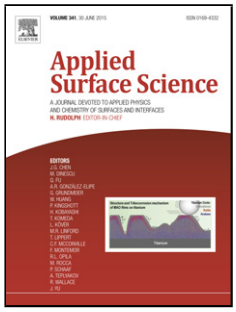

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Electrodeposition efficiency of Ni in the fabrication of highly ordered nanowire arrays: The roles of Cu pre-plating and barrier layer temperature

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Abstract

Investigation of new parameters affecting the electrodeposition process of nanowires (NWs) grown in solid templates is of considerable significance. In this work, the electrodeposition efficiency (EE) of Ni in the fabrication of arrays of pulsed ac electrodeposited NWs embedded in porous aluminum oxide template was investigated. By filling the branched nanopores formed at the bottom of aligned pores with Cu prior to the electrodeposition of Ni and also optimizing the alumina barrier layer temperature (T_{BL}), a steady-state electrodeposition was created at a high current density (j_{ed}) of 60 mA/cm^2. This was accompanied by a significant improvement in the EE of Ni and uniformity of 35 nm diameter NWs. In this respect, while a non-uniform growth of Ni NWs with an average length of 1.5 μm was obtained due to an EE of 10% using T_{BL}~ 8 °C, the use of T_{BL}~ 24 °C led to a uniform growth of 9 μm long NWs as a result of an EE of 55%. Alternatively, the crystallinity of Ni NWs along the [220] direction and their magnetic properties were considerably improved by increasing j_{ed} from 15 to 60 mA/cm^2, so that an approximately 95% increase in axial coercivity (from 570 to 1100 Oe) was achieved.

Keywords: Ni nanowire arrays; porous aluminum oxide; electrodeposition efficiency; barrier layer temperature; Cu pre-plating; magnetic properties.

Abbreviations: nanowires (NWs); porous aluminum oxide (PAO); electrodeposition efficiency (EE); barrier layer temperature (T_{BL}); current density (j_{ed}).

1. Introduction

Ni nanowires (NWs) have recently gained considerable attention due to their possible applications in magnetic nanodevices, biological sensors and battery anodes [1-7]. Fast fabrication of patterned Ni NWs with a high degree of uniformity, long length and high density together with mass production can be demanding and important from both applicability and theoretical points of view [1, 3, 8, 9]. Until now, a variety of methods including chemical vapor deposition, lithography, hydrothermal technique and electroplating have been employed to fabricate Ni NWs [10-13]. Amongst these approaches, the template-based synthesis of Ni NWs such as electrodeposition into porous aluminum oxide (PAO) templates has been more advantageous because of its low cost and flexibility [2, 14, 15]. Besides, it facilitates the fabrication of highly ordered Ni NWs with a large aspect ratio and tunable magnetic properties [1].

It is well known that the electrodeposition of different types of magnetic NWs into PAO templates has been performed by direct current (dc) and alternative current (ac) methods [1, 4, 16]. While the dc method provides a satisfactory electrodeposition efficiency (EE) and high crystallinity [17, 18], its drawback, for instance the necessity of making a conductive electrode at the pores' bottom by sputtering a metal layer (e.g., Au) after removing the insulating barrier layer, makes it less profitable for large-area production. Alternatively, the ac method provides the direct electrodeposition into the nanopores after reducing the barrier layer thickness by widening the pores using a chemical etching [19, 20]. Nevertheless, the hydrogen evolution at the pores' bottom would inhibit the growth of NWs obtained from this approach [4, 21].