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# Desalination of Seawater Using Graphene oxide Membrane

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ABSTRACT

Water a limited definite resource, vital for every existence of life on earth necessity for economic, social development and for environmental sustainability. Over 1.2 billion of people lack the access to portable water. The use of graphene oxide as the membrane in desalination plant can overcome the drawback of high capital and energy requirements as compared to all other process. Graphene oxide has good hydrophilicity and it has been used in thin films for water treatment in recent years. In this paper, the development and application of graphene membrane in water treatment is discussed. The production methods of graphene oxide membrane are reviewed.

**Keywords:** Water, Graphene, Graphene Oxide.

## 1. INTRODUCTION

In past few decades, membrane based technology has been an interesting topic in the research field. Advanced membranes with superior selectivity and permeability are essential to the development of membrane based technology. Polymeric membrane has governed the membrane technology market, including real world application and academic research, owning to its advantages of energy efficient, easy operation, low cost and simplicity. Restrictions of polymeric membranes still exists for most practical applications because most of them tend to foul, have low resistance to chlorine, strong acids, high temperature and suffer from aperture shrinkage under high pressure [1].

Graphene is an allotrope of carbon material, a two dimensional honeycomb lattice structure, and single layer atomic thickness [2]. The special structure of graphene has excellent mechanical properties, high electrical properties, excellent thermodynamic properties and large specific surface area.

There is a strong Van Der Waal's force between the graphene sheets which leads to the difficult application of graphene materials directly. The most common derivative of graphene is graphene oxide. When graphene is dispersed in water, the carboxyl group is hydrolyzed to negatively charged acid and hydrogen ions to form stable oxidized graphene dispersion. Researchers enabled the new properties of graphene through different modification methods [3]. The modified graphene can not only prevent the agglomeration of the lamellae in the solution, but also can be prepared by spray coating, spin coating, dip coating and layer by layer method. In this paper, preparation method of graphene oxide membrane is reviewed, and the research progress of graphene membrane in water treatment is reviewed.

## 2. PREPARATION OF GRAPHENE OXIDE

The synthesis of graphene oxide is two step procedure: first is oxidation of graphite and graphite oxide as shown in fig 1 [3]. Many methods have developed for the preparation of graphene oxide. These methods are discussed below. Graphene oxide [GO] is first synthesized by Brodie [12]. In this procedure first graphite is repeatedly oxidized by concentrated fuming nitric acid [$HNO_3$] with potassium chlorate [$KClO_3$] as the oxidant for 3-4 days [3] with C:O was 2:1. This procedure is time consuming and also generates toxic gas [$ClO_2$] which is unsafe and harmful to surrounding environment.

