Removal of Metallic Single-Walled Carbon Nanotubes Using Molecular Glass Thin Films

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1. INTRODUCTION

Single-walled carbon nanotubes (SWNTs) are a promising material for next generation field-effect transistors (FETs) [1]. It is one of the most important requirements to obtain purely semiconducting SWNT arrays. Recently, Jin *et al*. [2] have reported a method to selectively remove metallic SWNTs over the whole length by using thermocapillary flows of organic thin films. Here, we perform selective removal of metallic SWNTs by the thermal lithography method and show details of trench structure formation. We also report a novel electrical breakdown method which can overcome disadvantages of the traditional electrical breakdown method [3].

2. EXPERIMENTS

Figure 1 shows the schematics of the thermal lithography process. Horizontally-aligned SWNTs grown on quartz substrates by chemical vapor deposition were transferred onto silicon substrates and used as channels of back-gated FETs. An SEM image of a fabricated FET is shown in Fig. 2a. A molecular glass film was formed by spin-coating or thermal evaporation. A drain voltage (V_D) of -4 V and a gate voltage (V_{GS}) of +10 V were applied for a certain time. Trench structures along some SWNTs were formed on the film surface (Fig. 2b) due to surface tension gradients induced by Joule heating of metallic SWNTs, and then only metallic SWNTs were exposed. The exposed SWNTs were etched using oxygen plasma. Figure 3 shows current-voltage (I_D-V_{GS}) characteristics of the FET measured before and after the plasma treatment. On/off current ratio of the FET increased from 2.2 to 35. An SEM image of the FET after the plasma etching and dissolution of the film is shown in Fig. 2c. The I_D-V_{GS} characteristics and the SEM observation showed the selective removal of metallic SWNTs over the entire length. We also investigated the time evolution of trench formation and the substrate temperature dependence and found that substrate heating increased both trench formation speed and width-to-depth ratio of trenches (Fig. 4).

In addition, we performed electrical breakdown of metallic SWNTs in a molecular glass film and found that much longer parts of metallic SWNTs were removed than in air, as shown in Fig. 5. Several micrometers of breakdown were confirmed also by AFM observation and Raman imaging.

3. SUMMARY

We have reported two methods to selectively remove metallic SWNTs over the longer length by using molecular glass thin films. Both methods have similar advantages over the traditional electrical breakdown method.

REFERENCES

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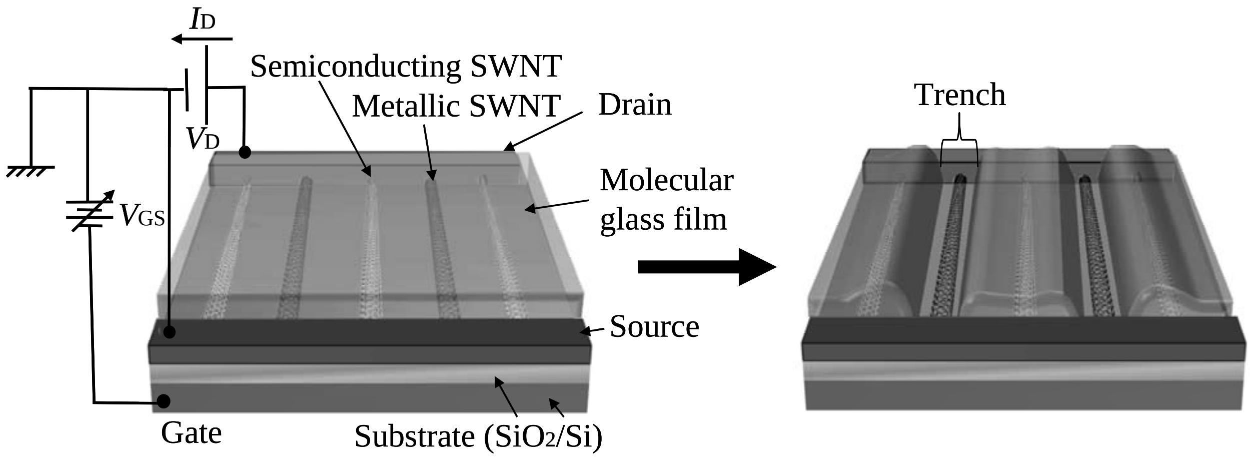

Figure 1 Schematics of thermal lithography using Joule heating of metallic SWNTs.

