Ultra-sensitive nitrogen dioxide sensor based on graphene

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Introduction

-There is an increasing demand for the cost-effective sensor for detection of environmental pollutants like NO_x in ppb (part per billion) range.

-Sensors based on exfoliated graphene exhibit an unique sensitivity, allowing detection of individual molecules at very low concentrations [1], but they are not suitable for mass production.

-Epitaxial graphene on SiC is the promising route for mass-production of uniform, wafer-size graphene layers for gas molecules detection [2].

-This technique also offers the integration of graphene-based sensors with high temperature electronics based on SiC.

Design and fabrication

Substrate morphology was improved by pre-annealing of the substrate at atmospheric pressure in hydrogen .

The graphene layers were grown by annealing single crystal SiC substrates in the argon ambient at 1650°C.

The number of graphene layers on top of SiC was evaluated using Auger spectroscopy.

Graphene channels were made by photolithography technique and reactive ion etching of a graphene surface in O/Ar plasma.

Current channels of the sensor devices were oriented along the atomic terraces on the graphene surface according to AFM image.

Double layer Ti/Au (5/50 nm) contacts were made by e-beam evaporation and lift-off photolithography.

Three different contacts types in first metallization were used: narrow metal fingers, metal dots and simple flat contact configuration.

Our improved layout has several advantages:

1) in the first metallization contact pads are deposited directly on the SiC surface and thus have much better adhesion.

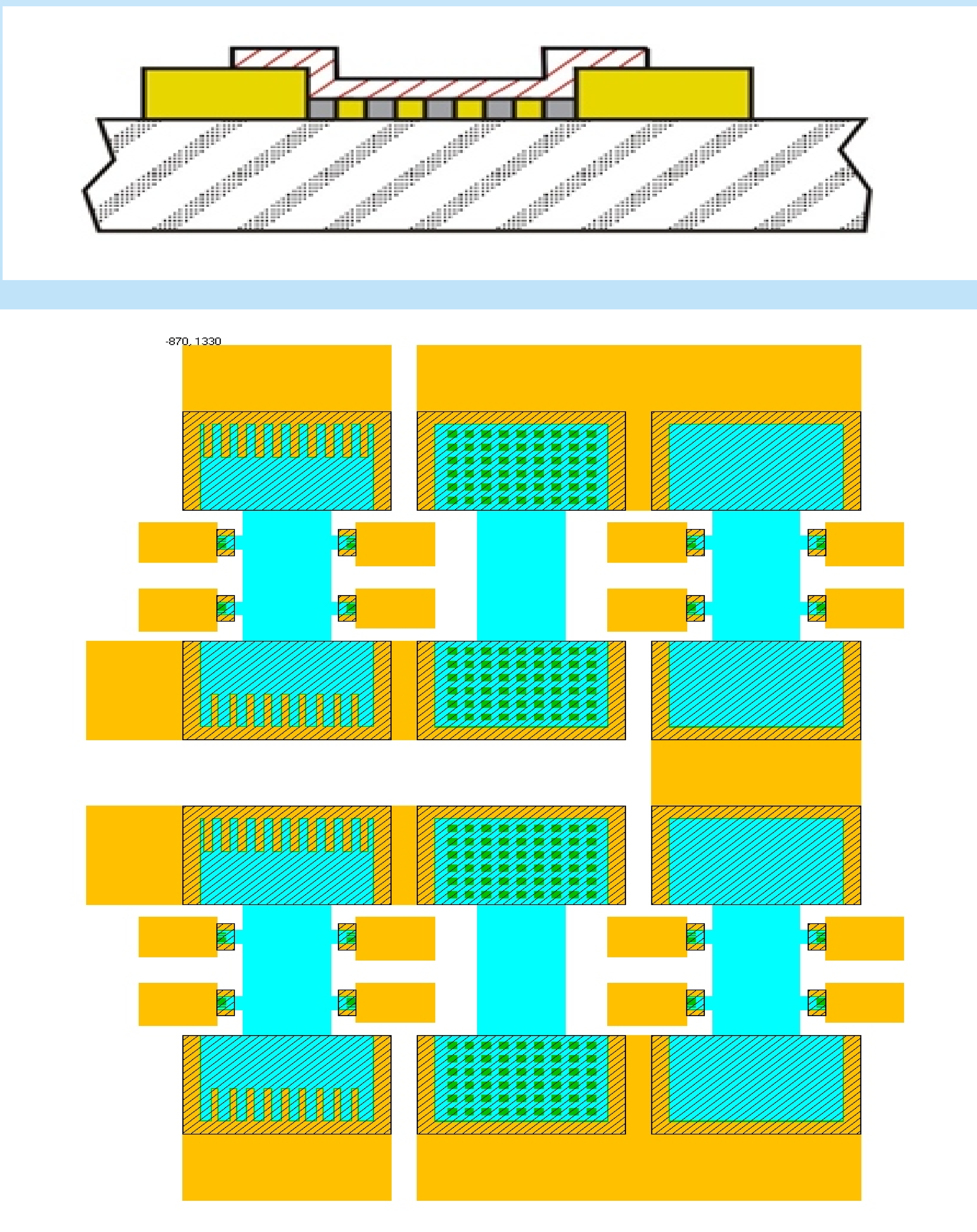
2) in the second metallization short metal ledges on top of graphene are less inclined to exfoliation.

