



The graphene derivative may contain a large number of hydrophilic groups. The number of hydrophilic groups contained in a graphene derivative may be determined, for example, by neutralization determination. Such determination may be difficult if the water-solubility of a graphene derivative is low. The hydrophilicity of a graphene derivative may be evaluated by determining the oxygen content of the graphene derivative. Carboxyl groups and hydroxyl groups are introduced by an oxidation reaction, and the number of carboxyl groups and hydroxyl groups contained in a graphene derivative may be assumed to be proportional to the oxygen content of the graphene derivative.

According to the present example embodiment, the oxygen content of a graphene derivative may be equal to or greater than about 1 wt %, for example, equal to or greater than about 3 wt %, or equal to or greater than about 5 wt %. Maintaining oxygen content within this range may help provide sufficient solubility to an alkali developer, e.g., a 2.38% aqueous tetramethyl ammonium hydroxide (TMAH) solution, which may be used in a resist pattern formation process.

According to the present example embodiment, oxygen content may be equal to or less than about 30 wt %, for example, equal to or less than about 15 wt %, or equal to or less than about 10 wt %. If oxygen content is excessively high, the graphene skeleton may be damaged to a large extent by an oxidation reaction, which may lead to reduction in extreme UV light transmission effect. The oxygen content of a graphene derivative may be determined by Energy Dispersion X-ray Spectroscopy (EDS) or Wavelength Dispersion X-ray Analysis (WDS).

The weight average molecular weight of the above graphene derivative may be, for example, about 1000 to about 20000, or about 2000 to about 5000, and the composition for forming a topcoat layer may have favorable coatability.

Various kinds of graphene derivatives and graphene oxides as mentioned above are commercially available. Examples include TimesGraph™ (manufactured by TimesNano Co.), G-Gosi and Sol-GoGo (manufactured by Graphos Co.), Rap Go and Rap b Go (manufactured by NiSiNa Materials Co.).

The content of the graphene derivative in the composition for forming a topcoat layer may be controlled according to the optical and gas-barrier characteristics desired of the topcoat layer, and may be about 0.01 to about 10 wt %, for example, about 0.5 to about 5 wt %, based on the total weight of the composition. The graphene derivative may function as a film-forming component by itself, rather than as an additive used in combination with a film-forming polymer for the topcoat layer, and in the composition for forming a topcoat layer, all the solid contents may be attributed to the graphene derivative.

The composition for forming a topcoat layer according to an embodiment contains a solvent, which may uniformly dissolve or disperse the above graphene derivative and, may include, polymers and additives. Examples of the solvent include:

- mono-alcohols, such as, methyl alcohol, ethyl alcohol, isopropyl alcohol, and methyl isobutyl carbinol;
- polyols, such as, ethylene glycol and glycerol;
- alkyl ethers of polyols, such as, ethylene glycol monomethyl ether, ethylene glycol monoethyl ether and propylene glycol monomethyl ether;
- alkyl ether acetates of polyols, such as, ethylene glycol monomethyl ether acetate and ethylene glycol monoethyl ether acetate;
- ethers, such as, diethyl ether and dibutyl ether;
- cyclic ethers, such as, tetrahydrofuran;
- hydrocarbons having 12 or less carbon atoms, such as, n-hexane, n-octane, and cyclohexane;
- aromatic hydrocarbons, such as, benzene and toluene;
- ketones, such as, acetone and methyl ethyl ketone;
- esters, such as, methyl acetate, ethyl acetate, and ethyl lactate; and water (for example, that may have low solvency to resist patterns).

Some organic solvents highly dissolve resist patterns. If such solvents are used, such solvents may be mixed with solvents having low solvency to resist patterns, for example, with water.

The composition for forming a topcoat layer may comprise only the graphene derivative and the solvent. The