Transfer printing of graphene structures onto gold contacts for transistors and photo detectors

Iris Bergmair[1], Barbara Einwögerer[1], Wolfgang Hackl[1], Thomas Fromherz[2], Maria Losurdo[3], Giovanni Bruno[3], Nalin Rupesinghe[4], Christoph Giesen[5], Michael Heuken[5], Thomas Müller[6], Michael Mühlberger[1]

[1]PROFACTOR GmbH, Functional Surfaces&Nanostructures, Im Stadtgut A2, 4407 Steyr Gleink, Austria
[2]Institute of Semiconductor and Solid State Physics, Johannes Kepler University of Linz, Altenbergerstr. 69, 4040 Linz, Austria
[3]Institute of Inorganic Methodologies and of Plasmas-CNR, Via Orabona 4, 70126 Bari, Italy
[4]Aixtron Ltd, Buckingway Business Park, Anderson Road, Swavesey Cambridge CB24 4FQ, United Kingdom
[5]Aixtron SE, Kaiserstr. 98, 52134 Herzogenrath, Aachen, Germany
[6]Institute of Photonics, Vienna University of Technology, Gußhausstraße 25-29, 1040 Vienna, Austria

iris.bergmair@profactor.at

Abstract (Arial 10)
We present an innovative technique to realize patterned graphene on gold contacts for the realization of transistors and photo detectors.
In previous work we described how to realize micro and nanostructures on graphene using UV-Nanoimprint Lithography (NIL) [1]. NIL is a powerful technique to realize micro and nanostructures on large area within seconds by using a nano patterned stamp [2]. Nevertheless the structuring of already transferred graphene to other substrates has high challenges like the insufficient adhesion of graphene and defects which occurred during transfer.
Further for applications like transistors and photo detectors gold contacts have to be realized on graphene. For photolithography this is a simple task realizing µm sized structures, but going down to nanostructured Au contacts it might become challenging. Of course e-beam writing can be used to define nanopatterned Au contats on graphene this method is not scalable for mass production due to the long writing time on large area. Therefore we have chosen NIL to demonstrate the scalability for mass production of our process. One drawback is the fact that NIL creates a residual layer which has to be etched away before deposition of Au. Doing this process on graphene does not work since etching residual layer also removes the graphene and no contact to Au can be formed.
Therefore we used a transfer print process for the gold contacts. We first fabricated the Au contacts on a substrate and transfer it afterwards into an Ormocere® (working like a glue) to another substrate. This method was described in ref. [3] for nanostructured gratings. The gold structures are imprinted in liquid Ormocomp and hardened with UV-light. Afterwards the Au sticks to the Ormocomp and can be peeled off from the substrate (Figure 1).
As a next step graphene is patterned on CVD graphene grown samples on Cu from Aixtron (Figure 2). Due to the fact that the graphene adheres quite well to the Cu a patterning of the graphene is quite easy in comparison to the trials of patterning already transferred graphene on SiO_2. Here the adhesion is often insufficient and routes have to be found to increase the graphene adhesion to the substrate before a structuring can be successful.
In our case the patterns are created on the Cu substrate by photolithography (Figure 3, 4) and transferred afterwards. The transfer method is done using a thermal tape. This tape is pressed on the structured graphene on the Cu (Figure 5,6) and the Cu is removed by a succeeding wet chemical etching step. After etching of the Cu the structured graphene remains on the tape and is pressed onto a SiO_2 wafer with 90 nm (Figure 7). In Figure 8 such graphene patterns on SiO_2 are shown. Some residues of the transfer tape can be found on the graphene, but can be avoided in the future by using and testing different tapes.
The aim is to combine the transfer process of Au structures in Ormocomp and transferring structured graphene on top for fabrication of graphene transistors and photo detectors. The contact of graphene to gold has to be examined and some annealing/cleaning methods applied. Raman measurements, optical as well as transport measurements will be performed.
The authors acknowledge funding from the NILgraphene project within the NILaustria Cluster and the European Community's 7th Framework Programme under grant agreement no. 314578 MEM4WIN (www.mem4win.org).