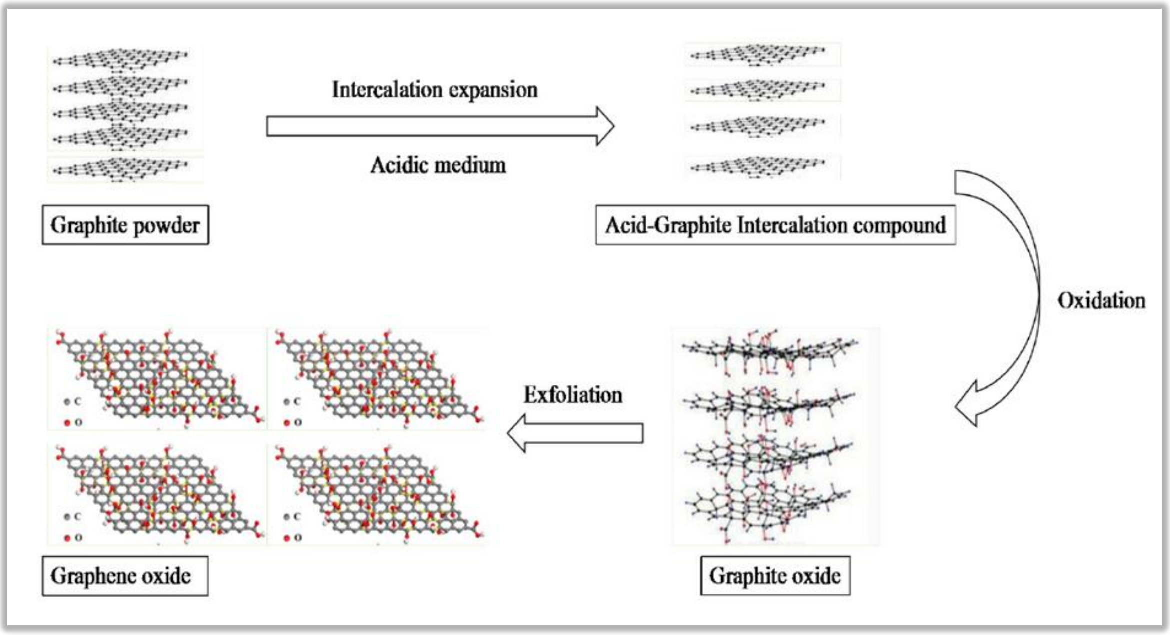


**Fig 1.** Preparation of GO [4]

In the year 1937, Brodie's method was modified by Hofmann by substituting fuming $HNO_3$ with non-fuming $HNO_3$ during oxidation process [3]. This process also took 4 days for complete production of GO, after 20 years, hummer modified the process by substituting $KMnO_4$ as oxidant with $NaNO_3$ and $H_2SO_4$, here GO was produced in less than 2 hours and also it produced toxic gases like to environment like $NO_x$ and $Mn^{+2}$ metal ion. Further it was modified with adding $K_2S_2O_8$, $H_2SO_4$ and $P_2O_5$ along $KMnO_4$ with $80^0$ C. in this process, highly GO was produced along with $Mn^{+2}$.

| Oxidant | Method | Acid | Reaction time | C : O | Note | Reference |
|---|---|---|---|---|---|---|
| **$KClO_3$** | Brodie | $HNO_3$ | 3-4 days | 2.16 | Toxic gas $ClO_2$ | [5] |
| **$KClO_3$** | Hofmann | $HNO_3$, $H_2SO_4$ | 4 days | - | Toxic gas $ClO_2$ | [6] |
| **$KMnO_4$** | Hummer's | $NaNO_3$, $H_2SO_4$ | 2 hours | 2.25 | Toxic gases $NO_x$, $Mn^{+2}$ | [7] |
| **$KMnO_4$** | Modified hummer's | $K_2S_2O_8$, $H_2SO_4$ and $P_2O_5$ | 8 hours | 2.3 | - | [8] |
| **$KMnO_4$** | Improved hummer's | $H_2SO_4/H_3PO_4$ | 1hour | - | $Mn^{+2}$ in GO | [9] |

**Table 1.** Comparison of methods of GO [4].

In order to develop more efficient and safer ways for production of GO Marcano et.al [9] proposed improved hummer's method in 2010 with $H_2SO_4/H_3PO_4$ with $KMnO_4$ as oxidant [3]. This process generated no toxic gas and also produced large scale of GO. But in all the cases $Mn^{+2}$was produced in trace quantity so, $KMnO_4$ was replaced by $K_2FeO_4$ as strong oxidant for the preparation process. In the production of GO membranes, we use improved hummer's method and the membrane are prepared by different methods.

## 3. PREPARATION OF GO MEMBRANE

Firstly prepared GO is added to deionized water to obtain oxidized dispersion through the ultrasonic and stirring [5], which give exact surface for GO membrane. The main methods of GO membranes are vacuum filtration, spray coating, dip coating and spin coating [5]. These methods require energy and the operation is simpler [3]. Here GO membrane thickness is uniform so it can easily transferred to other substrates.

### *3.1 Vacuum filtration*

Vacuum filtration process is most commonly used method for preparation of GO membrane. In this process specific concentration of GO solution is taken and deposited on to a membrane and sent for vacuum filtration. After filtration process, the membrane obtained on which GO is uniformly distributed and change in concentration of GO can change the thickness of GO membrane. By this process, the membrane obtained is flat by the equipment limitation and size of graphene oxide membrane is relatively small, so it is difficult to obtain in large number [3]. Here thickness of GO membrane is less than 100nm.

