SUPERLASERS FOR THE REAL WORLD

Orientation control, thickness control, positioning to transparent or opaque materials via ejection or stamping

LASER BASED PRECISE SELECTION AND TRANSFER OF ULTRA-NANOMATERIALS

WHITE PAPER

INTRODUCTION

Since the discovery of graphene in 2004, two dimensional nanomaterials which are atomically thin crystal structures, have been pursued scientifically for their unique physical properties. Their electronic and photonic properties have led to prototypes in photovoltaic devices, CCDs, field effect transistors, single photon transistors, quantum qubits, chemical sensors, energy storage devices and others. The promise of these materials and their applications has some of the largest funding drives in Europe from the one billion euros invested into the Graphene flagship project, to the Netherlands most recent science fund of € 650 million towards quantum computing which heavily relies upon 2D materials. This has created multiple companies and facilities which are developing pilot lines and commercial prototypes which utilize these two dimensional materials. This territory of 2D nanomaterials as new manufacturing media is a rapidly evolving landscape of new device architectures, which hold much promise for the future of electronics. Despite this promise, the assembly of nanomaterials are still complex resulting in inconsistency between devices. This paper introduces an all-in-one solution for positioning and placing these materials and other nano-objects, which could assist in rapid production and testing of these devices.

PROBLEM

Whilst 2D nanomaterials present a lot of opportunity for novel technologies, their intrinsically useful properties such as single crystallinity and atomic thickness, mean it is a sizable challenge to generate and manipulate them into position. Much of the initial study on the labscale revolved around using materials as simple as scotch tape to create them in a method which falls under a top down approach. This method creates a few high quality 2D materials amongst a sea of poor quality nanomaterials, where those few top down materials will then be manipulated into position through specialized glues which often leave a damaging surface residue. Whilst this approach can generate some high quality proof of principle devices, it is currently unscalable to the industrial level. Another approach often referred to as bottom up, utilizes chemical growth techniques to generate large area 2D materials. However, this method requires high temperatures and corrosive chemicals which make growth to specific positions and generation of stacked 2D material composites exceedingly difficult. Furthermore, the methods used to remove the growth substrate often result in damage to the generated materials. Thus, whilst the bottom up approach enables generation of quality 2D materials at scale, the latter manipulation results in an unscalable process.

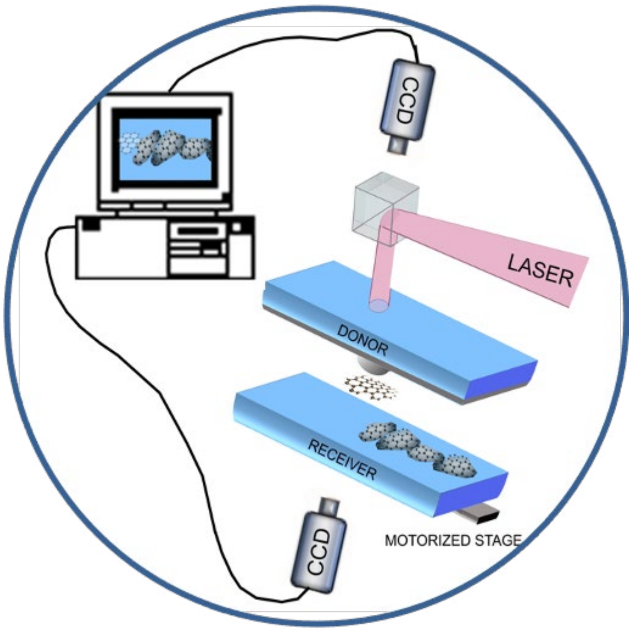


IMAGE OF DEVICE OPERATION WITH RED BOX INDICATING FUNCTIONAL ASPECT. LASER INDUCED FORWARD TRANSFER OF NANOMATERIAL.

The device and method proposed offers a novel method of transferring 2D nanomaterials with position orientation and speed taken into account which offers a pathway for scale generation of nano-devices from the top down methodology, or in some situations from a bottom up approach. Furthermore, the process which advances upon existing laser induced forward transfer methodology can assist in interconnects to standard circuitry.

