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Femtosecond laser processing of graphene for device applications

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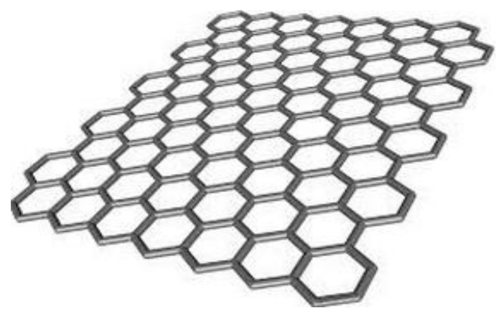
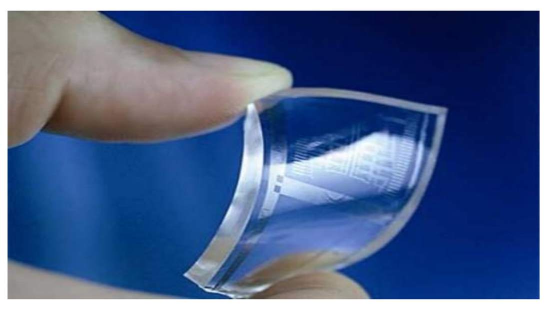
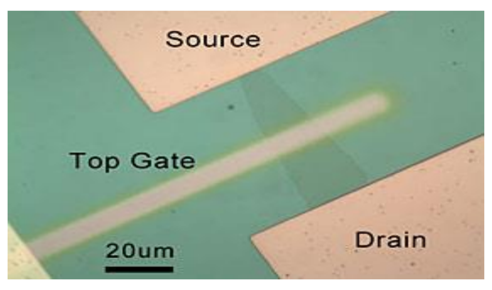
1. Introduction

Graphene, a 2D honeycomb lattice of carbon atoms, has generated wide research interest due to its exotic electronic and optical properties. This study aims to process graphene on SiO_2/Silicon substrates, making it suitable for direct device fabrication. This project seeks to achieve the high precision laser cutting in complex micro-patterns on single layer graphene.



Schematic of Graphene[1]





Graphene potential in electronic devices[2,3]

2. Objective

The aim of this project is to investigate the capabilities of high-precision laser profiling of monolayer graphene as a device manufacturing step. To achieve this, the central aim of this work is separated into two distinct objectives:

- Understand the underlying physics of the mechanism of ultrafast laser pulse interaction with single layer graphene during the ablation process.
- Based on this theory, experimental work will be carried out to allow optimization of cutting parameters.

Success of this project will deliver a new manufacturing route for graphene based devices such as sensors, transistors and solar cells.

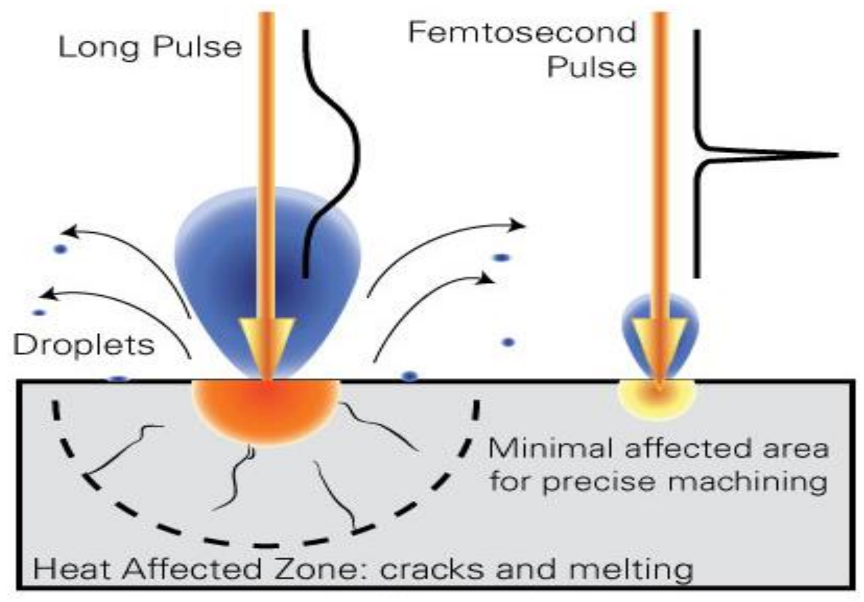
3. Experimental Method

Femtosecond laser interaction with materials

The micromachining process starts with the absorption of laser energy, followed by a laser induced breakdown process.

