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Review

Silver nanowires: Synthesis technologies, growth mechanism and multifunctional applications

Pei Zhang [a,b,c,e], Ian Wyman [d], Jiwen Hu [a,b,c,d,e,*], Shudong Lin [a,b,c,d], Zhiwei Zhong [a,b,c], Yuanyuan Tu [a,b,c], Zhengzhu Huang [a,b,c], Yanlong Wei [a,b,c]

[a] Guangzhou Institute of Chemistry, Chinese Academy of Sciences, Guangzhou 510650, PR China
[b] Key Laboratory of Cellulose and Lignocellulosics Chemistry, Chinese Academy of Sciences, 510650, PR China
[c] Guangdong Provincial Key Laboratory of Organic Polymer Materials for Electronics, 510650, PR China
[d] Department of Chemistry, Queen's University, 90 Bader Lane, Kingston, Ontario K7L 3N6, Canada
[e] The University of the Chinese Academy of Science, Beijing 100039, PR China

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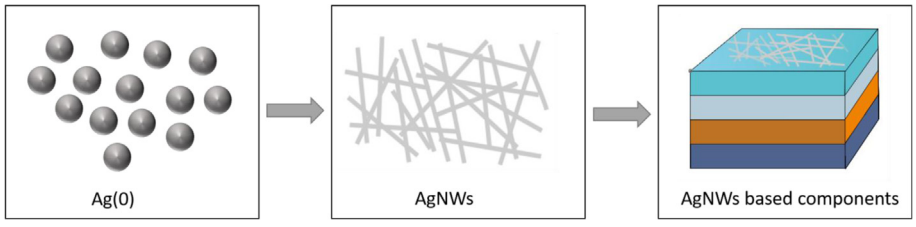
ABSTRACT

Silver nanowires have attracted a lot of attention in both academia and industry because of their potential applications in many electronic devices. In the past decade, there have been many research articles relating to silver nanowires, but there have been relatively few review articles focusing on these unique nanomaterials. In this review, the definition and the characterization of silver nanowires will be introduced. The synthetic methods employed to prepare silver nanowires and the factors that influence their final morphology will also be discussed in detail. Examples of typical synthetic technologies and the representative studies will also be summarized and discussed. In addition, the applications of silver nanowires as conductive materials and components of electronic devices will be reviewed. Lastly, the challenges that remain with silver nanowires will be proposed.



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* Corresponding author at: Guangzhou Institute of Chemistry, Chinese Academy of Sciences, Guangzhou 510650, PR China.
E-mail address: hujiwen@gic.ac.cn (J. Hu).

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1. Introduction

Silver nanowires (AgNWs) are 1-dimensional silver nanostructures with diameters that are typically in a range of 10–200 nm, and lengths in a range of 5–100 μm. Strategies for the synthesis of AgNWs are derived from those employed for the fabrication of quantum wires of semiconductors and metallic alloys, which were found to exhibit interesting electrical and magnetic properties [1]. Consequently, the traditional fabrication methods employed to synthesize quantum dots and wires were also used to fabricate metallic wires, such as gold wires, silicon wires, selenium wires, gallium wires, aluminum wires and silver wires. However, the nanoscale silver wires fabricated by these methods were not uniform, and these nanowires required complex separation processes, which limited their production to small scales.

During the first decade of the 21st century, many researchers dedicated their efforts toward the synthesis of AgNWs with uniform size and high yields [2]. These efforts have led to the development of numerous methods to prepare AgNWs, and these materials have a wide range of potential applications. The rapid growth of this field is demonstrated by the fact that if you type "silver nanowires" in the Google Scholar search engine, you will find more than 124,000 results [3]. This massive range of information can be overwhelming, particularly for researchers who are beginning to investigate this field. There are a few review articles describe some related aspects of AgNWs including synthesis, optical properties, and application of AgNWs. For example, Xia and coworkers have published various reviews on silver nanostructures [2,4–6] and 1-D metallic materials [7,8], these reviews have highlighted the progress that has been achieved with a diverse range of silver nanostructures and other 1-D metallic nanostructures and also discussed their physical properties. Most recently, a few reviews [9–15] highlighting transparent conductive films (TCFs) from AgNWs have also been published. Since reviews only cover various aspects of AgNWs [11,16–24], we believe that there is still a requirement for a detailed review that is aimed toward scientists and engineers who are relatively new to the field of AgNWs and are beginning to work or study in this area. The aim of this review is to summarize some of the recent developments that have been achieved with AgNWs, and provide not an overview of the synthetic methods, the growth mechanism and the applications of these materials, but a comparison of the results reported by different research groups which seems to be conflict sometime. This review is focused on the practical use of AgNWs, many details and specific discussions relating to the synthesis technique of AgNWs will be provided.

This review is organized in the following manner: Following the general overview that has been provided in Section 1, a brief description of the range of morphologies observed among silver nanostructures will be provided in Section 2. Subsequently, Section 3 will provide a brief description of the methods of characterizing AgNWs and a description of their optical properties. Section 4 will highlight the various synthetic strategies that are employed to synthesize AgNWs, while the effects of various parameters on the synthesis of AgNWs (primarily via polyol strategies) will be the focus of Section 5. The growth mechanism of AgNWs will be the emphasis of Section 6, while the various applications of AgNWs and their composites will be highlighted in Section 7. Lastly, the future outlook of AgNWs will be discussed in Section 8. It is our hope that this review will provide an useful