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Fabrication of particular structures of hexagonal boron nitride and boron–carbon–nitrogen layers by anisotropic etching

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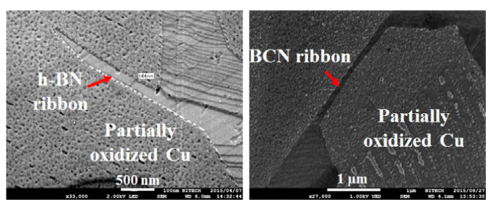
HIGHLIGHTS

- Demonstrated anisotropic etching of h-BN for nanoribbons fabrication.
- Synthesis of BCN layers using mixture of solid sources and their anisotropic etching.
- Raman studies confirm B and N incorporation in graphene and BCN layer formation.
- SiO_2 nanoparticles incorporated during growth assisted H_2-induced etching process.
- The etching process is significant to fabricate various h-BN related novel structures.

GRAPHICAL ABSTRACT

Anisotropic etching of hexagonal boron nitride and boron–carbon–nitrogen layers to fabricate nanoribbons and distinct etched structures by annealing in H2 and Ar gas mixture.



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ABSTRACT

Anisotropic etching of hexagonal boron nitride (h-BN) and boron–carbon–nitrogen (BCN) basal plane can be an exciting platform to develop well-defined structures with interesting properties. Here, we developed an etching process of atomically thin h-BN and BCN layers to fabricate nanoribbons (NRs) and other distinct structures by annealing in H_2 and Ar gas mixture. BCN and h-BN films are grown on Cu foil by chemical vapor deposition (CVD) using solid camphor and ammonia borane as carbon, nitrogen and boron source, respectively. Formation of micron size well-defined etched holes and NRs are obtained in both h-BN and BCN layers by the post growth annealing process. The etching process of h-BN and BCN basal plane to fabricate NRs and other structures with pronounced edges can open up new possibilities in 2D hybrid materials.

1. Introduction

Anisotropic etching is an important tool for microfabrication processes, creating distinct microscopic features. These microstructures obtained by anisotropic etching are commonly used for nanoelectronic devices, thereby achieving desired optical, electrical, and physical properties [1,2]. The development of various two dimensional (2D) materials in the last decade has attracted significant attention for electronic device applications [3–5]. In this prospect, achieving anisotropic etching of 2D materials can be one of the most important aspect for nanoelectronics. Anisotropic etching of graphite sheet, exfoliated few-layer graphene and chemical vapor deposited graphene has been significantly explored to obtain regular, well-defined zigzag or armchair edge structures [6–11]. Anisotropic etching of graphene basal plane has been achieved with metal catalytic nanoparticles in presence of H_2, selective oxidation, and water vapor at an elevated temperature [9–13]. The etching process enable to fabricate nanoribbons with particular

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edge structures of high quality graphene. Similarly, creating hexagonal hole in graphene with pronounced edges by the etching process also provide a platform to fabricate in-plane heterostructure with other 2D materials [14,15].

In contrast to previous reports, anisotropic etching of h-BN and BCN film is not addressed for possibilities of fabricating NRs or other regular structures. Very recently, we demonstrate possibility of opening triangular holes in triangular h-BN crystals by anisotropic etching [16]. h-BN is an insulating layered material consisting of sp^2 hybridized alternating B and N atoms with similar honeycomb lattice of graphene [17,18]. Monolayer and few-layer h-BN have been derived by exfoliation and chemical vapor deposition (CVD) synthesis process for field effect transistor (FET) applications [17,19–22]. Previously, theoretical analysis has predicted that the basic properties of h-BN can be changed by incorporating graphene in the h-BN lattice with an ordered structure [23–25]. Developing heterostructures with controlled shape, size and edges can introduce unexpected electronic and magnetic properties [25]. Further, it has been predicted that atomically thin h-BN NRs can exhibit narrow band gap with improved conductivity owing to transverse electric field or edge structures [26,27]. Similarly, half-metallicity in BCN NRs has been expected by theoretical analysis [28]. Till date, the only way to derive h-BN NRs is unzipping of nanotubes, while synthesis of BCN NRs is much more challenging [29,30]. The unzipping process of nanotubes has inevitable issues in precisely controlling the edge structures, width, number of layers and defects formation. In this work, we have developed an anisotropic etching process of atomically thin h-BN and BCN film to overcome the challenges for NRs fabrication. The anisotropic etching process can be very

