

# Reduction of Graphene Oxide Using Solution Plasma



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## Introduction

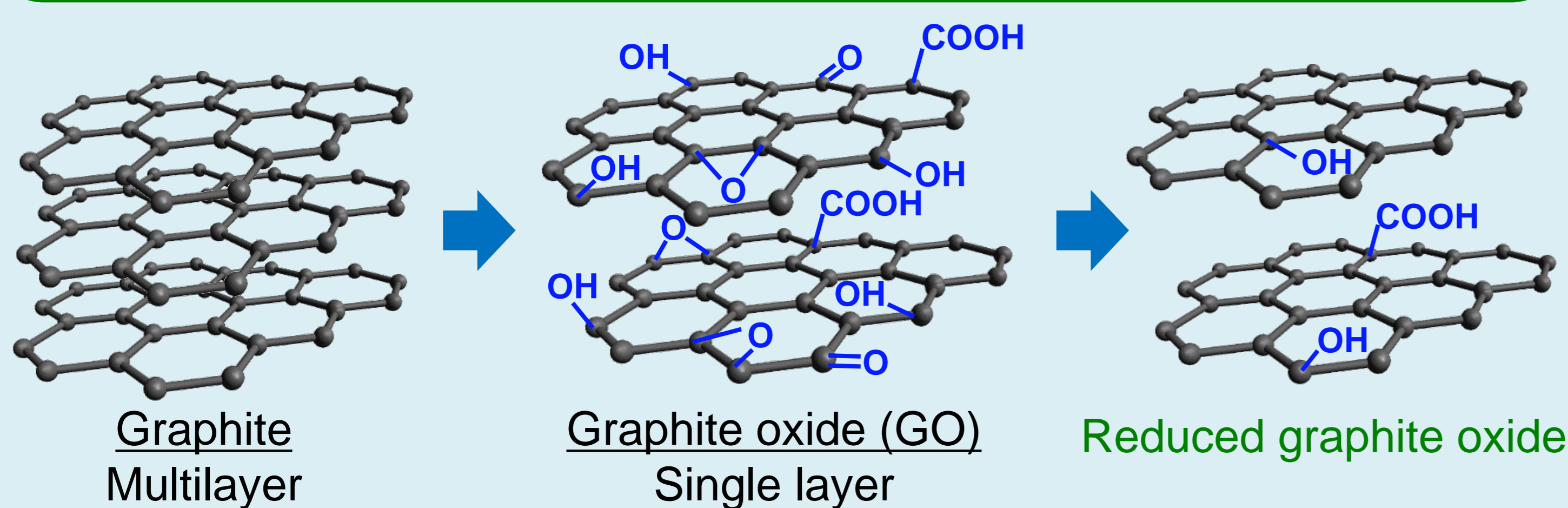
Graphene oxide (GO) was reduced by reductive radicals generated in liquid using the solution plasma method. The modification of the oxygen functional groups, the oxygen content, and the binding state of the carbon atom in GO were investigated using Fourier transform infrared spectroscopy (FT-IR) and X-ray photoelectron spectroscopy (XPS). The amount of oxygen functional groups including hydroxyl, carbonyl, and carboxyl groups decreased after plasma treatment. The ratio of carbon atoms to oxygen atoms in GO structure (C/O) increased from 2.53 to 2.75 with aqueous solution, and to 3.67 with ethanol solution.

## Objectives

### Reduced Graphene Oxide

- Cheap and mass producible material compared with graphene.
- Produced through the reduction of graphene oxide (GO), which is chemically synthesized from natural graphite.

