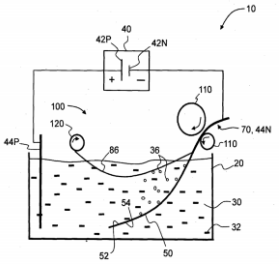
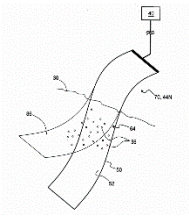
NUS National University of Singapore | Centre for Advanced 2D Materials

JOINT DEVELOPMENT OPPORTUNITY

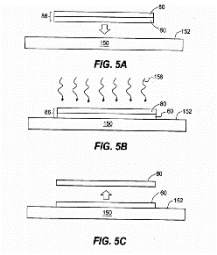
Non-destructive Delamination of Graphene Growth on Metallic Substrate



Electrochemical apparatus suitable for carrying out graphene delamination with acidic, alkaline, neutral organic/inorganic salt, or conducting solvent electrolytic solution and a roller system



Elevated view of delamination of graphene-metal (G-M) structure by peeling off the support layer and graphene (SL-G) structure



Transfer of the graphene film of the SL-G structure to a processing/ target substrate

Ref: Y. Wang, Y. Zheng, X. Xu, E. Dubuisson, Q. Bao, J. Lu and K. P. Loh, *ACS Nano* 2011, **5**, 9927-9933

TECHNOLOGY BACKGROUND

The exceptional properties of graphene that have been uncovered since its laboratory production in 2004 has generated huge amounts of interest from academia and industry. The key to successful commercial adoption of graphene lies in the ability to produce it at a consistent standard on an industrial scale. In particular, large-area, high quality graphene films formed using chemical vapor deposition (CVD) methods have high strength, flexibility, transparency and conductivity. Many methods transfer graphene onto other substrates like copper in which the metal serves as a catalyst for graphene formation. These methods usually involve etching away the metal and dissolving the substrate completely in solution in order to remove the graphene.

The etching and subsequent destruction of the metal substrate is not only costly but also complicated by the use of copious quantities of chemicals as well as the final recovery of the metal. All of these breeds issues of wasteful energy-consumption, high cost and over-complexity.

PROCESS

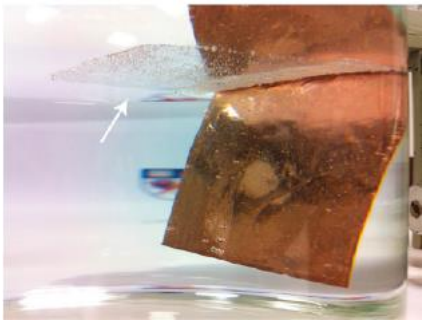
Separation of graphene film from its metal substrate by an electrochemical process

a) Use an input roller to receive the G-M structure and pull it partially into the electrolytic solution.

b) The electrochemical reaction (cathodic reduction of hydrogen ions) hydrolyses the water in the electrolytic solution, creating small (hydrogen) bubbles at the metal-film interface.

c) The graphene film cleaves away from the top of the metal substrate under gentle pressure from the bubbles. Eventually, the whole SL-G structure peels off the metal substrate.

d) Use a take-up roller to help to remove the SL-G as it is peeling off the substrate which is substantially preserved. (Photo on the right.)



e) Recover the metal substrate for future cycles of film growth.

f) Transfer the SL-G onto a processing (target) substrate having a top surface. This structure may then be annealed, e.g. at 90 ^{o}C for 5 mins, to sinter the graphene film onto the process substrate.

g) Remove the support layer, e.g. poly(methyl methacrylate) (PMMA), is then removed from the graphene film by immersing in acetone overnight, heating or by air-transfer of the graphene film, respectively.

Application Areas

- Large-scale applications where economies of scale benefits and high quality films are desired
- Engineering of 3-D strained structures by imprint lithography followed by electrochemical peeling;
- Polymer stamp-transfer lithography.

Benefits Offered

- Much less time is needed using electrochemical delamination (30 to 60 min) than conventional etching methods (more than 6 hours) to peel off a graphene film;
- Graphene films can be peeled off from the metal substrate while substantially preserving the metal substrate (unlike the damage caused to the metal in conventional etching-based processes);
- Recycling of the metals removed for use in multiple cycles of delamination;
- Pre-used metal substrates tend to produce higher-quality graphene;
- Higher efficiency with cost-effectiveness can be achieved using only a single-crystal substrate;
- These methods are totally integrable with industrial-scale ‘roll-and-release’ film-transfer techniques;
- An additional functionality of the methods is their capability to remove microscale-patterned graphene from a metal substrate;
- Functionalized graphene can be formed as a byproduct through the use of nanocrystals and nanoparticles.

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