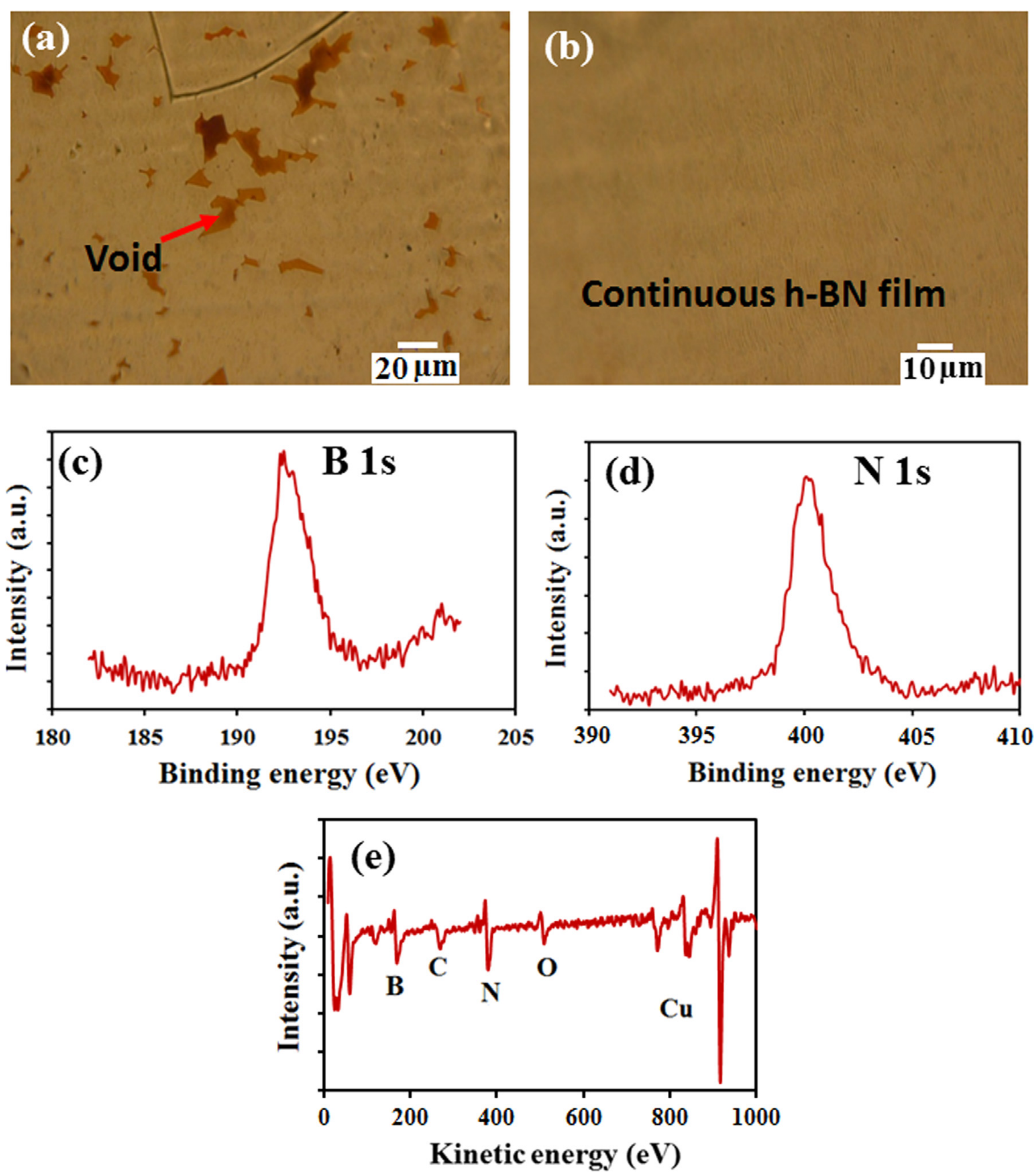

Fig. 1. Optical microscope images of (a) void formation with incomplete growth and (b) continuous h-BN film on Cu foil. XPS spectra of the h-BN film (c) B1s and (d) N1s. (e) AES spectra of as-synthesized h-BN film on Cu foil.