Electronic Supplementary Material (ESI) for Journal of Materials Chemistry C.

Supporting Information

Optical and electrical effects of thin reduced graphene oxide layers on textured wafer based c-Si solar cell for enhanced performance

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Polished silicon is dipped in aqueous solution of Graphene oxide and amine functionalized af-RGO and dried in vacuum at room temperature to make thin films. Wettability was measured with water through contact angle study using Drop Shape Analyzer (KRUSS GmbH – DSA25) instrument. The presence of hydroxyl and oxygen group, attached majorly with the edge and the basal plane of the graphitic phase of the graphene oxide (GO) made the surface of the GO hydrophilic in nature, producing an angle 45.2° with the surface of the GO, shown in figure SI1.a.

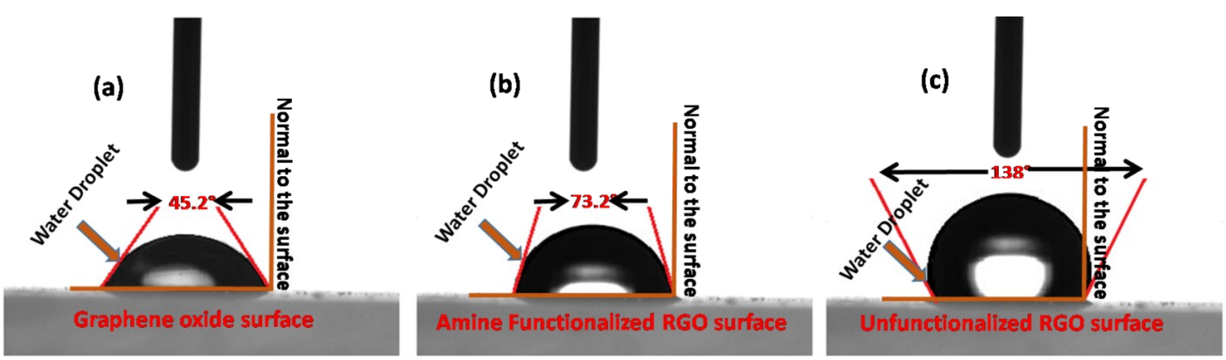
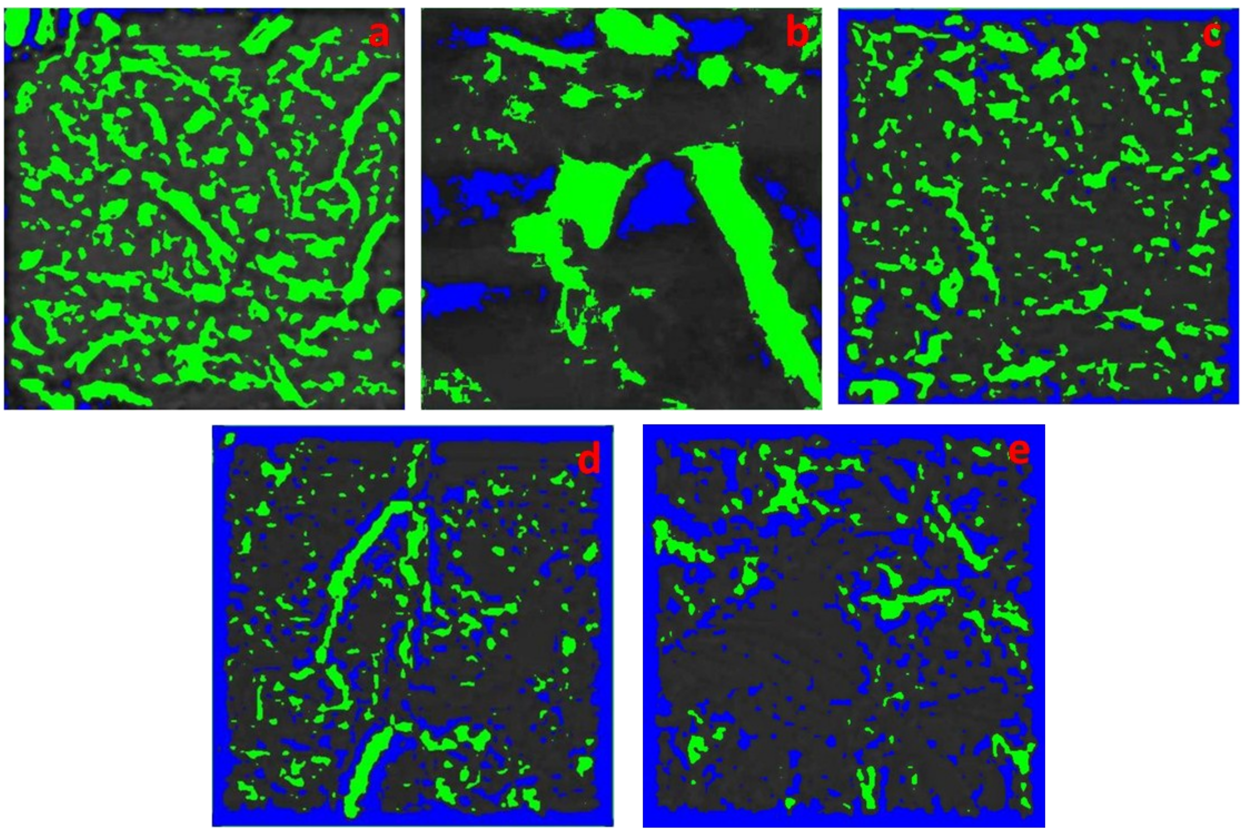


