A general method to transfer graphene with pick-and-place capability to soft surfaces: top electrodes for organic electronics and artificial graphite intercalation compounds

Jie Song,[a)†] Fong-Yu Kam,[a)†] Rui-Qi Png,[b)] Wei-Ling Seah,[b)] Jing-Mei Zhuo,[b)] Geok-Kieng Lim,[b,c)] Peter K.H. Ho,[b)] and Lay-Lay Chua,[a,b)*]

a) Department of Chemistry, National University of Singapore, Lower Kent Ridge Road, S117543, Singapore

b) Department of Physics, National University of Singapore, Lower Kent Ridge Road, S117542, Singapore

c) Primary address: DSO National Laboratories, 20 Science Park Drive, Science Park I, Singapore 118230, SINGAPORE

† These authors contributed equally to the work.

* Electronic mail: chmcll@nus.edu.sg

songjie@nus.edu.sg

Abstract

Recent advances in the chemical vapor deposition growth of graphenes on metal foils have made large graphene sheets available for research and development. For real applications to electronic devices however, further breakthroughs in the method of graphene transfer from its growth substrate to the application substrate are necessary. Although various methods have been developed, a general way to transfer these graphenes reliably onto arbitrary surfaces, including “soft” ones, with registration, is still not available. Here we report a general transfer method that uses a generic self-release layer (SRL) in conjunction with a conventional poly(dimethylsiloxane) elastomer stamp. This can transfer graphene with registration to almost all surfaces, including fragile polymer thin films and hydrophobic surfaces which were previously not possible. We demonstrate high-fidelity graphene monolayer transfer onto 45-nm-thick polymer dielectric films. This gives capacitors that show superior dielectric breakdown field strength over the ones with evaporated metal electrodes. We integrate graphene as top-gate electrodes into conventional organic field-effect transistors to achieve low-voltage operation using a sub-100-nm-thick gate dielectric layer made from conventional dielectric polymers. We also demonstrate a first “artificial” graphite intercalation compound (GIC) by stacking graphene monolayers alternately with a well-defined molecular intercalant of 2,3,5,6-tetrafluoro-7,7,8,8-tetracyanoquinodimethane (F_4TCNQ). This GIC is *p*-doped by partial hole transfer from F_4TCNQ (0.0035 per carbon), exhibits good electrical conductivity (400 ohm per square • sheet) and excellent thermal and humidity stability up to 175ºC. The transfer methodology is also applicable to other 2D materials and ultrathin metal films.