SOLUTION

Principles covered by the presented patent lead to a dedicated blister-based laser-induced forward-transfer (BB LIFT) system that will bring this technique to the state of an industrial-level solution with the speed and precision limited only by the laser, optics and positioning used. Through this methodology we can achieve positioning of single layer 2D nanomaterials, via ejection to location or direct stamping to the surface. This allows precision and speed contingent upon the laser, optics and positioning used. Current research indicates a resolution of positioning down to > 3 μm with room for improvement through higher quality optics. In situ characterisation is accomplished in order to achieve reproducibility, and the method is chemical free, thus reducing risk of contamination. This device and method offer significant potential in manufacturing high-quality heterogeneous micro and nano-objects in larger scale. The speed of material transfer and thus device generation is dependent upon the initial quality of 2D materials and the level of in-situ characterization required. Given the highest quality starting material the method allows for high resolution laser positioning material of cm scale array within seconds. The device can function as a standard LIFT capable device and thus is able to achieve precise laser deposited material, alongside the 2D nanomaterial positioning. This is suitable for small scale production with principles expandable to industrial use and enables connection to existing technology.

The key drawback to the proposed technique is the requirement of the 2D material to be upon a donor material, which typically a thin film of metal. Thus the material generation is still through top down or bottom up methodology. However, current research shows promising bottom up generation of large scale nano-material to this donor film.

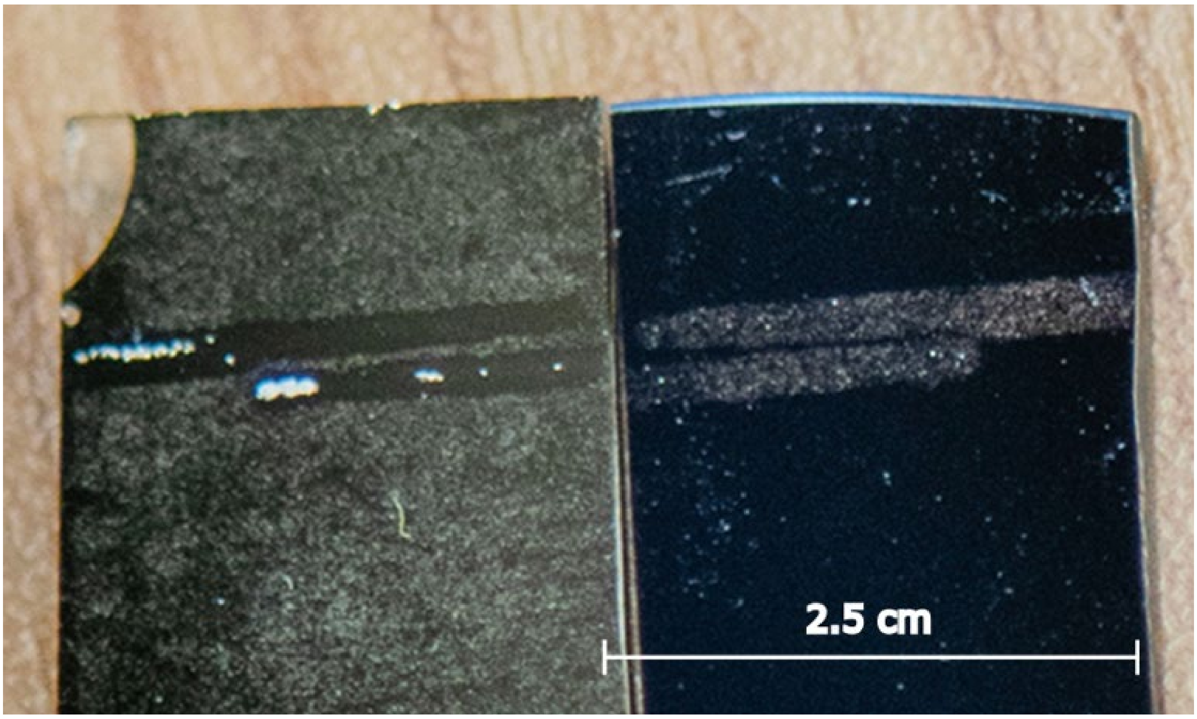
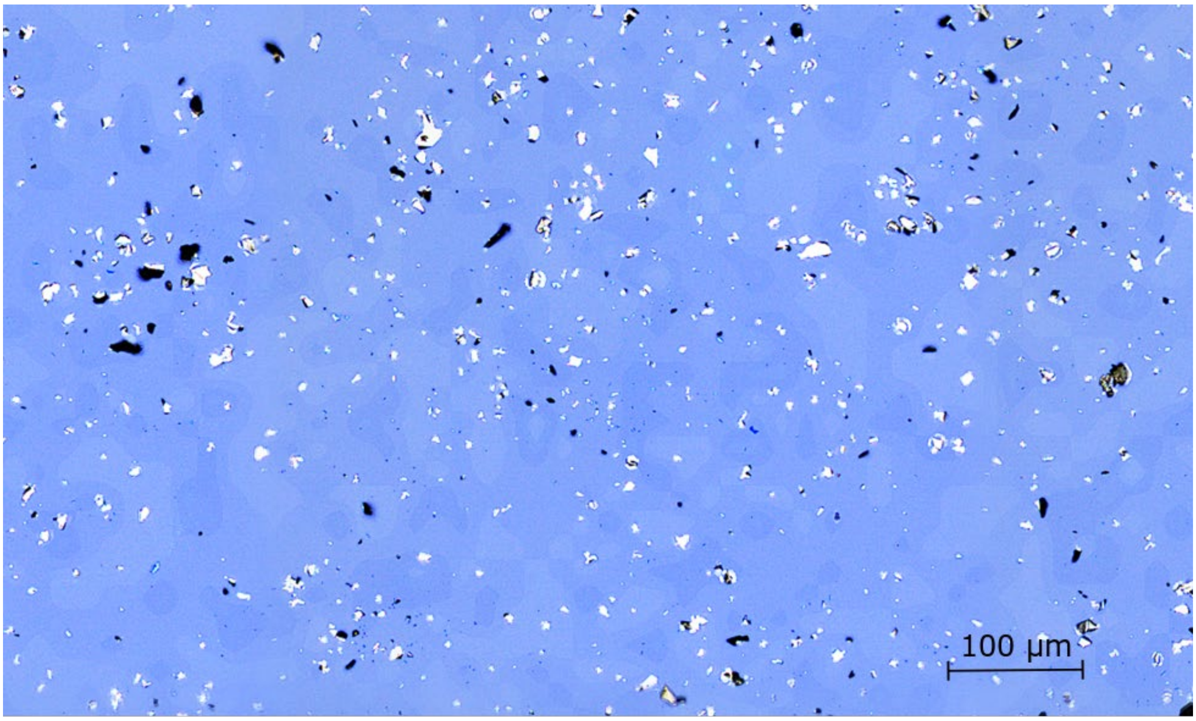


