Supporting Information

Comparative Study on Formation and Oxidation-Level Control of Three-Dimensional Conductive Nanofilm for Gas-Sensor Applications

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*E-mail: (J.S. Lee) junseop@gachon.ac.kr; Tel.: +82-31-750-5814; Fax: +82-31-750-5389

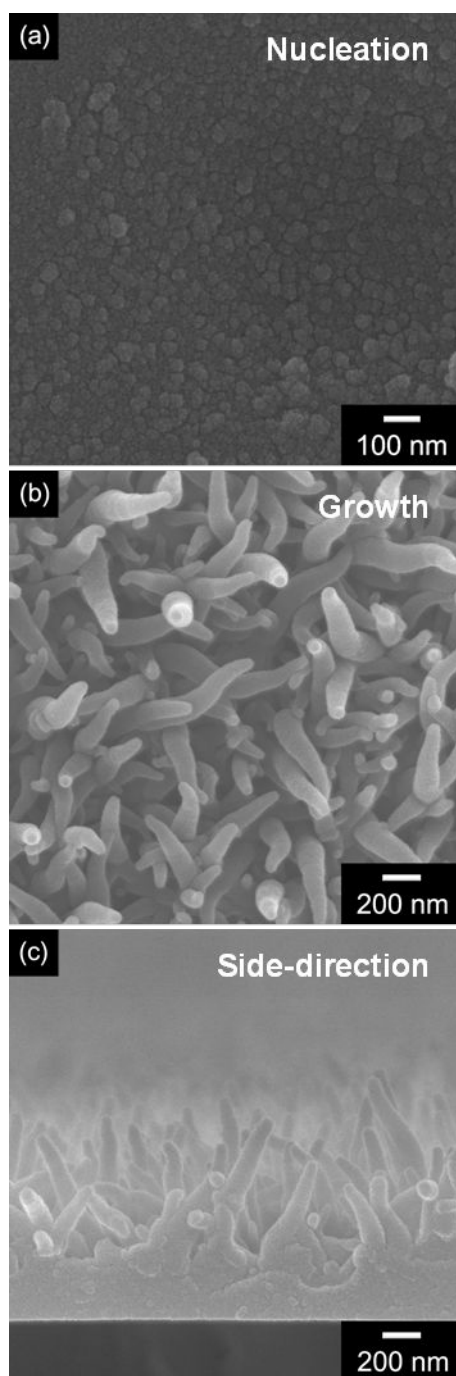# 1. Various images of the 3D-CNF at 25ºC polymerization

Figure S1. FE-SEM images of conductive nanofilm at 25ºC during (a) nucleation, (b) growth and (c) side-direction.

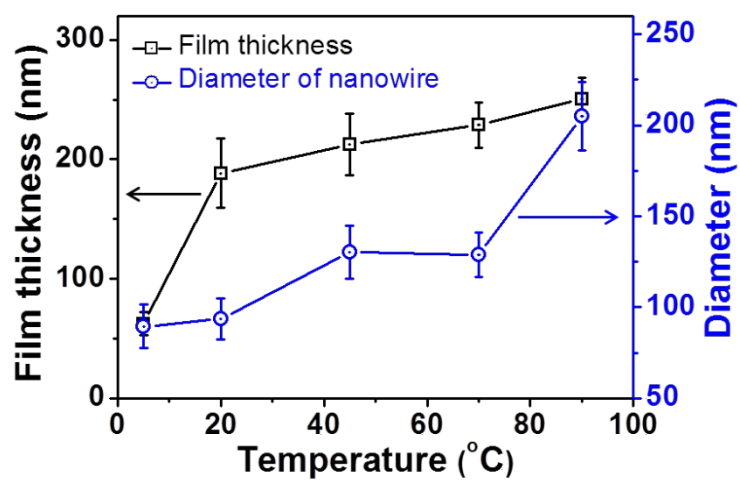**2. Size change of the 3D-CNF with temperature variation**

Figure S2. Thickness of films (black) and diameter of nanostructures in the 3D-CNF (blue) as a function of polymerization temperature.

