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Letter to the Editor

Synthesis of carbon nanosheets from Kapton polyimide by microwave plasma treatment

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ABSTRACT

Vertically-aligned carbon nanosheets (CNSs) have been fabricated on the Cu substrate from Kapton polyimide (PI) film under Ar/H_2 plasma irradiation. The high purity CNSs possess petal-like structures with many sharp edges, which are composed of few-layer graphene sheets. In addition, the irradiated Kapton PI film was covered by a layer of urchin-like carbon particles with about 4 μm in diameter, which also consist of few-layer graphene sheets along radial directions. Except for the morphologies, both the CNSs and urchin-like carbon particles demonstrate similar microstructures and chemical compositions.

Due to many open edges, high height/thickness ratio, large surface areas and chemical stability, carbon nanosheets (CNSs) which consist of few-layer graphene have been extensively investigated in many fields of biosensors, field electron emissions, supercapacitors, lithium ion batteries, fuel cells et al. [1]. Depending on their synthesis approaches, the CNSs with different morphologies can be achieved and are classified into two categories-vertical and random alignments which relate to substrates [2]. Among the various synthesis methods for CNSs, plasma-enhanced chemical vapor deposition (PECVD) has been considered as a promising method for the formation of vertically-aligned CNSs because of mass production, large area, and low cost as well as low-temperature growth [3]. Usually, carbonaceous gas (e.g. CH_4) as carbon source was decomposed into carbon radicals under plasma irradiation (e.g. H_2), and carbon radicals would deposit on the substrate to form the CNSs with vertical orientation because of the local field effect [4]. Very recently, besides carbon gas sources, some liquid organic precursors including honey, butter, and milk were used to fabricate the vertically-aligned graphene nanosheets by radio-frequency plasma treatments [5,6]. Our group utilized the microwave plasma of Ar and H_2 to generate vertical nanosheets with bi- and tri-layer of graphene from solid carbon source on the quartz tube [2].

In this letter, we report the growth of vertically-aligned CNSs obtained on the Cu substrate from Kapton polyimide film which is a solid carbonaceous polymer as carbon source under Ar/H_2 plasma irradiation. The experimental details

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are described in Supplementary Materials. After deposition without any carbon-containing gas, the surface of Cu substrate was covered by a thin film of black material, which was confirmed preliminarily to be carbon (inset of Fig. 1a). The morphologies of carbon films from PI as carbon source by microwave plasma treatment were observed by scanning electron microscopy (SEM, see Fig. 1a and b). Fig. 1a shows a typical high-magnification SEM image of as-synthesized carbon films. It can be found that the films were composed of petal-like nanosheets with many sharp open edges, which are similar to the CNSs obtained from CH_4 gas under plasma irradiation [7]. The low-magnification SEM image exhibits a uniform distribution of these nanosheets on the Cu substrate. The cross-sectional SEM image (inset of Fig. 1b) displays that the resulting nanosheets are oriented perpendicularly to the substrate. The average length and height of the nanosheets were calculated to be 1 and 4.5 μm, respectively. The thickness of the edges was about 2 nm, as was confirmed by transmission electron microscope (TEM) images (see in Fig. 1c).

Fig. 1d shows Raman spectrum of vertically-aligned CNSs, which includes four main features of D, G, D′ and 2D peaks. The D (1349 cm^{-1}) and D′ (1619 cm^{-1}) peaks are disorder-induced bands that are often observed in defective graphite

