Faraday Discussions Vol 164

Electroanalysis at the Nanoscale

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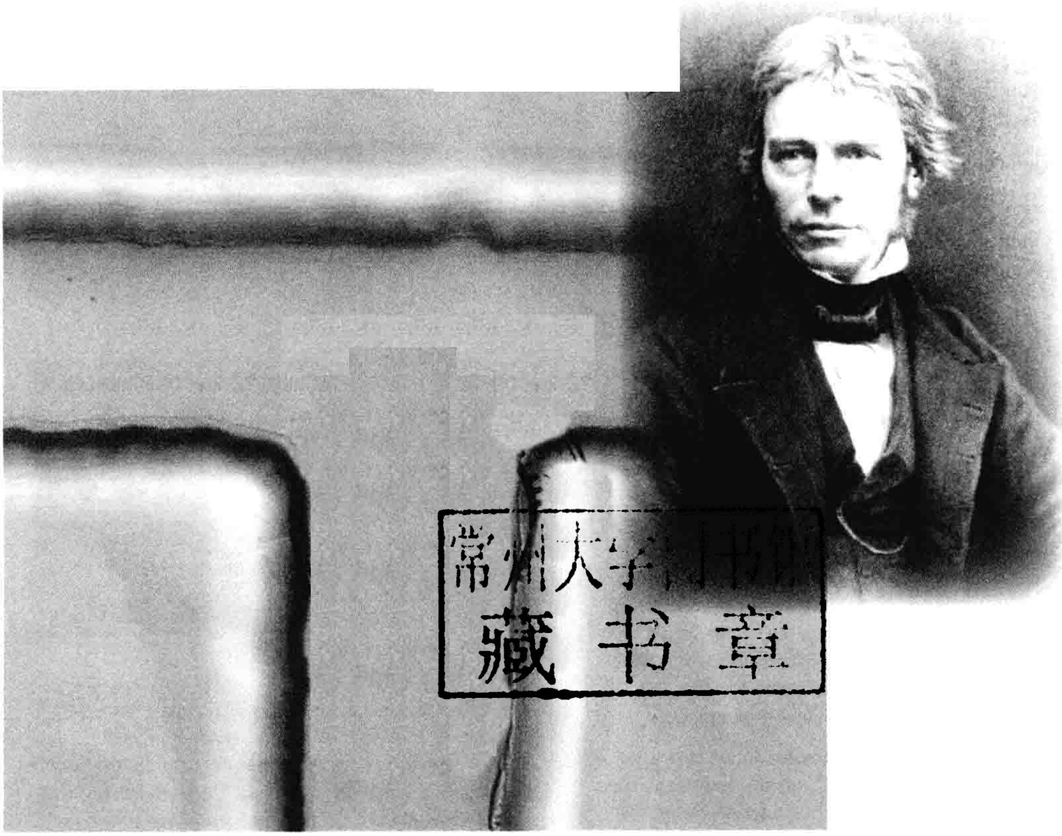
Electroanalysis at the Nanoscale

Durham University, United Kingdom
1–3 July 2013



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Electroanalysis at the Nanoscale

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A General Discussion on Electroanalysis at the Nanoscale was held in Durham, UK on the 1st, 2nd and 3rd of July 2013.

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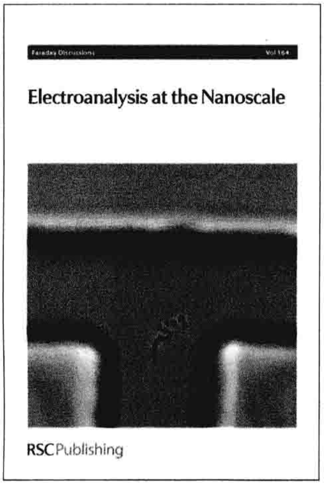

Cover
See Wang,
Faraday Discuss., 2013, **164**, 9.

Electrochemically-prepared antibody-functionalized catalytic micromotors for capturing and transporting target biomolecules in lab-on-a-chip devices.

Image reproduced by permission of Professor Joseph Wang from *Faraday Discuss.*, 2013, **164**, 9.

