hydrogen bonds exist. As a further test, the silicon substrate's transmission in this area was incredibly low.

Figure 4 displays the FTIR spectra of 50 &100 cycles of graphene-coated glass. The stretching vibration of OH molecules is represented by the absorption peak of 3296.7 cm^{-1}. The C-H stretching vibration was assigned to the peak values of 3000.3 $cm^{-1.}$ The C=C stretching vibration is represented by the peak values of 1607.08 $cm^{-1.}$ When graphene was coated on the glass substrate, the silica bond was weaker. This shows that the graphene has adequately bonded to the glass substrate. the peak band at the carbon-silica bond is 545 cm^{-1} [23] from the figure we conclude the graphene has a transmission value of 99.7%. the soda-lime glass has a transmission value of 70-80%. When graphene coats the glass, the coating glass has a transmission value near 100%.

3.3 UV analysis

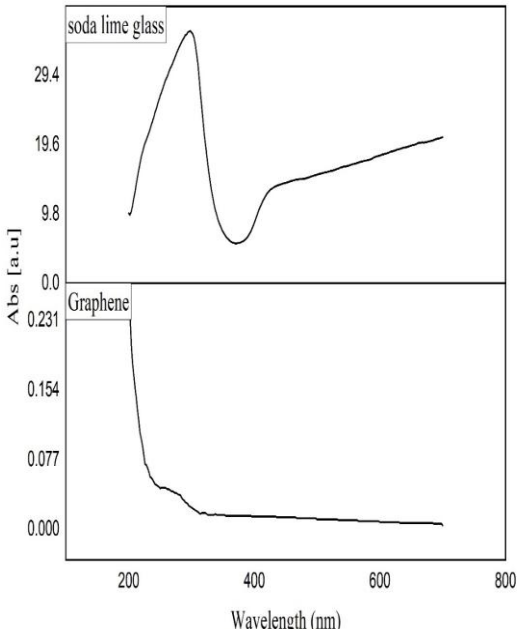

Fig 5 Wavelength Vs absorbance spectrum for graphene and soda lime glass

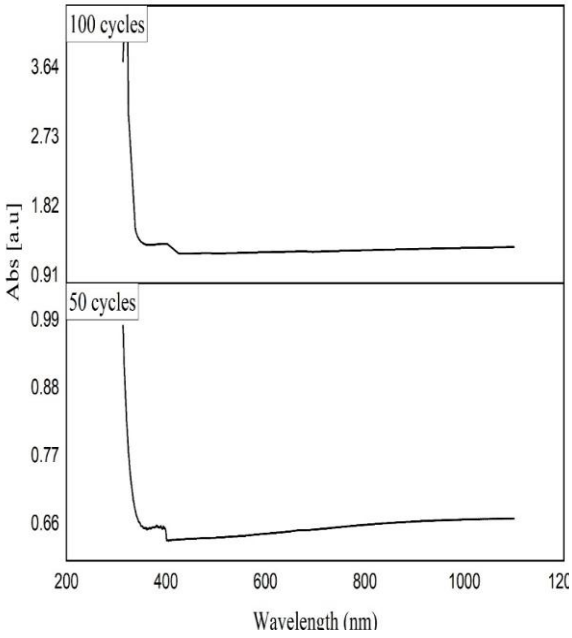

Fig 6 Wavelength Vs absorbance spectrum for 50 cycles of graphene-coated glass

Near ultraviolet cut-off wavelengths for graphene, pure glass, and glass that has been coated 50 cycles and 100 cycles are around 250nm, 296nm, 346nm, and 347nm respectively. The ultraviolet regions have strong absorption spectra and show a consistent drop in the visible region. Glass composition and ion concentration variations cause the absorption spectra to vary. The atoms that form networks are lacking from silica. There are few connections between the atoms that compose the network. [26] The absorption spectra of 50 cycles coated materials show C=O bond n-n* transitions. In the absorption spectrum for 100 cycles coated, the graphene surface groups were covalently linked patterns, based on the peak transition of the π=π*. [31]. The C=C bonds in the coated glass are represented by the peak transition n-π*. The bandgap energy for pure glass and graphene is 3.5 eV and 4 eV. the bandgap value for 50t and 100t graphene-coated glass, is around 3.57 eV and 3.58 eV. The band gap value varies as a consequence of Non-bridging oxygen. [33-34]

