FABRICATION OF 2D BASED PN JUNCTIONS WITH IMPROVED PERFORMANCE BY SELECTIVE LASER ANNEALING

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Abstract. There is a growing body of research on transistors based on nanomaterials such as 2D transition metal dichalcogenides (TMDs) (WS_2, MoS_2, etc.) and carbon nanotubes (CNTs). Here we co-deposited MoS_2 and WS_2 as PN junctions. The deposition could be performed on a PCB (printed circuit board) with Cu electrodes. The current-voltage characteristics were obtained using an Arduino board. The effect of laser irradiation could be investigated by studying the IV curves and light sensitivity for the same kind of devices in which one of the Cu electrodes was modified by a laser. The IV curves from the devices with and without laser treatment could be compared to quantify the changes in performance.

Introduction

Graphene as a two-dimensional (2D) material has attracted extensive attention due to its unusual physicochemical properties such as high conductivity, light transmission, and mechanical strength. Although graphene has great potential in various technological applications, its zero bandgap limits its use in devices such as channel materials in transistors which are the building blocks of electronics. A lot of work has been done on using CNTs as folded-up graphene with a bandgap. New research also revealed other 2D materials such as transition metal dichalcogenides (TMDs) (WS_2, MoS_2, etc.), which have energy bandgaps in the range 1–3 eV. One of the main issues in transistors based on these devices is high contact resistance. The possibility to improve the performance of CNT-based transistors was first suggested by the computational results from Nurbawono *et al*. [1] who showed that the laser annealing of the CNT/metal contact interface gives a way to control the Schottky barrier between them. Recently, Kwon et al. [1] showed the possibility to significatively improve the performance of MoS_2 field-effect transistors by the selective laser annealing of the MoS2/metal junction. We aim at investigating the possibility to use such an approach at the large-scale device level.

Materials and Methods

In CNT-FET transistors provided by Fraunhofer ENAS, Germany, we have performed laser annealing of the CNT/metal junction. The Raman measurements were used to characterize the change in the CNT structure, while the Kelvin-probe force microscopy measurements were used to characterize electronic properties of the junction.

In the second approach, MoS_2 and WS_2 were co-deposited as n and p-type materials, respectively, in order to form heterojunctions. The deposition was performed on a cleaned PCB (printed circuit board) with Cu electrodes. The electrical properties of the deposited materials could be measured by Arduino board which is used to obtain and record the current-voltage characteristics. One of the electrodes on PCB was irradiated by a laser. We checked the conductivity by Arduino board.

Results and discussions

According to the measurement results we observed a change in contact potential difference for a CNT transistor demonstrating the effectiveness of this approach to modifying the electronic properties of the junction. CNTs remained intact after the laser annealing procedure according to the results of the Raman measurements. The MoS_2-WS_2 heterostructures could also be modified by the selective laser processing.

Conclusion

Nanomaterials such as CNTs and 2D TMDs are widely used in different devices such as transistors, diodes, photosensors, and solar cells. Therefore, discovering effective ways to modify potential barriers in order to improve their performance has an important implication. The use of lasers to modify 2D based PN junction is a very convenient, cost efficient and scalable way to achieve that. The results of our work imply that laser treatment can be exploited to modify Schottky barriers and PN junctions in transistors resulting in improved performance.

References

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