### *3.2 Spray coating method*

In spray coating method by using spray equipment, the GO solution is uniformly sprayed over membrane. This process is very efficient for the large scale production compared to vacuum filtration but the uniformity of membrane is low due to the equipment spraying [3].

### *3.3 Spin coating method*

In spin coating method the substrate will be spinning, on that GO solution is sprayed uniformly, the obtained GO membrane is dried [5]. At the different rpm speeds the substrate speed is adjusted, it is seen that at 1600 rpm the desired GO film is obtained on the substrate [3].

### *3.4 Dip coating method*

Dip coating method is just immersing the substrate in GO solution by using the machine. The control of Go film is done by controlling temperature, concentration and pulling speed of solution [3]. This method can be efficient compared to other methods and desired film can be obtained.

GO membranes are prepared from above methods. These membranes are fabricated like normal membranes in plant. As known hydrated diameter of ion ($Na^+$= 0.72nm, $K^+$= 0.66nm) in water is larger than the effective size of water molecule (0.26). By this all the salt ion gets rejected. Even the diffused gases in water can't penetrate through membrane as the membranes are impermeable to gases.  The GO membrane are stacked on top of each of each other like bundle, the presence of hydroxyl, epoxy, groups offers spacing between the membranes. By this process purity of water is upto 95% to 98%.

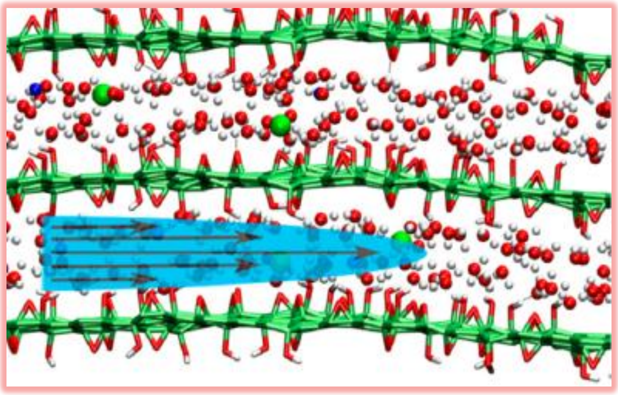

**Fig 2a)** Water flow between GO membranes [10]

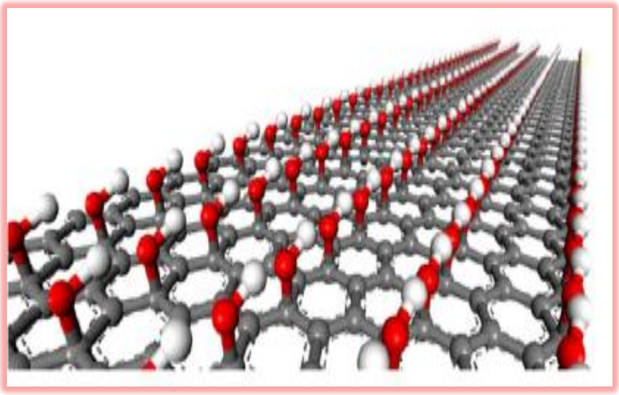

**Fig 2b)** Structure of GO sheet

## 4. CONCLUSION

Graphene based membranes have become most preferred candidates to next generation membranes due to coupling of high selectivity and permeability. However, it is not excepted that to uptake of graphene-based membranes may occur in the short term, as industrial membranes employed within current desalination processes must satisfy many additional criteria, and the novel desalination processes needed to take full advantages of the novel membranes are still to be designed. Based on unique single atom thick and 2D structure with an excellent physicochemical property, GO as an emerging Nano building material has attracted great interest in membrane based separation field [5]. The further progress of graphene-based membranes requires a more systemic approach in addition to basic material research. The design of novel desalination processes is of paramount importance for the uptake of graphene, that otherwise may not deliver the sought improved cost-to-benefit ratios within today's processes.

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