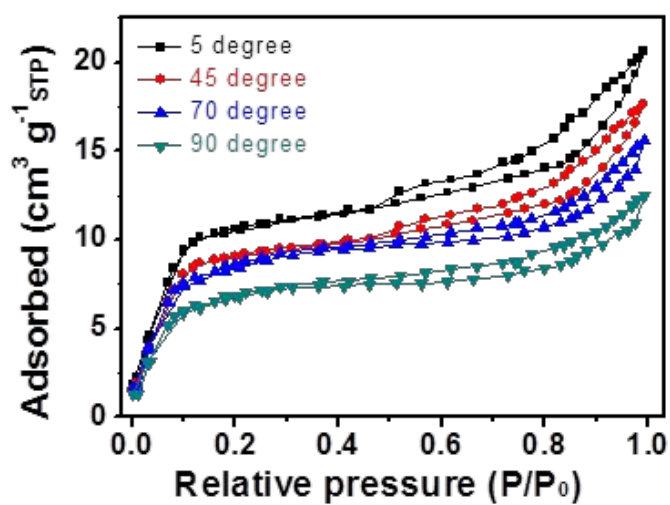## 3. Surface area of the conductive nanofilms with different temperatures

Figure S3. Nitrogen adsorption-desorption of different conductive nanofilms: 5°C (black); 45°C (red); 70°C (blue); 90°C (green).

4. Different polypyrrole chain structure with changing of oxidation level

Neutral (-1.2 V)

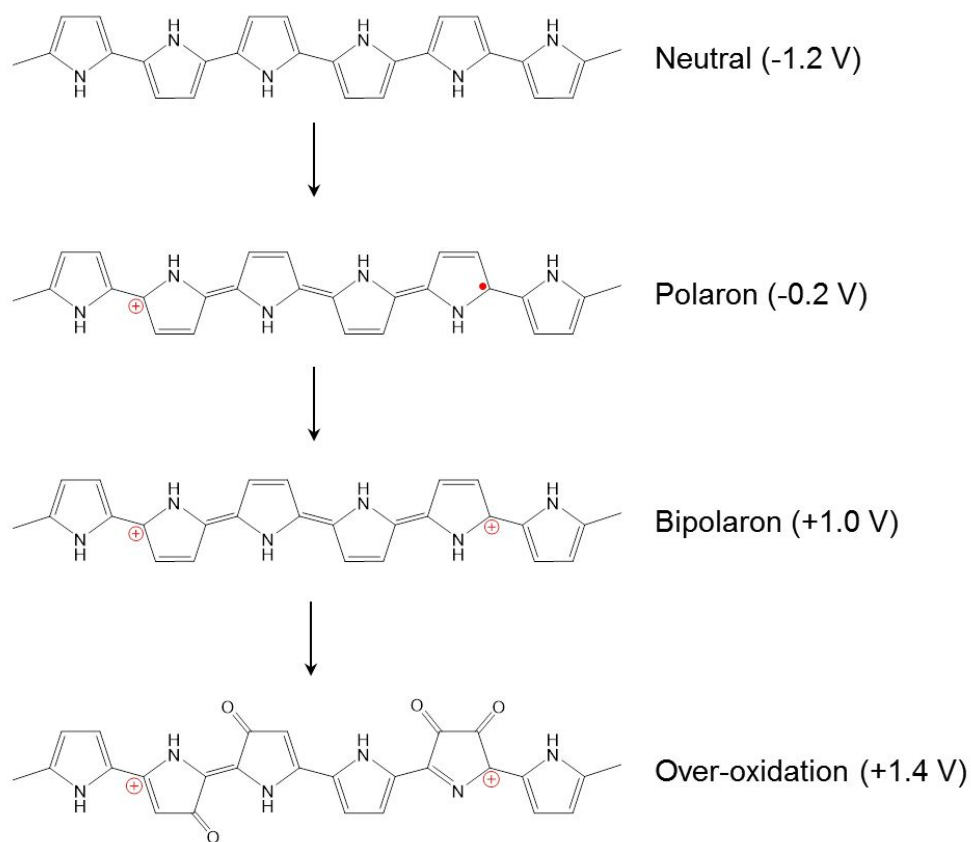Polaron (-0.2 V)

Bipolaron (+1.0 V)

Over-oxidation (+1.4 V)

Figure S4. Chemical structures of polypyrrole chain at different chemical states.