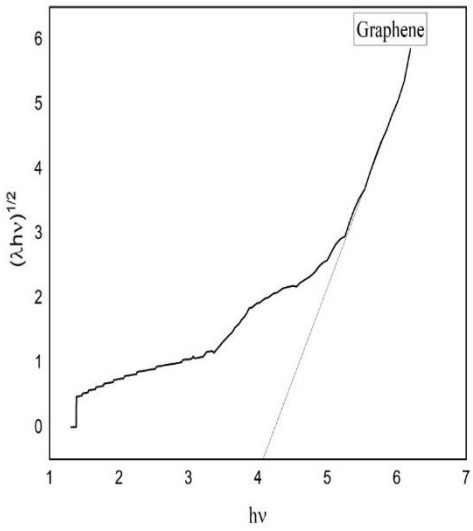

Fig 7 Tauc's plot for graphene

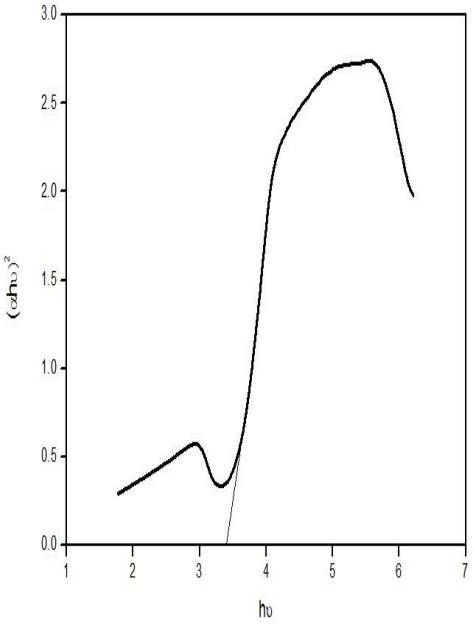

Fig 8 Tauc's plot for glass

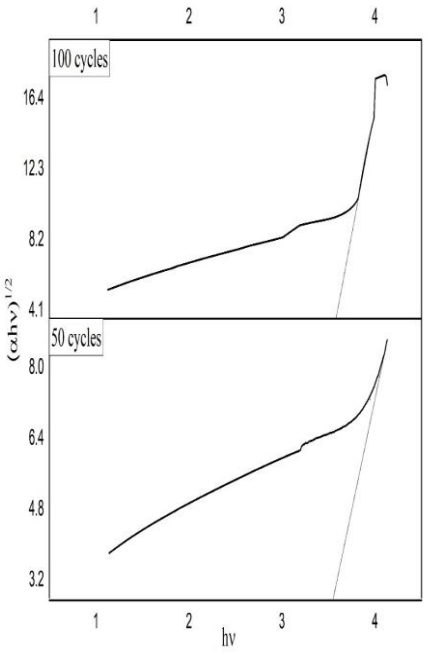

Fig 9 Tauc's plot for 50 and 100 cycles of graphene-coated glass

3.4 SEM Analysis

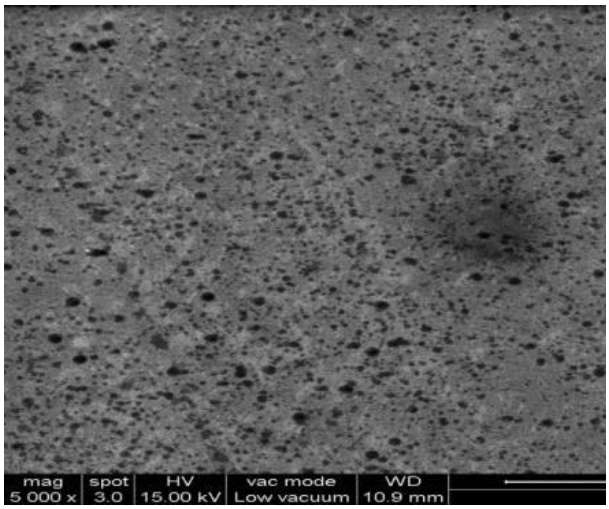

Fig 10a SEM images of glass

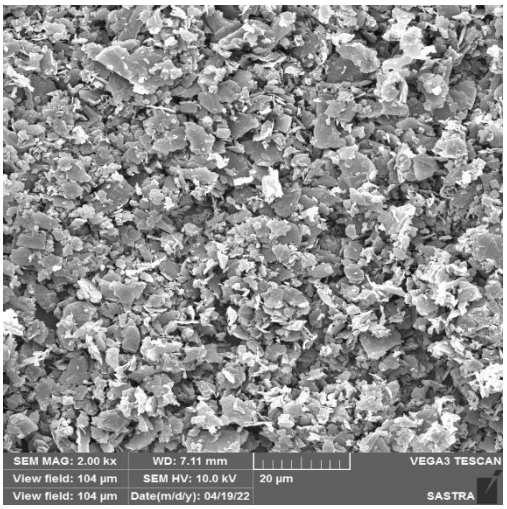

Fig 10b SEM images of 50 cycles of graphene-coated glass

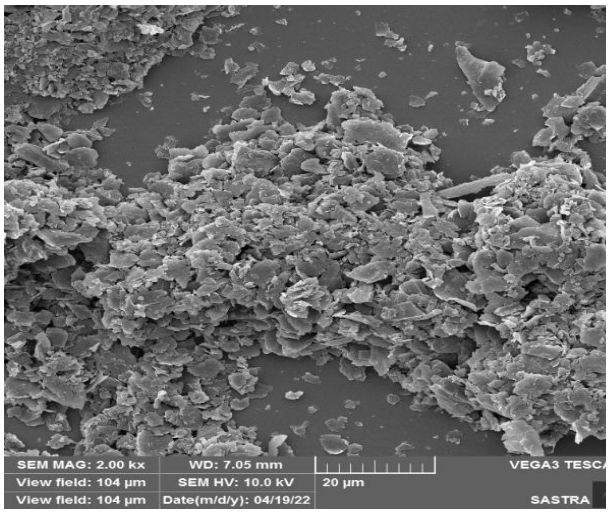

Fig 10c SEM images of 100 cycles of graphene-coated glass

The irregularity of the atoms is visible in the surface morphology of glass shown in fig 10a. The misallocation of the atoms reveals the amorphous nature of the glass The images clearly illustrate the samples' porosity and mechanical strength were evaluated. By using SEM examination, the surface morphology of glass coated with graphene was shown in Figures 10b&10c. It shows graphene that has been deposited on glass. The glass had graphene on it, which has several surface morphologies depending on the heating temperature.

3.5 Contact Angle

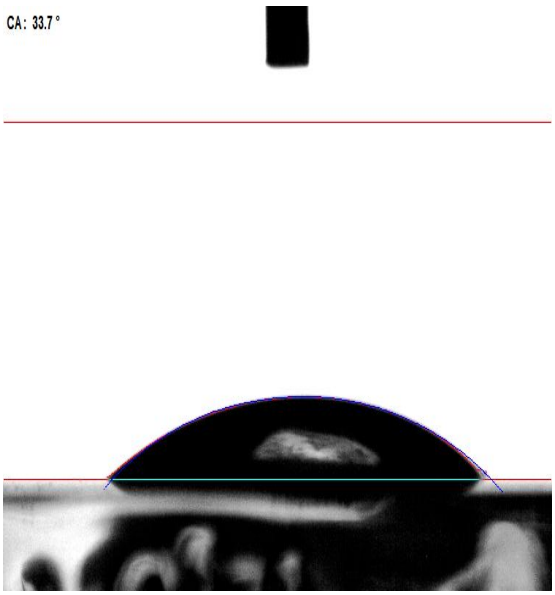

Fig 11a contact angle for glass

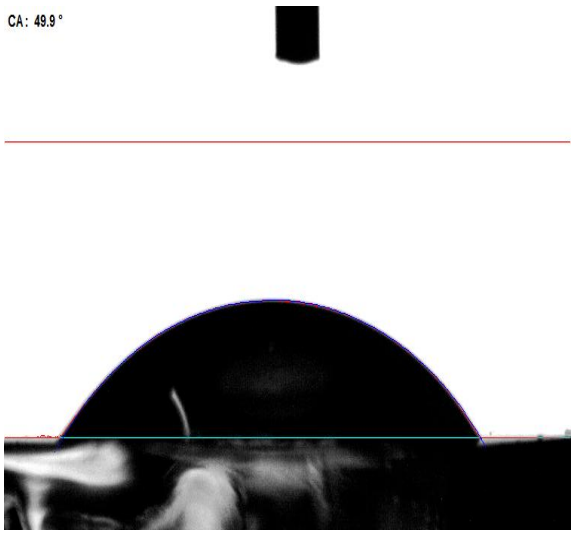

Fig 11b contact angle for 50 cycles of graphene-coated glass

Fig 11c contact angle for 100 cycles of graphene-coated glass

Figure 11a–c displays the contact angle images of uncoated and coated with graphene glass. The contact angle value of pure glass is 33.7. graphene-coated 50 cycles and 100 cycles contact angle value is 49.9 and 54.2 respectively. The contact angle meter was used to measure wettability. When graphene is coated, the angle changes from 33.7 for pure glass to 49.9 for graphene-coated glass. As the number of graphene coating cycles increases, it also raises the contact angle value.

4. Conclusion

Graphene was produced using the Hummers modified process. The graphene on the glass was coated using the dip-coating technique with 50 and 100 coating cycles. To assess the structural, morphological, and optical characteristics of the manufactured samples, a variety of characterization techniques were applied. The peak of the XRD spectrum revealed the graphene and soda lime glass. The stretching and bending vibrations of graphene and soda lime glass are confirmed by FTIR. Due to non-bridging oxygen, the energy band gap value for glass varies from 3.5 eV to 3.58 eV, as revealed by UV- Visible spectroscopy. SEM confirmed the morphology of the graphene that has been deposited on the glass. In relative to pure glass, graphene-coated glass has a greater contact angle value.

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