Ultrafast laser ablation has many advantages when compared to longer pulse laser matter interaction [4]:

- Material excitation dominates the process instead of plasma expansion, thus plasma shielding is diminished dramatically.
- Multi-photon absorption will become crucial with the increase of laser intensity, which decreases the ablation threshold fluence (J/cm^2).
- Sub-wavelength structures can be produced through a selection of peak laser fluence that is slightly above the ablation threshold.



Different mechanisms in material processing[5]

4. Results and discussion

Equipments and materials

Amplitude Systèmes Satsuma laser : 1030nm, 5kHz, 280 fs, in air.

Monolayer graphene: produced by CVD on copper and then transferred on SiO2/Si substrate.

- When the pulse fluence was higher than 120 J/cm^2, the laser ablated both graphene and the substrate;
- When the pulse fluence was lower than 66 mJ/cm^2, there was no evidence of cutting.

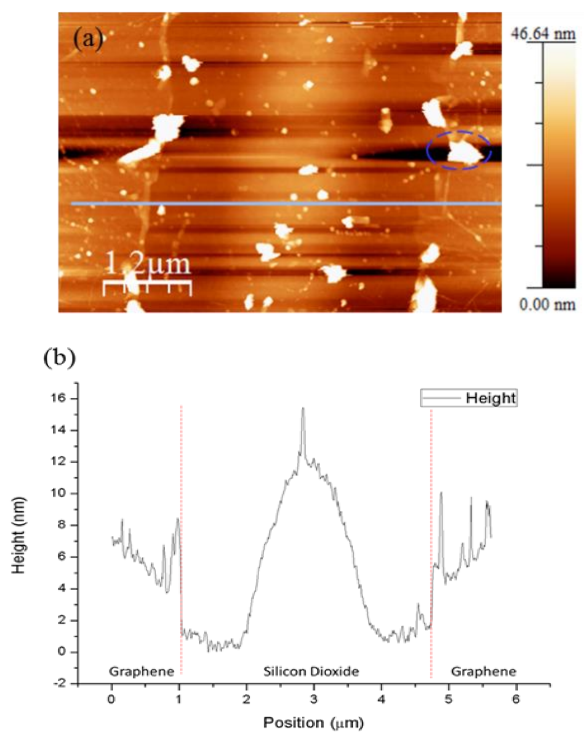


Fig 1. AFM profile of graphene laser cutting kerf.

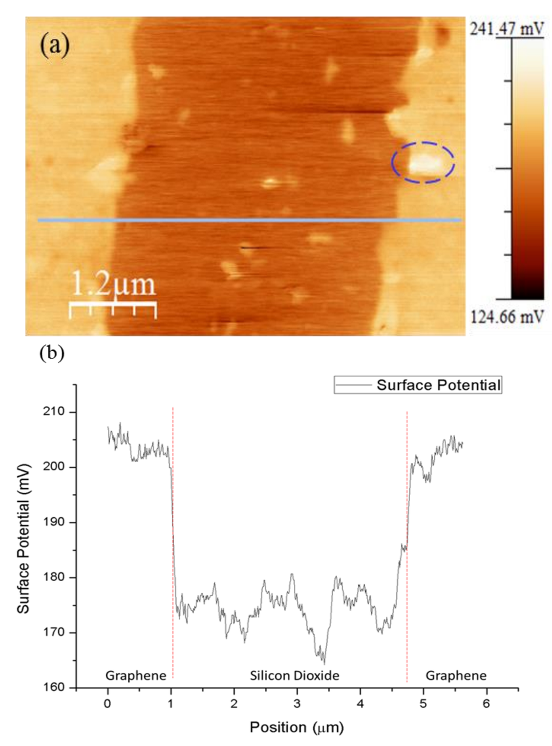


Fig 2. Surface potential map profile of graphene laser cutting kerf.