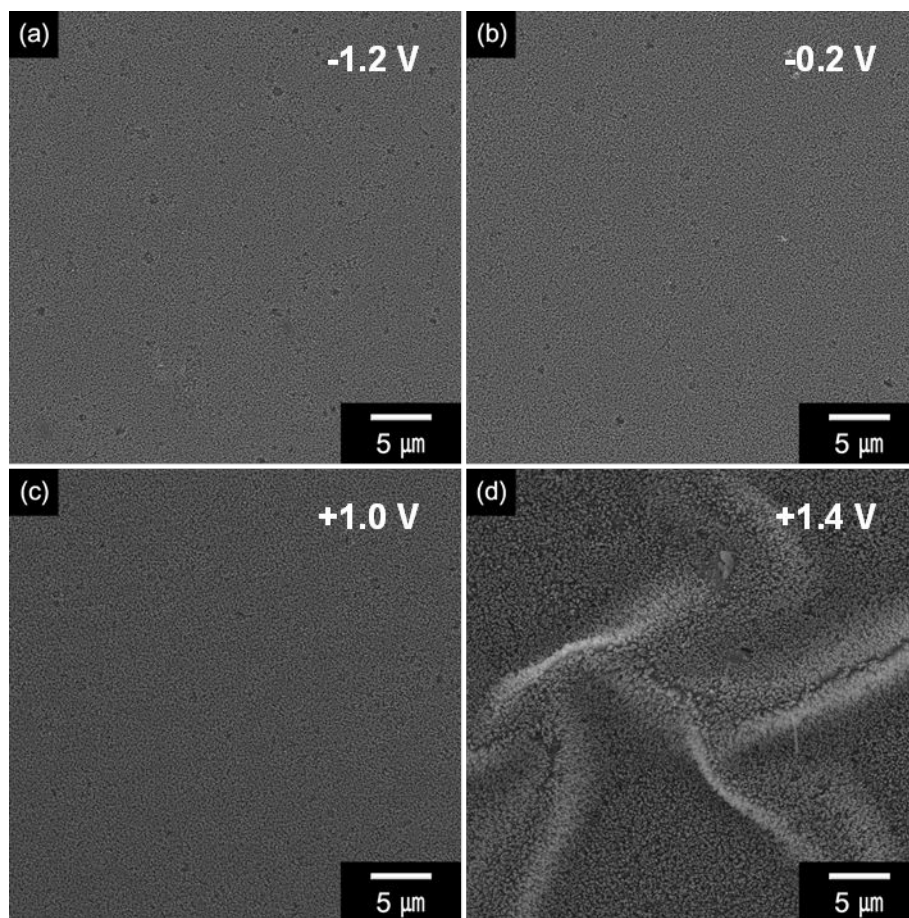**5. Large scale FE-SEM images as a function of oxidation level**

Figure S5. Low-magnification FE-SEM images of the 3D-CNF as a function of applied voltage variation: (a) -1.2 V; (b) -0.2 V; (c) +1.0 V; (d) +1.4 V.