3) stripe-like shape has more fraction of "end-type" contacts between metal and graphene [3] as compared to the conventional geometry.

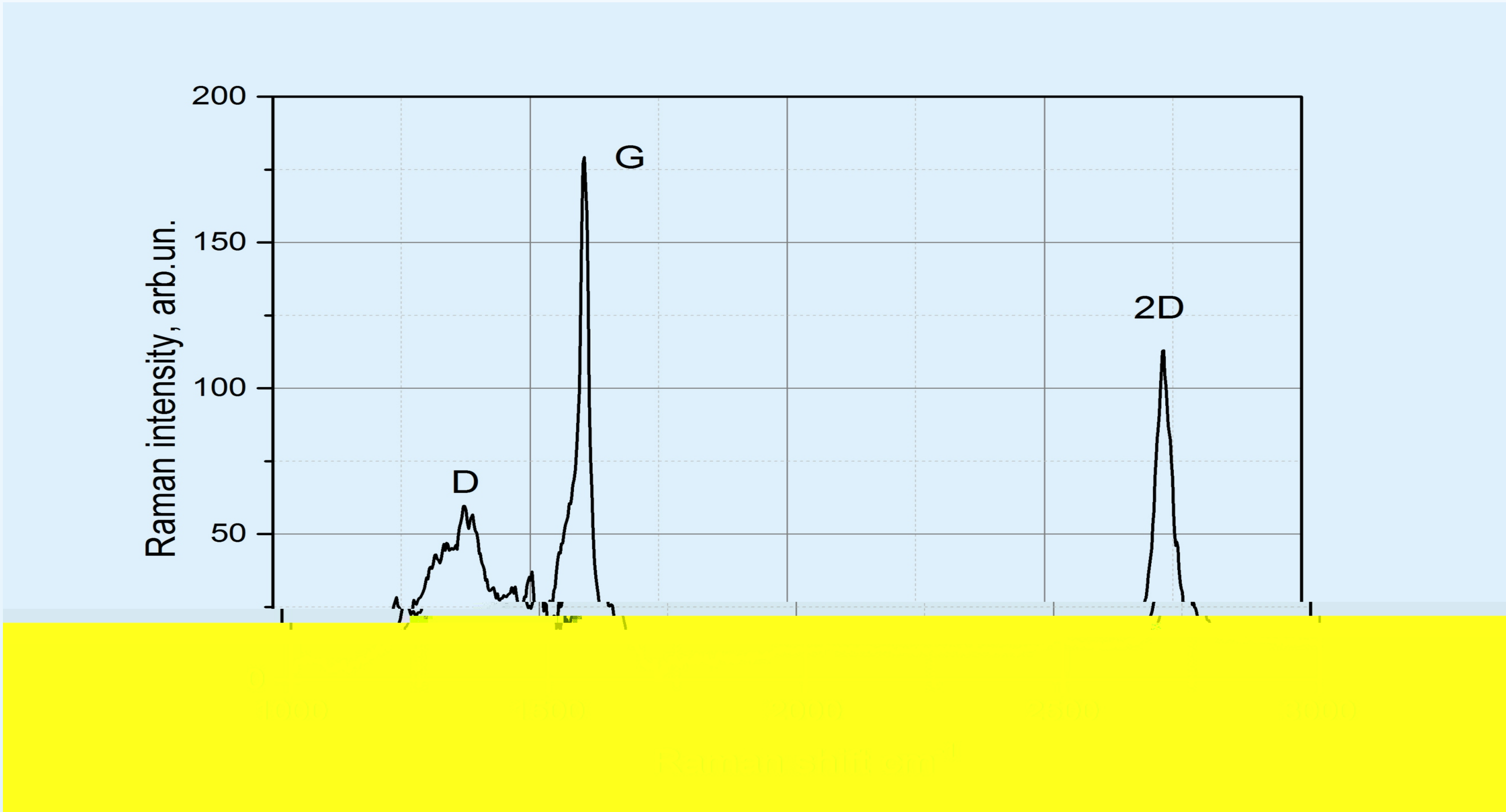
The channel width was 200 um, and the length 400 um.