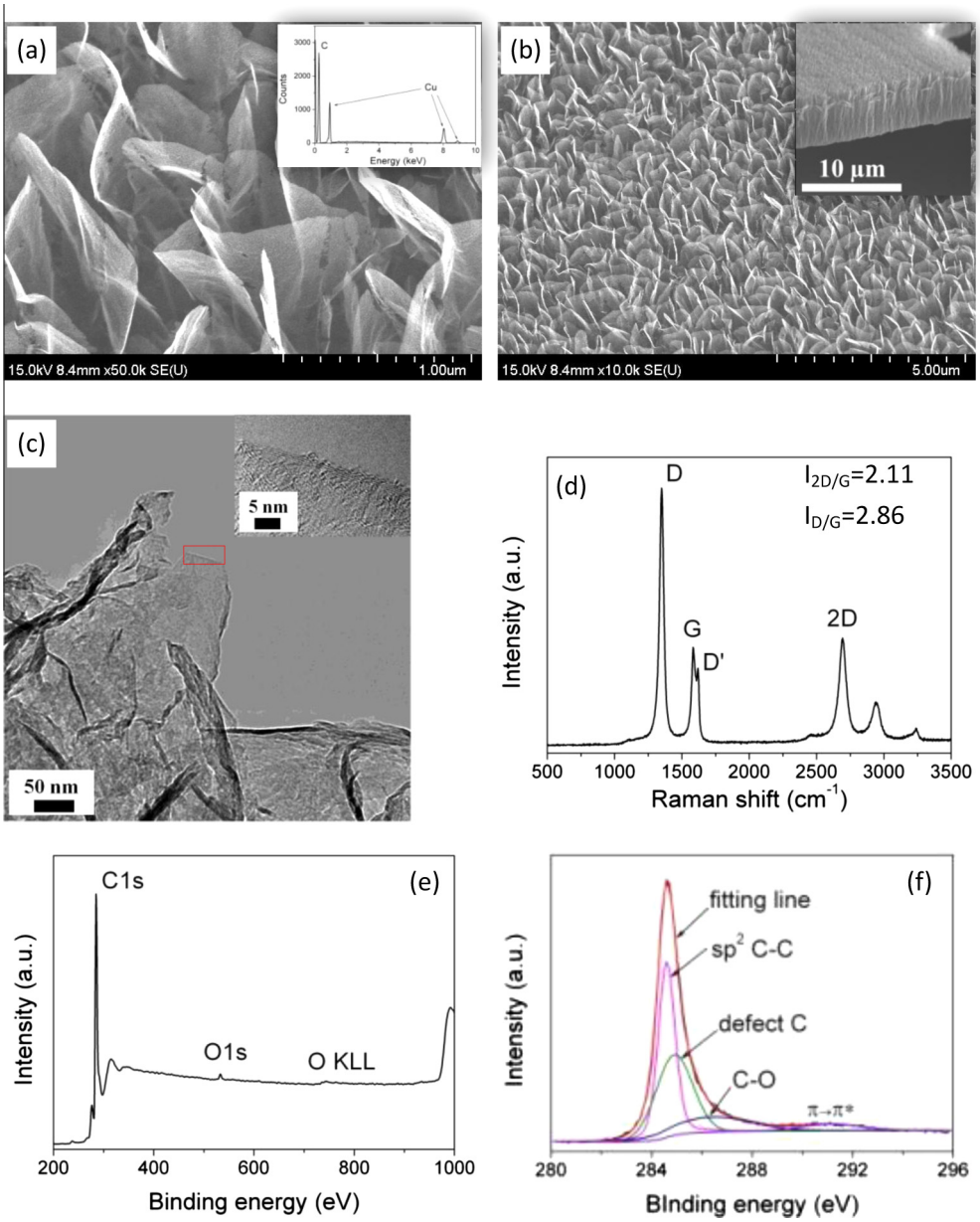

Fig. 1 – (a) High- and (b) low-magnification SEM images of vertically-aligned CNSs on the Cu substrate from Kapton PI film as carbon source under Ar/H_2 plasma irradiation. Inset in (a) and (b): EDX pattern and cross-sectional SEM image of vertically-aligned CNSs, respectively. (c) Typical TEM image of as-synthesized CNSs. Inset: TEM image of a five-layer graphene edge. (d) Raman spectrum of the CNSs. (e) Survey scan and (f) the C 1s curve fitting of XPS spectra of the CNSs. (A colour version of this figure can be viewed online.)