IMAGE OF EXFOLIATED GRAPHENE ON DONOR FILM (LEFT) TRANSFERRED TO SILICON RECEIVER (RIGHT). THIS WAS ACCOMPLISHED FOR DEMONSTRATION WITH A 1 MM BEAMSIZE WITH DONOR AND RECEIVER AND CLOSE PROXIMITY, RESULTING IN THE DIRECT STAMPING OF MATERIAL FROM THE DONOR TO A MIRROR LOCATION ON THE RECEIVER.

THE GRAPHENE STAMPED VIA 1 MM SPOT SIZE BEAM MAINTAINS ITS ORIGINAL STRUCTURE AND CHARACTERISTICS POST TRANSFER. WITH THE DEVICE PRESENTED SMALLER TARGETED REGIONS WITH A RESOLUTION DOWN TO FEW μm CAN BE ACHIEVED ENABLING SELECTED TRANSFER OF THE 2D MATERIAL WITH PRECISION, ORIENTATION CONTROL, AND SPEED.



SUMMARY

The device presented within this whitepaper filed under Patent application number LU102294, "A method and device for nanomaterial structure" defines a method and device for transfer of nanomaterials down to 1 atom thick. The resolution is currently recorded at 10 µm, with speed of orientation controlled positioning up to 100 per second (pre-characterization and nano device requirements depending). The method is universally applicable and capable of refinement based upon components used. The material consumables are minimal with electricity and low energy laser usage, as the peak costs. The precision, speed, orientation control, repeatability, pre and post characterization attached to a device capable of printing standard interconnects for full device attachment, greatly expand the options of what can be manufactured, whilst saving on time. We excited for the possibilities within this patent and are keen to further develop this technology in collaboration with industrial partnerships.

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