Mass Transport on Graphene

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Abstract:

A graphene channel with various widths for atomic mass transportation was fabricated photolithographically. Transportation of aluminum nanoparticles on graphene ribbon under ambient condition was demonstrated.

Summary of Research:

The development of nanotechnology requires versatile manipulation tools for atomic scale assembly and controlled material delivery. Scanning tunneling microscope (STM), atomic force microscope (AFM) have been demonstrated as powerful tools for manipulation of atoms and molecules on clean surfaces. However, these tools suffer from low delivery efficiency: they are not capable to deliver nanometer scale features containing large amounts of atoms, and they cannot deliver atom efficiently to the desired work area (sticky). Carbon nanotubes and graphene have been suggested as possible nanoscale mass conveyors with an electric field as the source of applied force. Controllable and reversible atomic metal transportation along carbon nanotubes (CNTs) and transport of more than 10^7 atoms have been demonstrated [1-3]. Graphene is mechanically robust and chemically inert; it can sustain large current density similar to CNTs. It has the advantage over CNTs that more complicated mass transport circuits can be designed with lithographic techniques [4-7].

We fabricated graphene ribbon with traditional photolithography process as shown in Figure 1. Pt/Au contact pads were patterned on top of the graphene channel or the graphene electrodes. Thin Al pads (around 2 µm wide and 7 nm thick) were evaporated on the graphene circuits (as shown in Figure 2 (a)) for demonstration of atomic mass transportation on graphene. After deposition of the Al pads, it was annealed under vacuum to reflow the Al, the topography of the Al after annealing is shown in Figure 3 (b). The Al atoms are manipulated by applying large electric field along the graphene circuit. Mass loss of Al and mass increase near the electrode were observed after applying large electric field, as shown in Figure 3.

Conclusions and Future Steps:

The motion of thin Al pads along graphene circuit under ambient condition was demonstrated. The characterization of the actuation should be studied further, especially the contribution of the thermal effect to the motion. We should also find the electric field that is large enough for continuous manipulation of the atoms without damaging the graphene device.

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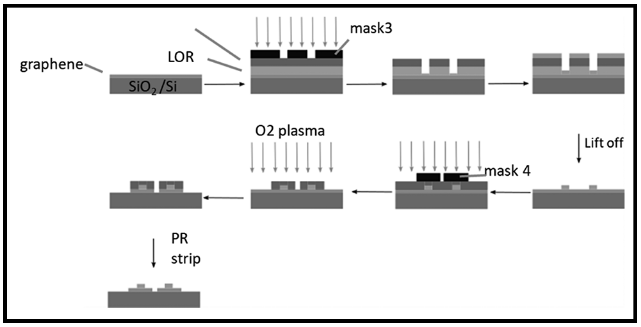

Figure 1: Process flow for making Al pads on graphene ribbon by lift off.

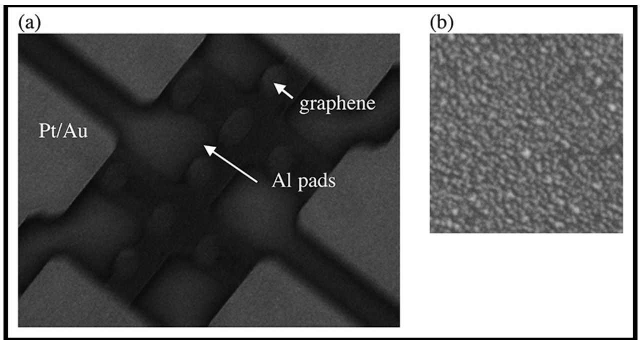

Figure 2: (a) SEM image of the graphene circuit with Al pads.
(b) Topography of thin aluminum film after annealing.

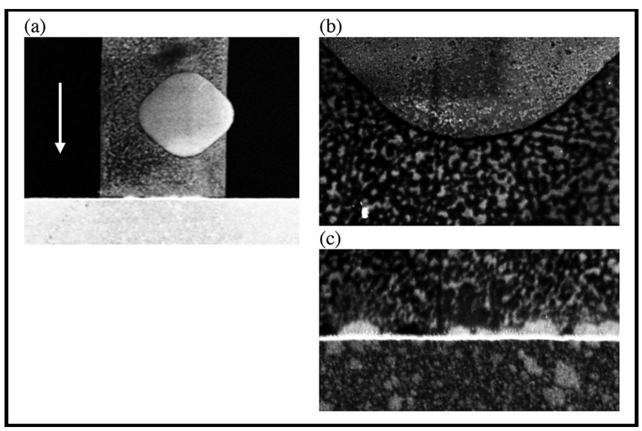

Figure 3: (a) SEM image of an Al pad after applying electric field in air.
(b) Edge of the Al showing mass loss after applying electric field.
(c) edge of the electrodes showing mass increase.