6. Size deformation of the 3D-CNF as a function of oxidation level
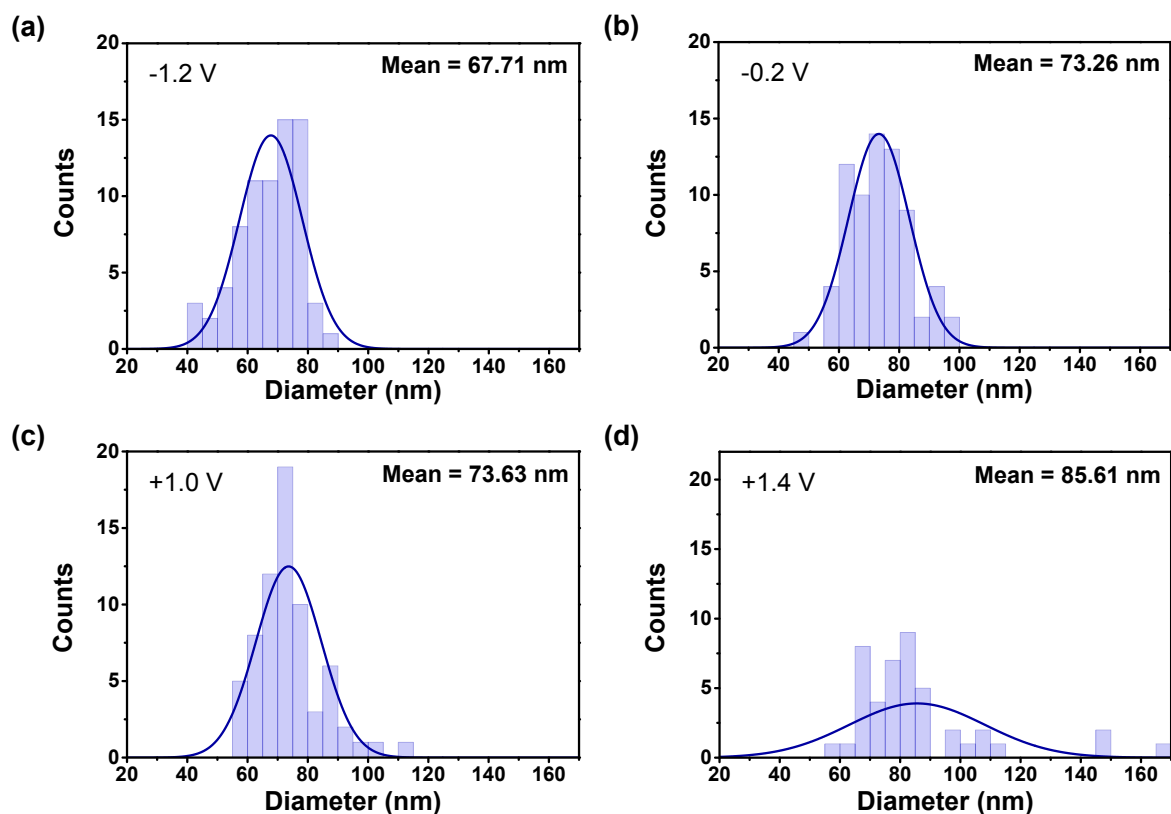

Figure S6. Diameter distribution of the polypyrrole nanowires in the 3D-CNF with different oxidation levels: (a) -1.2 V; (b) -0.2 V; (c) +1.0 V; (d) +1.4 V.

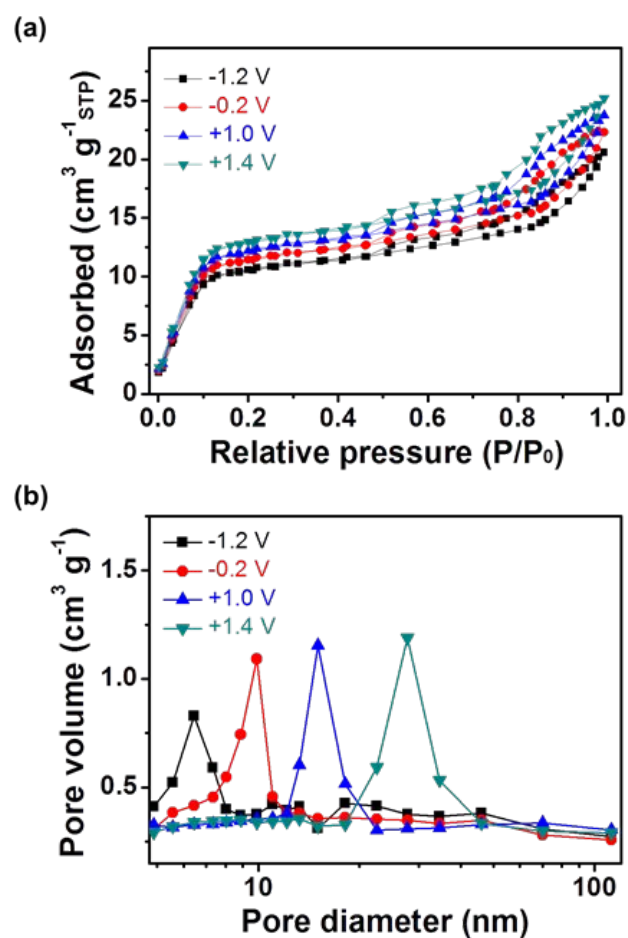**7. Surface area and pore distribution of the 3D-CNF with voltage variation.**