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PAPER

Template electrodeposition of catalytic nanomotors

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The combination of nanomaterials with electrode materials has opened new horizons in electroanalytical chemistry, and in electrochemistry in general. Over the past two decades we have witnessed an enormous activity aimed at designing new electrochemical devices based on nanoparticles, nanotubes or nanowires, and towards the use of electrochemical routes – particularly template-assisted electrodeposition – for preparing nanostructured materials. The power of template-assisted electrochemical synthesis is demonstrated in this article towards the preparation and the realization of self-propelled catalytic nanomotors, ranging from Pt–Au nanowire motors to polymer/Pt microtube engines. Design considerations affecting the propulsion behavior of such catalytic nanomotors are discussed along with recent bioanalytical and environmental applications. Despite recent major advances, artificial nanomotors have a low efficiency compared to their natural counterparts. Hopefully, the present *Faraday Discussion* will stimulate other electrochemistry teams to contribute to the fascinating area of artificial nanomachines.

1 Introduction

The first Royal Society Discussion Meeting held under the name "Faraday Discussions", was held in 1947, and was devoted to the topic of "Electrode Processes".[1] This Introduction is intended to provide some background to the topic of the present *Faraday Discussion* 164 on Electroanalysis at the Nanoscale, starting with a short history of the subject. The trend to miniaturization of electrodes started in the mid 1970s, prior to the nanotechnology boom. Leading electrochemists have recognized for a long time that the miniaturization of working electrodes has obvious practical advantages, and opens up fundamentally new possibilities.[2–4] Ultramicroelectrodes have been widely used for over three decades for local electrochemical investigations, and particularly for *in vivo* monitoring of neurotransmitters.[2,4] The emergence of nanotechnology, and the introduction of nanoparticles, nanotubes or nanowires and in the 1980s and 1990s, has opened new horizons for designing new electrochemical devices and electroanalytical strategies. Over the same periods we have witnessed

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considerable efforts in the use of electrochemical routes for preparing nanostructured materials. The field of nanoscale electrochemistry has thus been growing very fast.

2 Use of nanomaterials in electroanalysis and electrochemistry

Major efforts, starting in the 1980s, have greatly improved the way of making, assembling, positioning and imaging nanomaterials of different compositions with controlled sizes, shapes and functionality. The unique properties of nanoscale materials have paved the way to new and improved electrochemical sensing devices.[5,6] The range of nanomaterials used in electrochemistry is wide and diverse. Nanomaterials such as carbon nanotubes, gold nanoparticles, or silicon nanowires have thus made a major impact on the field of electrochemical biosensors, ranging from glucose enzyme electrodes to DNA hybridization sensors.[5–7] For example, various nanoparticles have been used towards effective electrical communication between the redox proteins and the electrodes or as amplification tags for ultrasensitive electrochemical bioaffinity assays.[8,9] Nanomaterial–biomolecule hybrid systems have also led to the development of new and improved biofuel cells. Electrocatalytic sensing and energy-conversion applications have also benefited from the ability to vary the size, composition and shape of nanomaterials, and hence tailoring their electrochemical reactivity. The newest nanoscale carbon material, graphene, has already been shown to be extremely useful for enhancing greatly a wide range of electrochemical sensing and energy storage applications.[10] Considerable attention has been given recently to understanding the various factors and parameters that affect the electrochemical reactivity of nanoscale carbon materials, owing to uncertainties associated with the source or quality of these nanomaterials.[11]

3 Use of electrochemical methods for preparing nanostructured materials

Electrochemical deposition has been shown to be extremely useful for preparing nanomaterials. In particular, the membrane-template electrosynthesis method, introduced by Charles Martin in the mid 1990s, has been one of the most widely used electrochemical routes for preparing nanostructured materials.[12] Such template-assisted electrochemical growth of different nanowires involves electrodeposition into the cylindrical void nanopores of a host porous membrane template, followed by dissolution of the template.[13,14] Nanoporous membranes (*e.g.*, track-etched polycarbonate, anodized alumina), with a wide range of pore diameters (0.03–10 μm) and pore densities (10^5–10^9 pores cm^{-2}), are available commercially from companies such as Millipore or Whatman, and are the most widely used sacrificial template.

The template electrodeposition method is very general as it entails synthesis of the desired material within the cylindrical pores. The method has thus been extremely useful for preparing nanowires with broad range of chemical compositions, including metallic, polymeric and semiconductor nanowires. This is accomplished by depositing first a thin film of metal on one side of the template to create the working electrode and electrical contact. The membrane is then