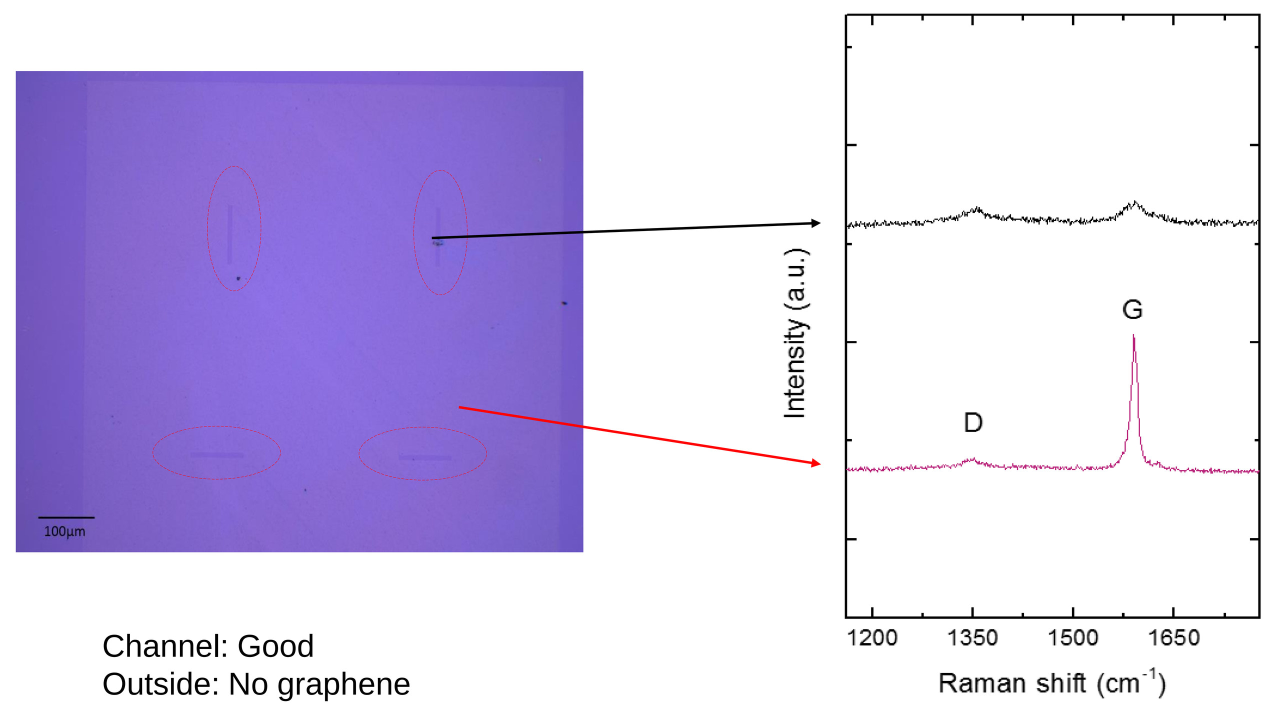


Fig 3. Laser profiling of graphene patterns for FET devices.

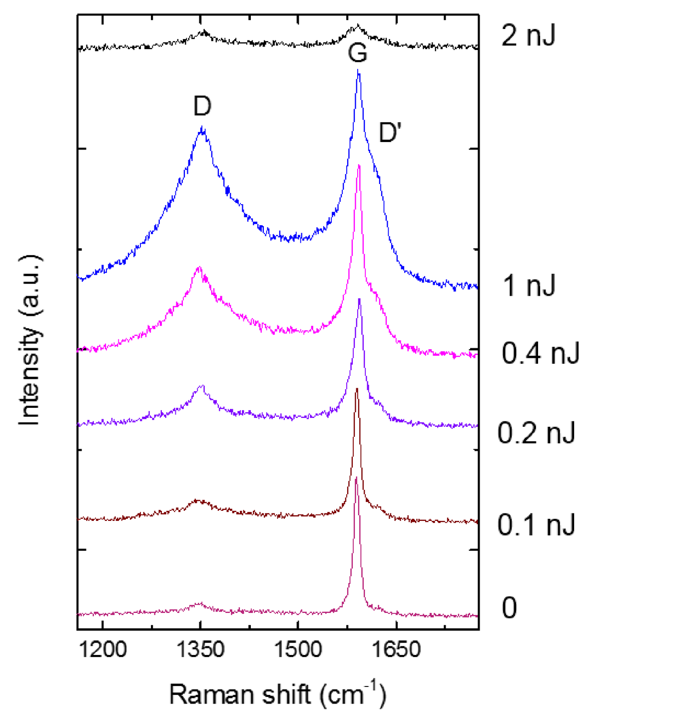


Fig 4. Raman analysis of laser irradiated area.

5. Conclusions and future work

Conclusions

To summarise, the femtosecond laser cutting of graphene has shown its potential in future device application as follows:

- Defined selective ablation, functionalization region.
- Raman spectroscopy proved completely removal of graphene(Line and Area).
- AFM revealed little removal of SiO2 and no damage to the silicon substrate.
- Subthreshold processing introduced defects in graphene.

Future work

Work proposed illustrated the feasibility of cutting fine lines by using ultrafast laser. To achieve a high precession patterns with different widths on graphene based devices, future explorations will be :

- Laser assisted functionalization of graphene devices.
- Laser metal deposition of graphene to fabricate contacts

6. References

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4. P. S. Banks, B. C. Stuarf, A. M. Komashko, M. D. Feit, A. M. Rubenchik, and M. D. Perry, Femtosecond Laser Material Processing, March,2010
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