The sample chip was assembled on the holder together with two Pt100 resistors. One of the resistors was chosen for temperature measurements while another was used as a heater.

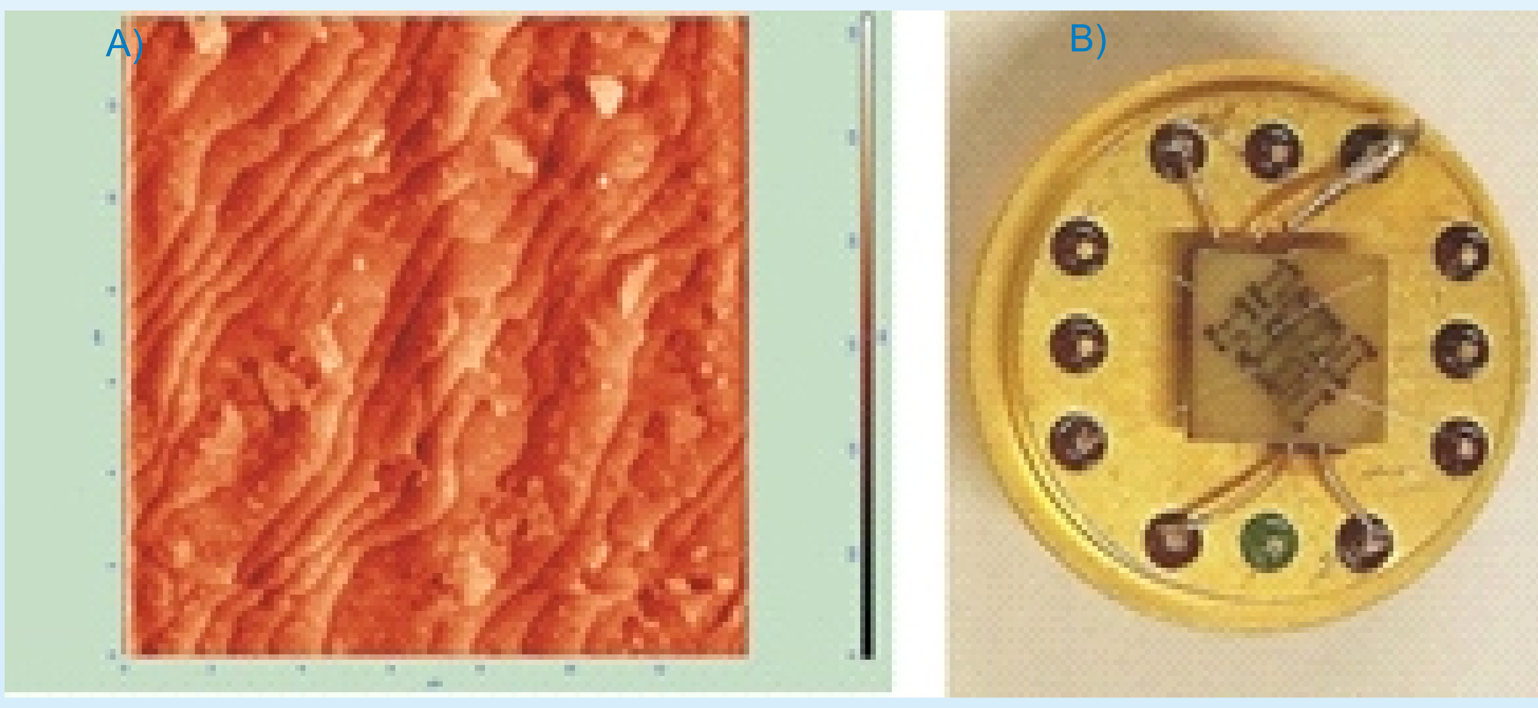
Double stage dilution (1:1-1:1000000) gas system was used for generation the gas mixture.