Figure SI1. Drop test showing the different contact angle for a) graphene oxide surface and b) amine functionalized RGO surface and c) unfunctionalized RGO surface [1].

The nucleophilic substitution of primary amine group in the place of hydrogen in hydroxyl group and epoxy group enhances the nature of hydrophobicity of af-RGO and this can be confirmed by the wettability test of the functionalized RGO because the contact angle measured 73.2° to the surface (SI1.b). Contact angle of amine functionalized RGO measuring 73.2° suggests the presence of primary amine in the network (majorly at the edge of the network) [1, 2].whereas the unfunctionalized completely reduced RGO shows higher hydrophobicity than GO and af-RGO [1] (Figure SI1.c).



FigureSI2: Colour mapping of uncovered area (Blue zone), agglomerated af-RGO coated area (Green zone) and planner bi/tri layered RGO coated area (Black zone). a), b), c), d) and e) showing the coverage area of the sample S1 (90%RGO+10%DI water), S2 (70%RGO+30%DI water), S3 (50%RGO+50%DI water), S4 (30%RGO+70%DI water) and S5 (10%RGO+90%DI water) respectively.

Figure SI2 depicts the uncovered area (blue), area covered with ~ 2nm thick planner af-RGO (black) and area covered with agglomerated af-RGO more than 2nm thicknesses, corresponding to the height profile of AFM images (Figure 4) with different area coverage are mapped by image J software (version: 1.50d; a Java-based image processing program developed at the National Institutes of Health, USA).

Colour distribution mapping in figure SI2.a, figure SI2.b, figure SI2.c, figure SI2.d and figure SI2.e represents the surface coverage by three individual entities (uncovered (blue zone), planner af-RGO (black zone) and agglomerated af-RGO (green zone)) of respective af-RGO diluted solution coating (S1, S2, S3, S4 and S5) on polished silicon wafer. Individual colour is a measure of thickness for the three individual entities like uncovered zone (considered height ranging from All the considered AFM two dimensional (2D) images has been converted to 16 bit images, where $2^8 \times 2^8$ pixels matrix actually presenting the image. Generally, pixels with intensity 0 and 65,536 are black and white respectively. All the other pixels with values greater than 0 and less than 65,536 come under the regime of intermediate grey and/or colour scale. In order to set a threshold value of every disjoint segment in the image, representing various particles have upper and lower limit of threshold value. The particle and/or disjoint area having frequency within the set specific limit, accounted within the specific kind of set showing a specific colour. This can be done by adjusting lower and upper limit of threshold values. During the time of thresholding, a histogram (distribution of pixel intensities), we incorporated the upper and lower limit of the set frequency of the pixels and the selected area showing selected colours [3].
0nm to ~ 0.2nm), planner af-RGO film (considered height ranging from 0.3nm to 2nm) and agglomerated af-RGO cluster zone (considered height ranging from 2nm and above) and the threshold has been assigned accordingly. The coloured areas were taken under the consideration and the said areas are calculated with respect to the frame size.
From the figure SI2.c, it can be suggested that the planner af-RGO has obtained the best coverage, while sample S3 coated on the textured and polished silicon wafer. While the maximum and minimum uncovered af-RGO zone can be found in the corresponding ImageJ mapping of sample S1 and S5 in figure 4A (Column a and b) and figure 4C (Column a and b), which further supported by ImageJ distribution mapping in figure SI2.a figure SI2.e. Highest agglomeration for S1 and least agglomeration for sample S5 has been found and shown in scheme figure 4 (Row A (Column c)) and figure 4 (Row C (Column c)) respectively. Thus by controlling the dilution of af-RGO,

