Multigraphene growth on lead-pencil drawn silver halide print paper irradiated by scanning femtosecond laser

Satoru Kaneko1,6, Yoshitada Shimizu1, Takeshi Rachi1, Chihiro Kato1, Satomi Tanaka1, Yasuhiro Naganuma1, Toru Katakur2, Kazuo Satoh3, Mikio Ushiyama4, Seiji Konuma5, Yuko Itou4, Hirofumi Takikawa5, Goon Tan6, Akifumi Matsuda6, and Mamoru Yoshimoto6

1Kanagawa Industrial Technology Research Institute, Ebina, Kanagawa 243-0435, Japan
2RDS Platform, SONY Corporation, Atsugi, Kanagawa 243-0014, Japan
3Technology Research Institute of Osaka Prefecture, Izumi, Osaka 594-1157, Japan
4Kanagawa Academy of Science and Technology, Kawasaki 213-0012, Japan
5Toyohashi University of Technology, Toyohashi, Aichi 441-8580, Japan
6Tokyo Institute of Technology, Yokohama 226-8503, Japan

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Drawings were made on various types of paper using lead pencils of grades from 4H through 10B. Raman spectroscopy verified both G and D peaks on all the drawings on PC print paper, PC photopaper, kent paper, and paper for silver halide print. After irradiation with a scanning femtosecond laser, silver halide paper drawn on with a 10B lead pencil maintained its surface flatness compared with the other types of paper. Raman spectroscopy on silver print paper showed a high-intensity G peak and a low-intensity D peak. After irradiating the scanning femtosecond laser on silver halide paper drawn on with a 10B lead pencil, Raman spectroscopy showed a high-intensity G peak and less intense of D peak together with a 2D peak around 2,700 cm−1 corresponding to the existence of multigraphene. © 2016 The Japan Society of Applied Physics

1. Introduction

After the discovery of graphene1–3 prepared by peeling Scotch tape off graphite, graphene has been prepared by other methods such as thermal decomposition of SiC4–6 and chemical vapor deposition with catalysts such as Ni, Cu, and Fe.7–11 In this study, we propose another method of preparing graphitic carbon: irradiating pencil-drawn print paper using a femtosecond laser.

Pulsed laser deposition is one of the most versatile methods of growing metals,12 oxides,13–15 and multilayers16,17 including graphene18,19 and diamond.20 In this technique, an incident laser beam irradiates a target in a vacuum chamber, and the vaporized materials from the target surface reach a substrate placed against the target, resulting in the growth of film. A femtosecond laser is often used as a laser source.21,22 We drew on a sheet of printing paper with a lead pencil, and irradiated the drawn paper with a femtosecond laser in atmosphere at room temperature. Compared with conventional methods, this simple method of using pencil lead as a source material does not require either a high-vacuum atmosphere or high temperature. A vacuum chamber is not required and the scanned area is only dependent on the movement of the X–Y stage (sample holder), resulting in the large advantages of high productivity and large sample size.

The solid core of a pencil is made of graphite mixed with a clay binder, and is “harder” with more clay in the solid core and soft with more graphite. The ratio of graphite to clay determines the grade of the pencil from “H” for hardness to “B” for blackness, and an intermediate grade “F” for fine. A set of pencils ranging from a very hard, light-marking pencil to a very soft, dark-marking pencil usually ranges from hardest to softest with different amounts of carbon, clay, and wax.23 as shown in Fig. 1. The grade 10B was not available until Mitsubishi Corp. produced the 10B lead pencil, which is available only in some regions of Japan.

Although paper and pencil are literally primitive materials, an interesting approach has been presented.24–27 Lin et al. used pencil traces drawn on print paper as strain gauges and as chemiresistors. Graphite particle chains in a U-shaped pencil trace have varying resistance depending on the deformation of the paper. As shown in Fig. 1, the grade 10B with a high graphite content was mainly used for drawing on a sheet of paper in this study. Various types of paper were also prepared for this study: printing paper for a PC printer, photo print paper for a PC printer, kent paper, and print paper for silver halide prints. The paper for silver halide prints showed lower background fluorescence in Raman spectroscopy compared with other types of paper; thus, the grade 10B lead pencil was used for drawing on the back of the silver halide print paper in this study.

2. Experimental procedure

The types of paper used in this study were (1) print paper for a PC printer (PC paper), (2) photo print paper for a PC printer (PC photo paper), (3) kent paper, and (4) paper for silver

Fig. 1. Grades of lead pencils. “H” (for hardness) to “B” (for blackness), as well as “F” (fine), a letter arbitrarily chosen to indicate midway between HB and H.