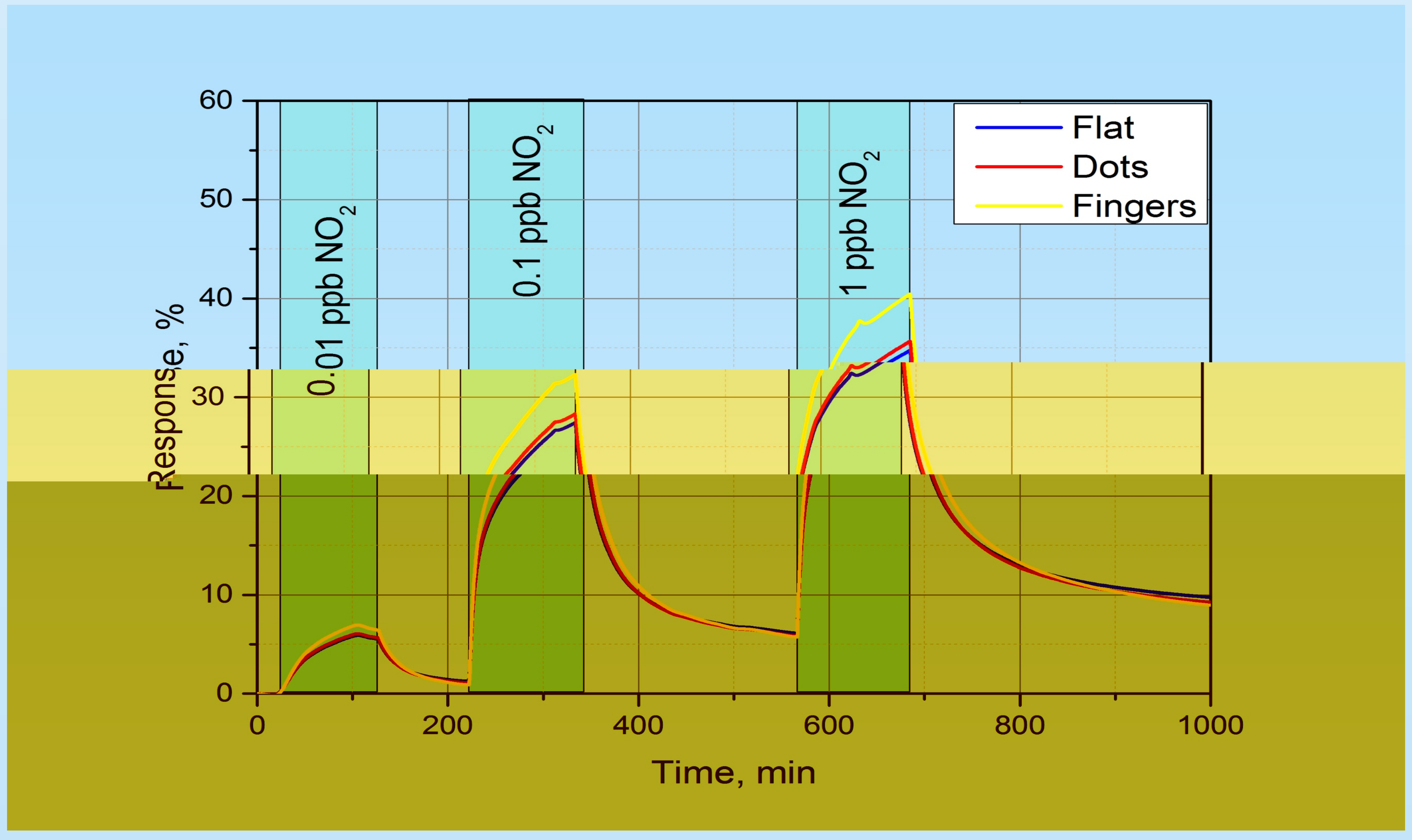
Cross section and top views of the two-step metallization process of the metal-graphene contact fabrication.



Raman spectrum of epitaxial graphene. SiC background is subtracted.



AFM image of 13x13μm graphene surface area (a) and sensor chip with 6 devices mounted on TO-8 holder (b).



Response on exposure of gas mixture containing NO_2 gas at 120°C.

Results

-D-peak in Raman spectrum indicates relatively high density of structural defects.

-A relative resistance change of 5% was obtained upon exposure to the gas mixture containing NO_2 at a concentration as low as 0.01 ppb.

-Devices with the finger-like contact metallization exhibit superior performances, compare one with dots and flat metallization.

-The sensitivity of the presented device to NO_2 gas is significantly higher, (up to 4 orders) as compared with results reported in [4-5].

-High concentration of high adsorption energy centers in our samples is the probable reason for the outstanding performance of our sensor.

References

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