Applications : Electrode of super capacitor, Catalyst of fuel cell



### Conventional reducing methods in liquid

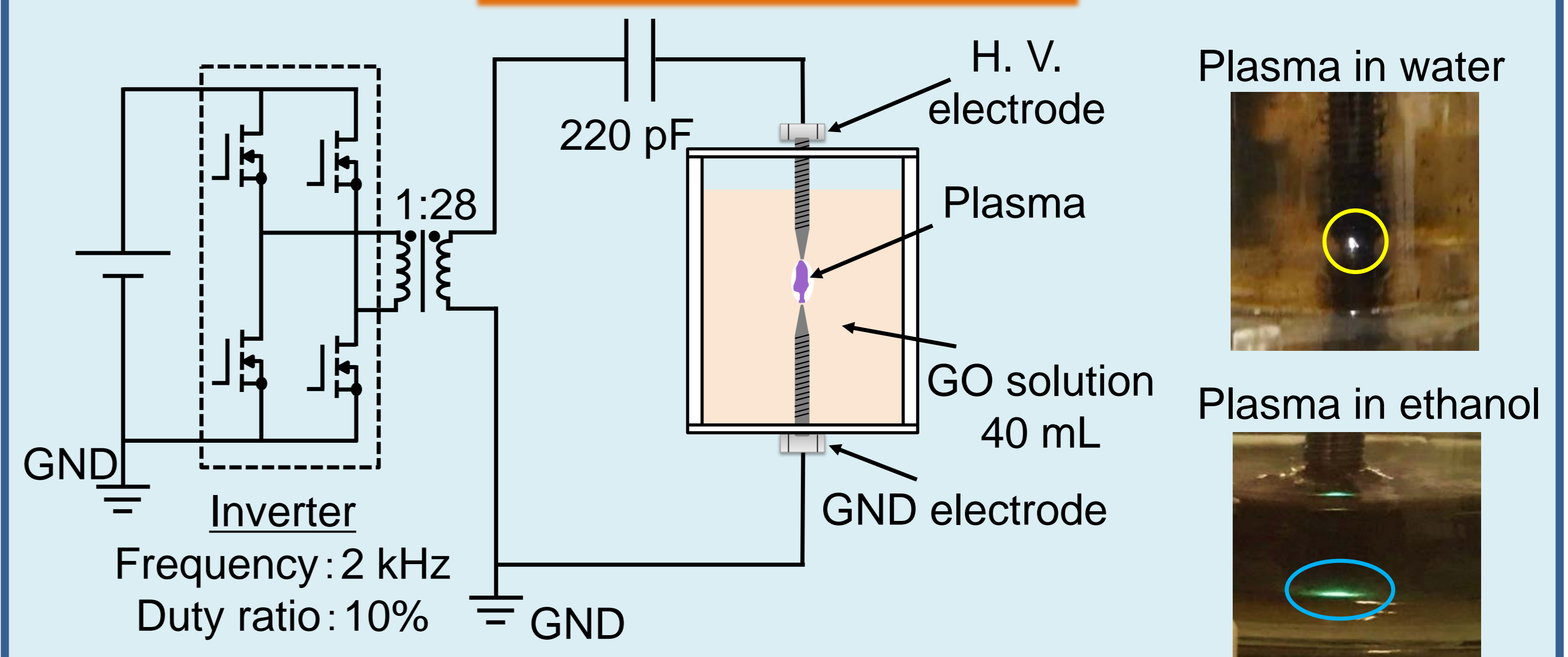
- Chemical reduction ( $N_2H_4$ ,  $NaBH_4$ )
- Solvothermal reduction

### Solution Plasma Method

- ✓ Solution plasma is eco-friendly, energy-efficient, and can be done at normal temperature and pressure.
- ✓ GO is reduced by reactive species. And the reactive species to be generated depend on the solvent.

Investigation of reduction characteristics in various solvent is required.

## Methods

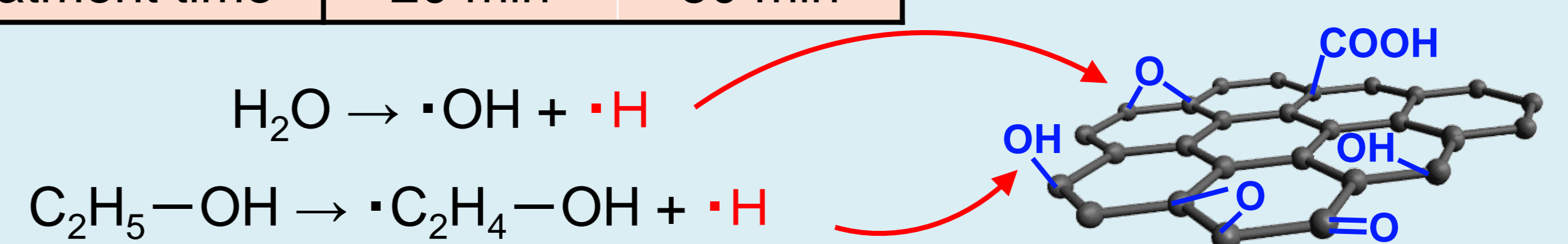


### Experimental Conditions

Solvent	Pure water	Ethanol
GO concentration	50 mg/L	100 mg/L
Conductivity	19 $\mu$ S/cm	2.5 $\mu$ S/cm
Gap distance	2 mm	1 mm
Output voltage	6 kV	4 kV
Input power	33 W	5.2 W
Treatment time	20 min	50 min

### Plasma generation process

1. Voltage is applied between two electrodes.
2. Solvent is heated and bubbles are produced.
3. Breakdown occurs in bubbles and plasma is generated.



