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Supplementary Information

Realize large current field emission characteristics of single vertical few-layer graphene by constructing a lateral graphite heat dissipation interface

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Methods and parameters of temperature distribution simulation during field emission

The simulations were performed by COMSOL Multiphysics software. The heat transfer in solids and electric currents modules were used for the temperature distribution of field emission. For the simulation of temperature distribution on the body of graphene, the classic heat balance equation was adopted which has been widely used to analysis the heat-related problem in literature.[1] It is expressed as follow:

$$J \cdot E - \nabla \cdot \ (k\nabla T) \ - \varepsilon\sigma S(T_{amb}^{4} - T^{4}) = 0$$

where J is electric current density, E is electric field, k is heat conduction coefficient, ε is surface emissivity, σ is Stefan-Boltzmann constant, S is surface area, T_{amb} is ambient temperature.

The first term of the equation is related to heat generation of Joule heating in our experiment system. The second term is related to heat conduction from graphene flake to the tungsten tip substrate. The third term is related to heat radiation from graphene flake to the ambient. Due to the small surface area (~ 10^{-10} m^2) of graphene flake, even in a high temperature of 2000 K, the heat radiation is very small when compared with the Joule heating and heat conduction. Thus, the third term can be neglected.

Therefore, the temperature distribution is determined by emission current, size of graphene, size of interface, electrical conductivity and heat conduction coefficient of graphene and interface. Here, we focused at the interface's effect on the temperature distribution during field emission of FLG. Three kind of interface layer were designed: continuous graphite layer, isolated graphite layer and continuous amorphous carbon layer and the other parameters including the size, electrical conductivity and heat conduction coefficient of graphene and emission current were set as the same. The length, width and thickness of FLG were set as 1.5 μm, 100 nm and 1.02 nm (3 layers) respectively. The electrical conductivity of three-layer graphene, graphite layer, amorphous carbon and tungsten were 5×10^5 S/m, 1×10^5 S/m, 1×10^3 S/m and 1.8×10^7 S/m respectively.[2-5] The thermal conductivity of FLG, graphite in plane, graphite in cross direction, amorphous carbon and tungsten were 2200 W/k•m, 600 W/k•m, 7 W/k•m, 1.5 W/k•m and 173 W/K•m respectively.[6-7] The field emission current was set as 100 μA at the edge to make the current density to be around 1×10^8 A/m^2 which is the same magnitude of our experiment results. The initial temperature of the tungsten is set as room temperature of 293 K. The electric contact between graphite and tungsten is set as Ohmic contact.

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