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Increased Sensitivity of Carbon Nanotube Sensors by Forming Rigid CNT/metal Electrode

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Carbon nanotube (CNT) field effect transistors and sensors use CNT as a current channel, of which the resistance varies with the gate voltage or upon molecule adsorption. Since the performance of CNT devices depends very much on the CNT/metal contact resistance, the CNT/electrode contact must be stable and the contact resistance must be small. Depending on the geometry of CNT/electrode contact, it can be categorized into the end-contact, embedded-contact (top-contact), and side-contact (bottom-contact). Because of difficulties in the sample preparation, the end-contact CNT device is seldom practiced. The embedded-contact in which CNT is embedded inside the electrode is desirable due to its rigidness and the low contact resistance. Fabrication of this structure is complicated, however, because each CNT has to be located under a high-resolution microscope and then the electrode is patterned by electron beam lithography. The side-contact is done by depositing CNT electrophoretically or by precipitating on the patterned electrode. Although this contact is fragile and the contact resistance is relatively high, the side-contact by far has been widely practiced because of its simple fabrication process. Here we introduce a simple method to embed CNT inside the electrode while taking advantage of the bottom-contact process. The idea is to utilize a eutectic material as an electrode, which melts at low temperature so that CNT is not damaged while annealing to melt the electrode to embed CNT. The lowering of CNT/Au contact resistance upon annealing at mild temperature has been reported, but the electrode in these studies did not melt and CNT laid on the surface of electrode even after annealing. In our experiment, we used a eutectic Au/Al film that melts at 250^{o}C. After depositing CNT on the electrode made of an Au/Al thin film, we annealed the sample at 250^{o}C in air to induce eutectic melting. As a result, Au-Al alloy grains formed, under which the CNT was embedded to produce a rigid and low resistance contact. The embedded CNT contact was as strong as to tolerate the ultrasonic agitation for 90 s and the current-voltage measurement indicated that the contact resistance was lowered by a factor of 4. By performing standard fabrication process on this CNT-deposited substrate to add another pair of electrodes bridged by CNT in perpendicular direction, we could fabricate a CNT cross junction. Finally, we could conclude that the eutectic alloy electrode is valid for CNT sensors by examine the detection of Au ion which is spontaneously reduced to CNT surface. The device sustatined strong washing process and maintained its detection ability.

Keywords: Carbon nanotube, Contact resistance, Sensor