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Investigation on the role of cost effective cathode materials for fabrication of efficient DSSCs with TiNT/TiO_2 nanocomposite photoanodes

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ABSTRACT

Free-standing, micrometer long TiO_2 nanotube arrays (TiNTs) were synthesized via anodization by utilizing selected transition metals and non-transition elements as cathode materials. Free-standing TiNTs arrays with the maximum tube length up to 153 µm was fabricated with Ti cathode material, whereas, the cost effective cathodes materials of charcoal and graphite pencil yielded nearly 100 µm long nanotubes for an anodization time of 48 h. The barrier layer was removed from the bottom of the free-standing TiNT arrays using chemical etching process. The as-synthesized open ended free-standing amorphous arrays were then crystallized into anatase phase. The annealed free-standing TiNT array was powdered and mixed with TiO_2 nanoparticles (NP) to form TiNT/TiO_2 NP composite and then utilized as photoanodes to fabricate dye sensitized solar cells (DSSCs). The J-V characteristics and the performances of the solar cells were studied and compared. The results indicate that the TiNT arrays developed with different cathode materials are similar to or in some cases superior to those nanotubes obtained using Pt cathode. Thus, the strategy employed in this work provides a simple, efficient and economical fabrication method for large scale production of TiNT arrays.

1. Introduction

Among the materials being developed for photoelectrolysis applications, titania (TiO_2) remains the most promising because of its high efficiency, low cost, chemical inertness and photostability [1–3]. TiO_2 has found multifunctional properties which highlight many important applications including photocatalytic environmental remediation, water splitting for hydrogen fuel, CO_2 reduction, self-cleaning coatings, electrochromic devices, sensors and low cost solar cells [4–7]. For energy applications, fundamental understanding and innovative design of TiO_2 based materials are of high importance to make further inroads towards high energy conversion efficiency. Ever since the anodizing process in a fluoride electrolyte gave rise to the development of high aspect ratio nanotube (NT) arrays, then on several anodizing approaches for finding the optimal electrolyte and experimental parameters have been explored to effectively achieve high quality self-organized titania nanotube (TiNT) arrays [8–11]. Anodization is found to be the best method to fabricate TiNT. Researchers, in general, employ the platinum cathode material during anodization owing to the reason that it can be reused for a significant amount of times due to its robust stability. However, the cost of platinum is a key issue that needs to be addressed. Therefore, it is highly desirable to find an alternative cathode material which serves the purpose of platinum while sustaining the TiNT architectures.

Among the various published works in this field, the influence of the cathode materials over the properties of the anodized TiNT arrays remains as a grey area, needing better understanding and clarifications. It was in 2008, the research group of Allam authenticated a study on the effect of cathode materials in anodization of titanium and it has opened up the possibility of finding an alternative cathode material to platinum [12]. Taking inspiration in this line, this article focuses on the effect of different types of cathode materials on the structure and morphology of TiNT arrays along with their performance as photoanodes in dye sensitized solar cells (DSSCs). Particular attention is paid in introducing cost effective and readily available forms of carbon such as charcoal (Chr) and graphite (Gr) pencil as cathode materials. We believe that by successful utilization of these materials as cathodes in anodization process, the cost to fabricate TiNT arrays can be drastically reduced.

TiNTs prepared by electrochemical anodization has been verified to be an ideal photoanode in photoelectrocatalytic devices due to its improved charge collection efficiency and short pathway for the

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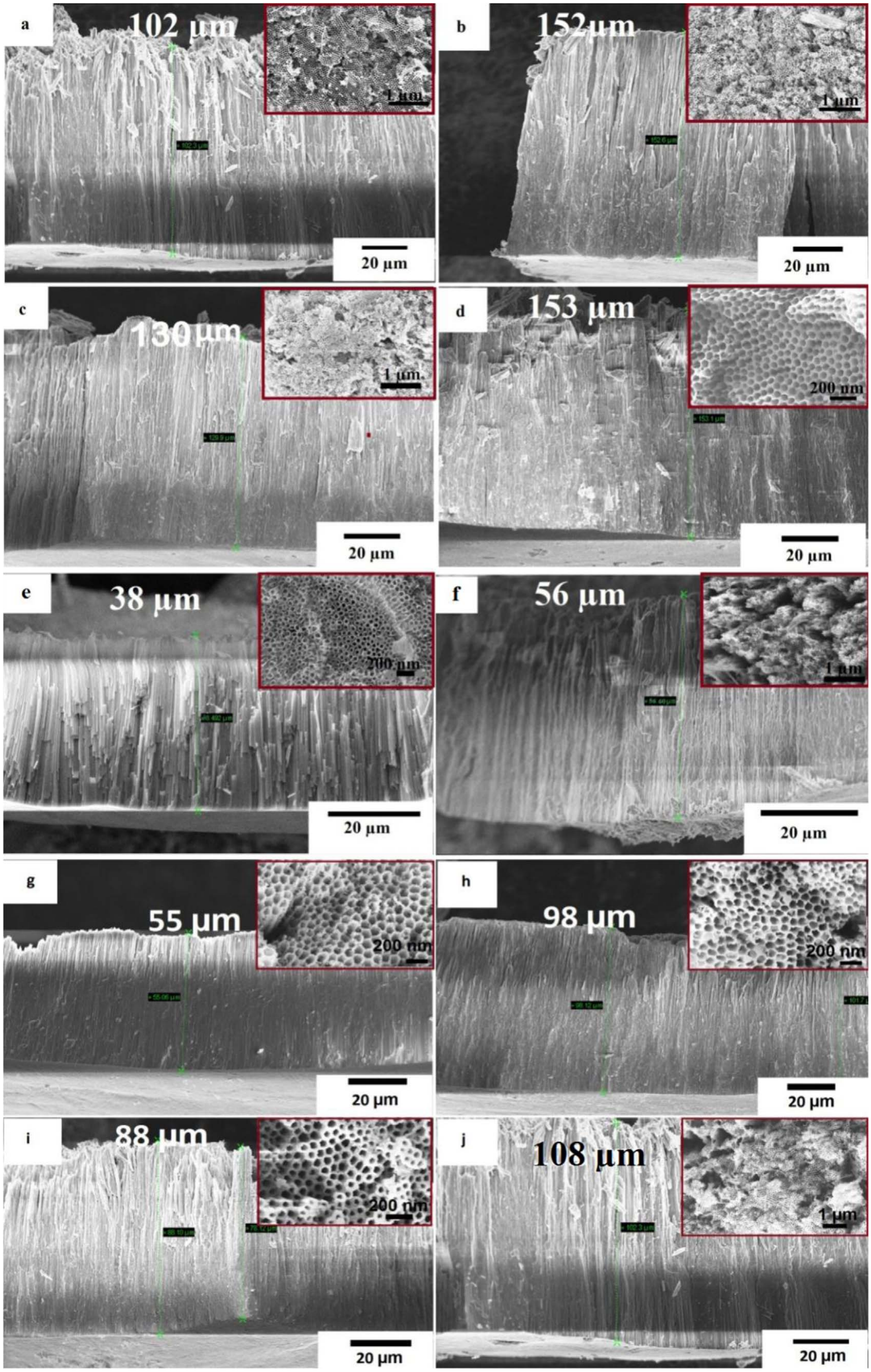

Fig. 1. FESEM images of free-standing TiNT arrays fabricated using different cathodes for 24/48 h (a–b) platinum, (*c*–d) titanium, (*e*–f) iron, (*g*–h) graphite pencil and (*i*–j) charcoal.