Figure S7. (a) Nitrogen adsorption-desorption and (b) pore size distribution curves of 3D-CNF with different oxidation levels (black: -1.2 V; red: -0.2 V; blue: +1.0 V; green: +1.4 V).
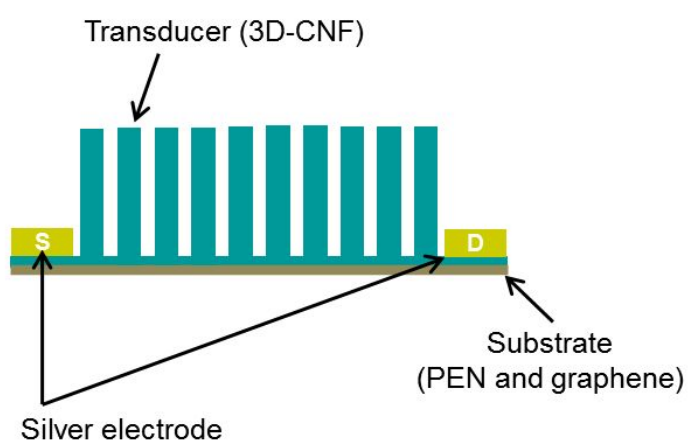
8. Structure of sensor electrode

Figure S8. Structure of 3D-CNF based chemical sensor electrode.

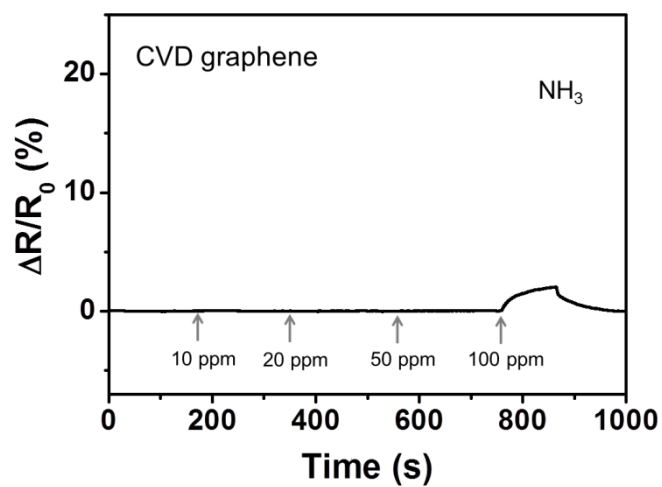## 9. Sensing performance of CVD graphene

Figure S9. Normalized resistance changes of the CVD graphene upon sequential exposure to NH$_3$ gas.

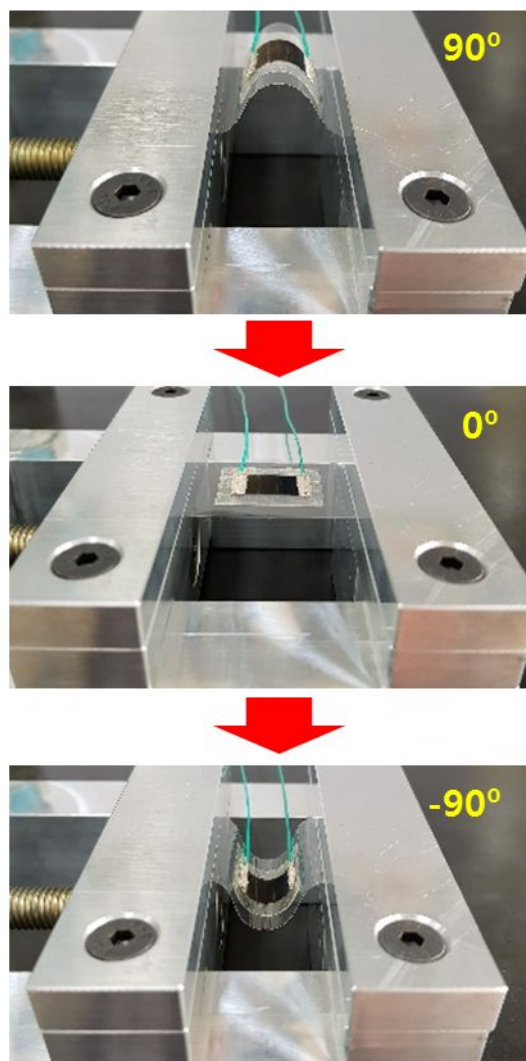## 10. Real bending images of the sensor electrode

Figure S10. Photograph real images of the sensor electrode under different deformations for 1 cycle.