## Results and Conclusions

### 1. State of graphene oxide solution



A : GO in pure water

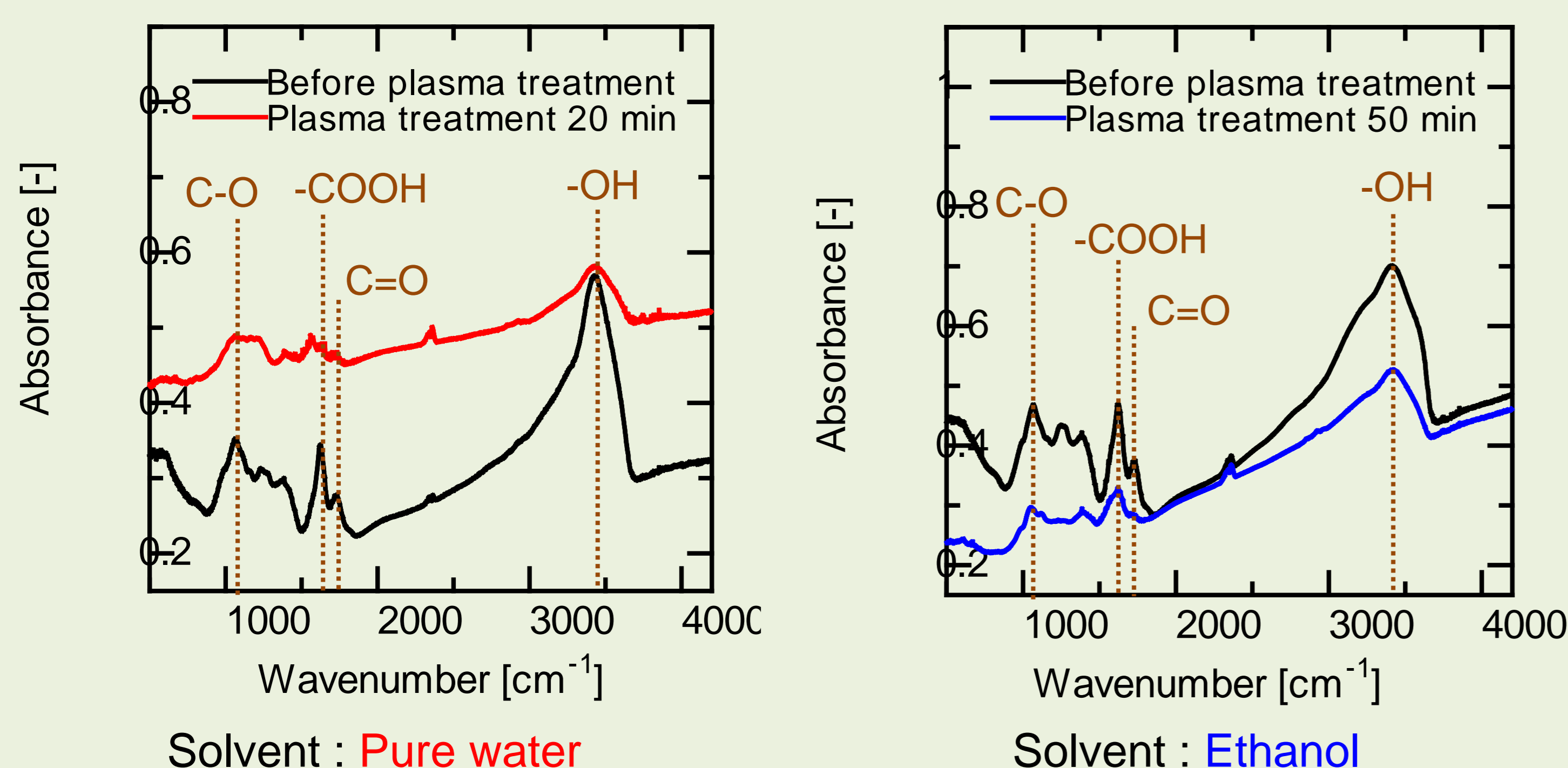
B : After plasma treatment 20 min

C : GO in ethanol

D : After plasma treatment 50 min

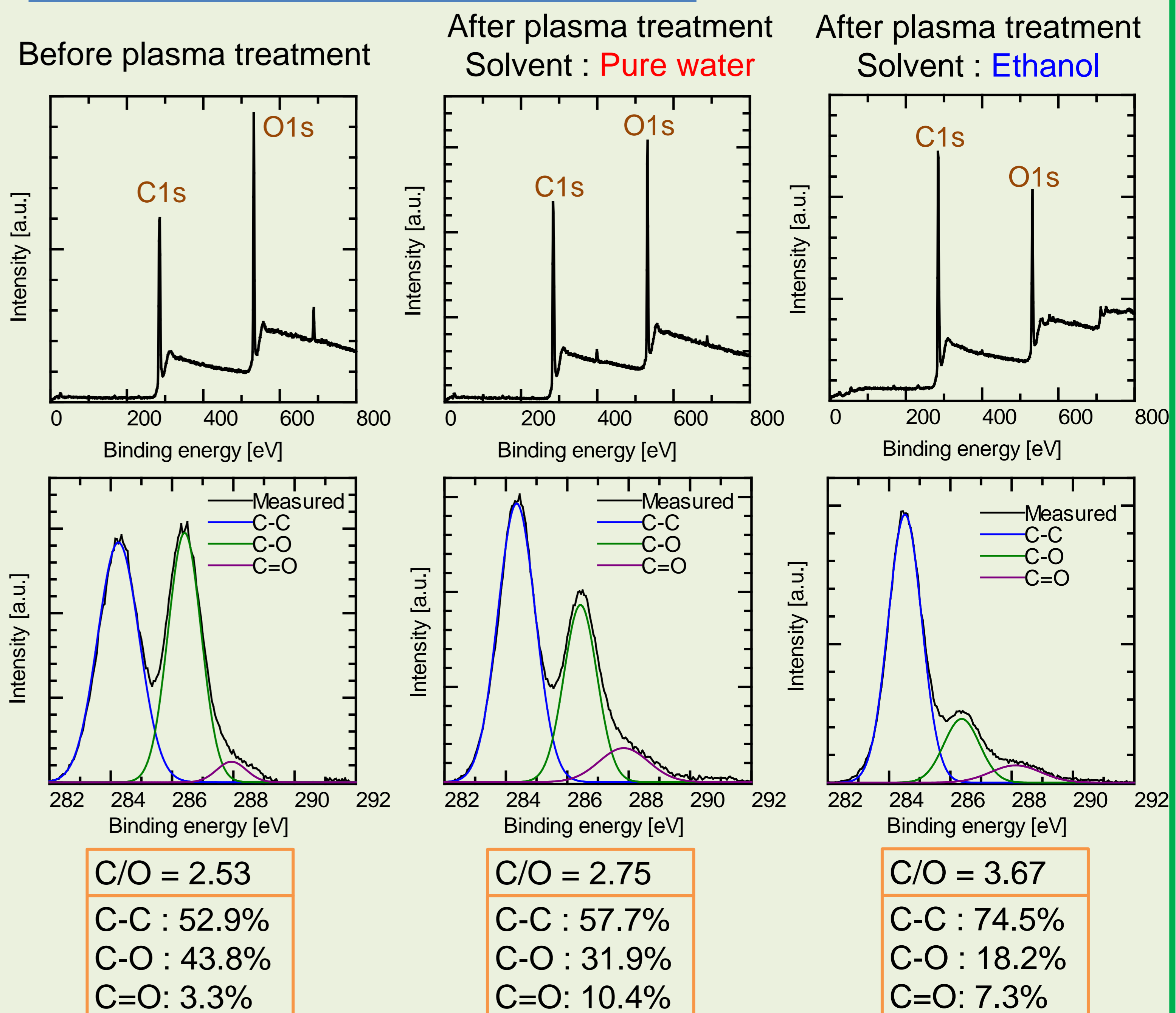
The color change of GO solution from brown to black indicates the structural change in GO through the reduction process.

### 2. FT-IR spectra



Intensity of some oxygen functional groups decreased after plasma treatment, which indicates the removal of oxygen atoms from GO.

### 3. XPS survey spectra and C1s spectra



- ✓ The atomic ratio (C/O) and the proportion of carbon to carbon bond (C-C) in GO increased in both solvent.
- ✓ Reduction rate is considered to increase by extending the plasma treatment time or by increasing the input power.