**Research and Development**

**Extended Abstract**

# Graphene 2018: Synthesis and application of vertical graphene network-Mineo Hiramatsu-Meijo University, Japan

## Abstract

Graphene (monolayer and few layers) is a two-dimensional material with the large anisotropy between in-plane and outof-plane directions. Carbon nanowalls (CNWs) are few-layer graphenes with open boundaries, standing vertically on a substrate. The sheets form a self-supported network of mazelike-wall structures. CNWs and similar graphene structures can be synthesized by several plasma enhanced chemical vapor deposition (PECVD) techniques. CNWs are sometimes decorated with metal nanoparticles and biomolecules. The structure of CNWs with large surface area would be suitable for the platform in electrochemical and biosensing applications. CNW films can be potentially used as electrodes of electrochmical sensor, capacitor, dye-sensitized solar cell, polymer electrolyte fuel cell (PEFC), and implantable glucose fuel cell (GFC). Among these, CNW electrodes in fuel cells should be decorated with catalytic nanoparticles such as Pt. From a practical point of view, control of CNW structures including spacing between adjacent nanowalls and crystallinity is significantly important . Furthermore, formation method of catalytic metal nanoparticles should be established. It is carried out CNW growth using PECVD employing CH4 /H2 /Ar mixtures with emphasis on the structure control of CNWs. It is reported that the effects of ion bombardment and catalytic metals on the nucleation of vertical nanographenes to realize active control of interspace between adjacent walls. Besides, CNW surface was decorated with Pt nanoparticles by the reduction of chloroplatinic acid or by the metal-organic chemical deposition employing supercritical fluid. It is also reported that the performances of hydrogen peroxide sensor, PEFC and GFC, where CNW electrode was used.
The Last Decade attested an enormous breakthrough in the research of graphene. Graphene an allotrope of carbon in the shape of two-dimentional (2D) SP2- hybridized crystalline sheet has a special mixture of outstanding properties such as excellent mechanical strength and elasticity, extreme carrier mobility, excessive service mobility, supreme electrical and thermal conductivity, and excessive optical transmission. These properties, together with its quite massive surface area, without problems modifiable surfaces, and tunable structure by means of incorporating foreign atoms, make graphene versatile in diverse application areas ranging from electronic devices, sensors, catalysis, to power harvesting and storage. In particular, along with the growing necessities of flexible, safe, and portable devices, utilization of graphene and graphene- based composite electrodes has led to prominent growth in creating new electrochemical energy storage and conversion systems, such as supercapacitors, batteries, and fuel cells.

The structural design of an electrode is one of the most essential factors affecting its reaction kinetics, the capability of mass transportation with electrolyte, and subsequently the performance of an electrochemical power storage or conversion system. A profitable approach that has been widely established is to assemble a 3D nanoscale- structured electrode, which enables more suitable ion and electron transport, increased active material loading, and improved mechanical stability. Based on its outstanding properties, graphene has shown first-rate promises as a constructing cloth for the development of new electrodes in electrochemical systems. Moreover, a 3D graphene- based porous framework should be employed concurrently as the structural spine and cutting-edge collector in a free- standing and binder- free electrode, which benefits the fabrication of lightweight and bendy devices. In line with this strategy, more than a few 3D graphene structures have been synthesized and utilized for energy storage and conversion, which can be genuinely categorized to graphene foams (GFs) and vertically aligned graphene nanosheet arrays (VAGNAs).

Recently, another kind of 3D graphene, i.e., Vertically Aligned Graphene Nanosheet Arrays (VAGNAs), has attracted increasing Interest for its application as electrochemical electrodes due to its optimum reaction kinetics and mass transportation capability to that of GFs. With a thickness of a number of to tens of graphite carbon layers, Vertically Aligned Graphene Nanosheet Arrays are also named as carbon nanoflake arrays or carbon nano wall arrays elsewhere. Vertically Aligned Graphene Nanosheet Arrays are normally synthesized via PECVD with gaseous carbon sources, in which 2D graphene nanosheets are grown perpendicularly to the substrates to construct a 3D ordered and interconnected array shape with enriched edges of graphene sheets exposed. The Synthesis is processed at relatively low temperatures ranging from 300 to 800 °C, which approves more choice of substrates for the development of Vertically Aligned Graphene Nanosheet Arrays. VAGNAs can be easily and uniformly embellished with other energetic materials, which further leads to a exceptional variety for their application.
Based on these inherent advantages, Vertically Aligned Graphene Nanosheet Arrays s have been utilized in exclusive fields, such as gas sensors, biosensors, electrocatalysts, field electron emission, surface- enhanced Raman spectroscopy (SERS), EDLCs, Faradaic pseudo capacitors, LIBs, and fuel cells, as summarized in . Recently, some necessary progresses have been accomplished in the development of Vertically Aligned Graphene Nanosheet Arrays s and their composites for high- efficiency integrated electrode applications in electrochemical power storage and conversion. It is trusted that it is well timed and essential to look again into the recent lookup of this crew of nanomaterials, in particular with the increasing requirements of electricity storage elements in emerging flexible and wearable devices. As in contrast with the previous critiques in the field, the current work emphasizes more the success of VAGNAs and related composites in the electrochemical electrode functions derived from their wonderful merits of structure and properties. The morphology and graphitization degree additionally had essential influences on the performance of VAGNA electrodes. It used to be proven that the vertically aligned graphene nanosheets grown at a high temperature (≈850 °C) had extra curved surfaces as compared with that prepared at low temperature (≈750 °C). As a consequence,the VAGNAs grown at high

temperature had large accessible surface place and greater defect density, which in flip led to a higher capacitance

The article begins with a brief introduction to the synthesis methods and growth mechanism of Vertically Aligned Graphene Nanosheet Arrays, accompanied with a summary of the bodily and chemical properties of Vertically Aligned Graphene Nanosheet Arrays. Then we highlight the state- of- the- art development of novel Vertically Aligned Graphene Nanosheet Arrays electrodes and their overall performance in the views of their pros and cons as compared with other 3D graphene- based electrodes. At last, we will talk about the task and chance of VAGNAs for the similarly development of new electrochemical energy sources.

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