References
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[2] Chou, S.Y. et al., Appl. Phys. Lett. 67 (21) 3114 (1995)
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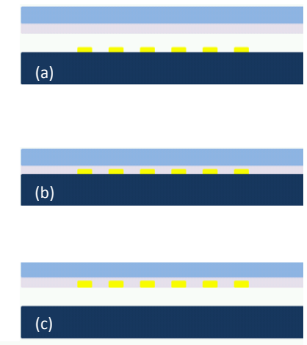

d) 

Figure 1: Shows the schematic transfer process for Au contacts into Ormocomp a) Au structures on Si substrate fabricated by NIL, imprinting of Au structures into Ormocomp and UV curing of material c) Peeling off Au structures d) shows a micrograph image of one Au contact fabricated by NIL.

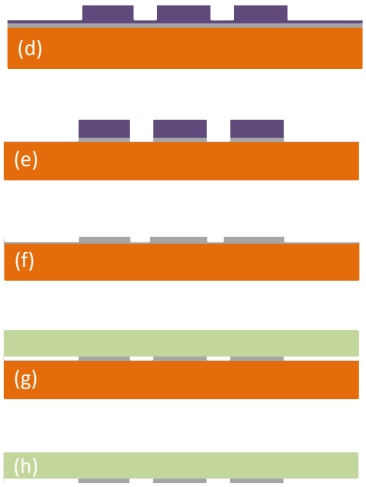

Figure 2: Shows the schematic structuring process of graphene on Cu and transfer to thermal release tape. d) photolithography on graphene on Cu wafer, e) etching of graphene, f) removing photoresist, g) adhesion of thermal release tape on graphene h) etching of Cu

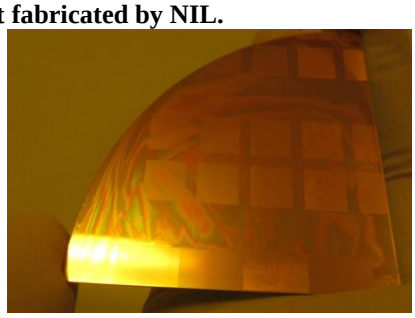

Figure 3: Microstructures patterend on quarter of 4" AIX graphene/Cu wafer

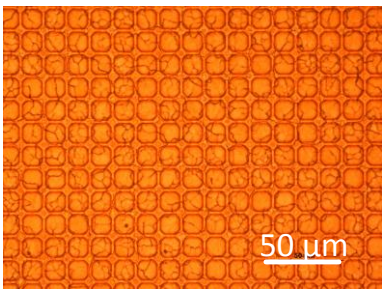

Figure 4: Microscope image of microstructures on 4" AIX graphene/Cu wafer

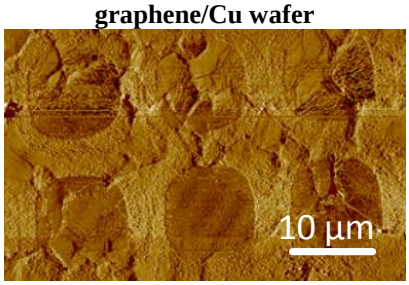

Figure 5: AFM topography image of structured graphene on Cu wafer

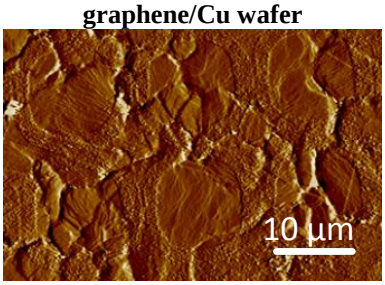

Figure 6: AFM phase image of structured graphene on Cu wafer

Figure 7: i) j) schematic drawing of structured graphene transferring on i) adhesion of graphene on tape onto 90 nm SiO_2 j) thermal release of tape

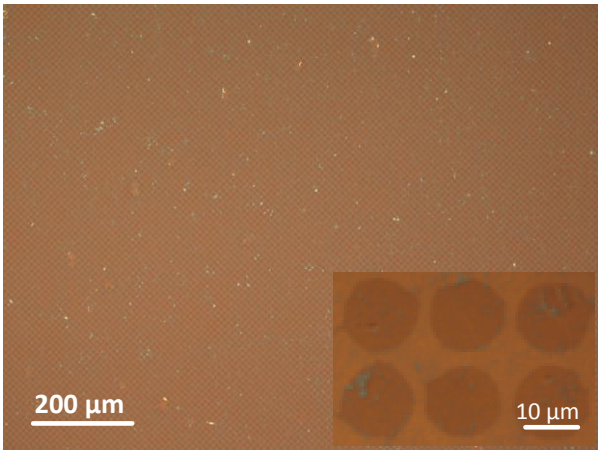

Figure 8: microscope image of transferred patterned graphene dots