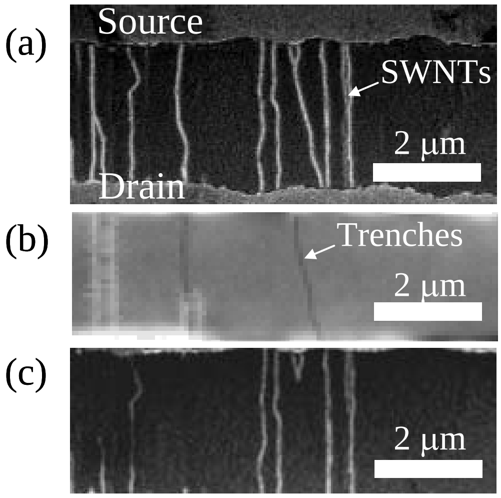

Figure 2 (a, c) SEM images of a typical FET before and after the oxygen plasma etching and dissolution of the film. (b) AFM image of the thin film with trenches.

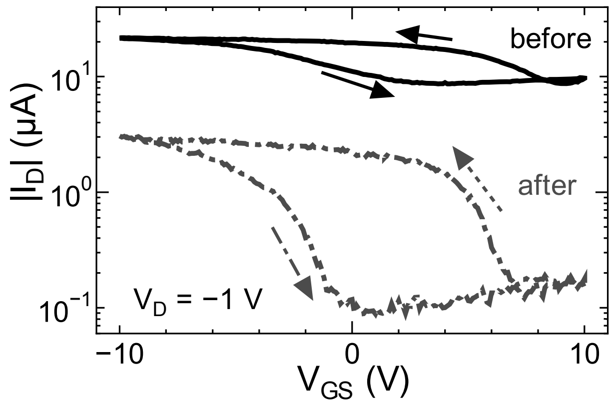

Figure 3 I_D-V_{GS} characteristics of the FET before and after the oxygen plasma etching.

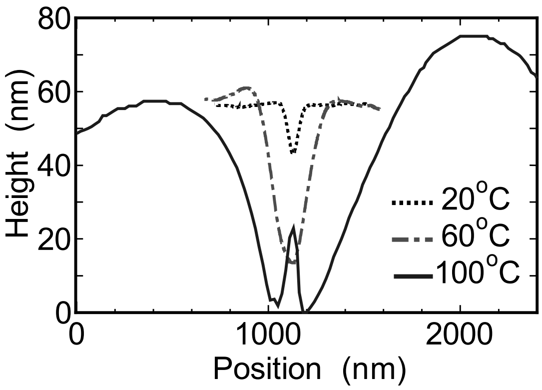

Figure 4 Cross section profiles of typical trenches with different substrate temperatures.

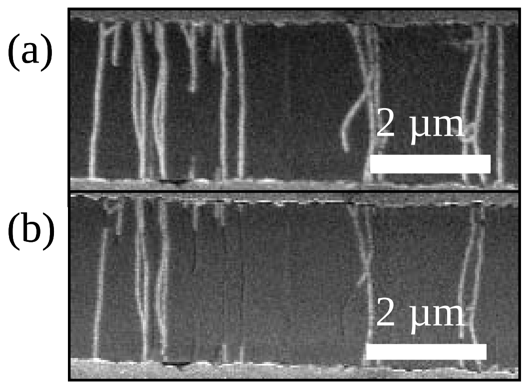

Figure 5 SEM images of channels of an FET before and after the breakdown in a molecular glass film.