sample S3 on coating on silicon wafer is found to be the highest coverage of planner af-RGO sheet with less agglomeration, which is crucial for the solar cell application and can be correlated by figure SI2.c.

Easy and potential standard hot probe technique has been practiced by many researchers to discriminate between p-type and n-type semiconductor using a heated probe and a multimeter. This kind of experiment is carried out by connecting hot probe to the positive terminal of the meter and negative terminal is kept unheated. While applying hot probe in the positive terminal voltage read positive for n-type material and negative for p-type material [1]. Majority free charges at the hot probe attain thermal excitation, which drives the majority charges sweep away from the point, making the point opposite to the nature of material.

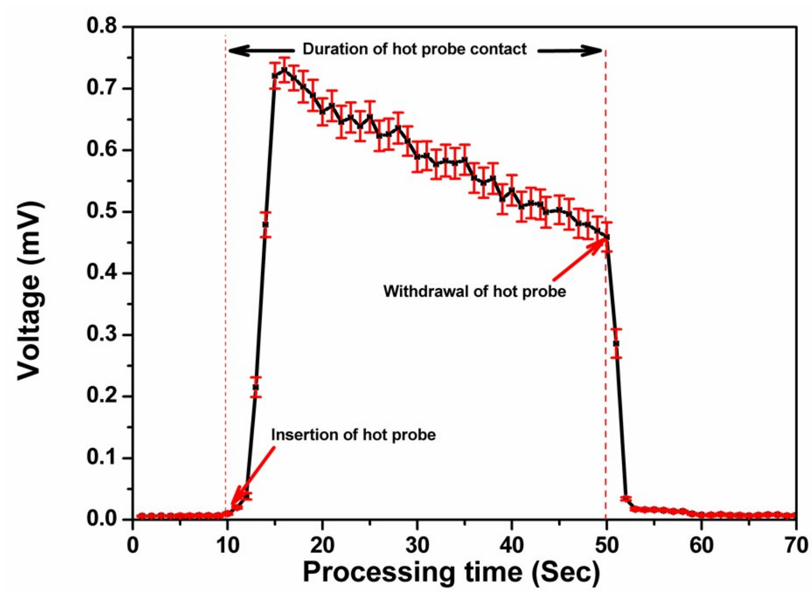


Figure SI3. Thermoelectric (hot probe) test showing the doping type of synthesized amine functionalized af-RGO.

Opposite charges retained at the place near hot probe while the zone in touch with the other probe consists of majority charges, which creates a potential difference between two probed points. A glass withtwo gold electrodes at centre was dip coated in af-RGO solution (separation between two electrode is 500µm) to get the continuity. The two probes are kept on two different electrodes making a distance of 10mm in between. The two probes are connected to Agilent automatic test station (U3606A Multimeter/DC power supply) to measure the corresponding voltage and current. When a soldering iron with its maximum heating (450°C) has been touched to the positive terminal of the hot probe, a steep rise in voltage has been noticed and keeping it for another 40sec., a sharp fall of the voltage graph is observed (Figure SI3). Positive rise in voltage can be noticed after touching the positive terminal by hot probedue to potential difference created between two touching point. Near hot probe positive charges accumulated and at the other probe negative charges have been accumulated, which measures a positive voltage in between. After withdrawal of hot probe, thermally created minority charges again recombined and localized potential difference (developed due to hot probe) diminished. Sharp gradient of voltage rise and fall can be co-related as generation and recombination of minority charges, which is almost same [4-5].

Reference:

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