DIRECT CHEMICAL VAPOUR DEPOSITED GRAPHENE SYNTHESIS ON SILICON OXIDE BY CONTROLLED COPPER DEWETTING
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ABSTRACT
In this paper we present a novel method for direct uniform graphene synthesis onto silicon oxide in a controlled manner. On a grooved silicon oxide wafer is copper deposited under a slight angle and subsequently the substrate is treated by a typical graphene synthesis process. During this process directional dewetting of the copper into the grooves was observed. A layer of graphene was directly deposited onto the silicon oxide while the copper was retracting from the surface. This method opens new possibilities for graphene devices, since the technique can be applied wafer-scale.

KEYWORDS: graphene, direct synthesis, chemical vapour deposition, copper, dewetting

INTRODUCTION
Popular graphene synthesis technique is by chemical vapour deposition (CVD), where transition metals (copper, nickel etc.) are used as a catalyst for the decomposition of gaseous alkanes (methane, ethane). For practical devices however, the graphene should be presented at a dielectric. To release the CVD graphene from the metal substrate a transfer protocol is required, which is labour intensive and hard to automate. Earlier research has shown that direct graphene synthesis is possible by dewetting of thin copper films on silica substrates using a CVD production method [1]. Disadvantage of this route was that the copper dewetting process on a flat substrate is not controlled but results in random graphene patches. For proper integration of graphene into practical devices, a direct synthesis process suitable for wafer scale application is crucial. We achieve control by regulating the dewetting of copper on the silicon oxide substrate by combination of a grooved surface and copper deposition under a slight angle.

THEORY
During the process the copper is both dewetting and evaporating and simultaneously graphene is deposited directly on the silicon oxide substrate. The dewetting is a curvature-driven diffusion process, where metal is transported from regions with positive curvature (corners) towards regions with negative curvature (grooves) [2], during which process the flat areas are emptied of copper until it becomes disconnected.

EXPERIMENTAL
An oxidized <100> silicon wafer was patterned using conventional lithography with a line mask of 400 lines ranging from 1 µm to 10 µm width. After performing dry etching of the silicon oxide, silicon was wet-etched using 25% KOH at 75 °C to manufacture the grooves. Subsequently the grooved substrate was oxidized for 300 nm for optimal graphene visualization. Next, 500 nm of copper was deposited using e-beam evaporation, either perpendicular or at an angle of 11 degrees (Figure 1). While the substrate was heated to 950 °C (ramping up and down at 60 °C/min), the CVD-process was executed at a pressure of 10 mBar with a hydrogen flow of 200 sccm and methane flow of 10 sccm. Afterwards the Raman spectrum of the synthesized graphene was measured using a WiTec Raman system at of 532 nm at a laser power of 1 mW integrated for 2 seconds.
RESULTS AND DISCUSSION

Figure 1. Cross-sectional SEM images of copper-covered groove-patterned silicon wafers before CVD graphene deposition. (Left): The fabricated substrate is completely covered by a thin layer of copper. (Middle, right): Due to the Cu deposition under a 11° angle, the copper thickness is different for the three different planes. The annotation shows the thickness of the copper film (dark grey) together with the silicon oxide thickness (white).

Figure 2. (Left, optical micrograph): Uncompletely dewetted flat areas when using perpendicular copper deposition. (Middle, optical microscope graph) and (Right, false coloured SEM): Angled copper deposition leads to directional dewetting of the narrow (3 µm) flat areas after the CVD process.

Figure 3. (Left, optical micrograph; Right, false coloured SEM): Flat areas wider than 5 µm are not completely dewetted after the CVD process.
Whether the flat area on the substrate dewetted was found to depend on line width and deposition angle. Copper deposition perpendicular to the substrate gave no directional dewetting while after deposition at an 11° angle, narrow lines (up to approximately 3 µm) became fully dewetted to the thicker copper plane (Figure 2). However, wider lines were not completely dewetted (Figure 3). From the Raman spectrum of the synthesized graphene (Figure 4) it is clear that graphene is deposited, though its quality can still be improved. Further work will aim at optimizing the dewetting procedure as well as the graphene quality.

CONCLUSION

With the present method was possible to directly synthesis graphene onto silicon oxide surfaces in a controlled manner. Lines up to a width of approximately 3 µm were fully dewetted using the graphene synthesis process. Optimization of the process is required to increase the dewetted line width and the deposited graphene quality.

REFERENCES


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