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Structural and Multifunctional Properties of Magnetron-Sputtered Fe-P(-Mn) Thin Films

P. Decker, H. S. Stein, S. Salomon, F. Brüssing, A. Savan, S. Hamann, A. Ludwig

Institute of Materials, Ruhr-University Bochum, Bochum, Germany

Alfred Ludwig: Tel.: +49 234 3227492; fax: +49 234 3214409

E-Mail: alfred.ludwig@rub.de

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Abstract

Structural and magnetic properties of magnetron-sputtered Fe-P(-Mn) thin films with compositions around the Fe_2P single phase region are reported, revealing the compositional range of the Fe_2P-type structure and the change of the magnetic properties within this composition spread. The structural analysis shows that in order to obtain crystalline Fe-P phases the P content must be higher than $(Fe_{0.97}Mn_{0.03})_{2.33}P$. A maximum phase fraction of the Fe_2P-type structure is obtained in the examined $(Fe_{0.97}Mn_{0.03})_{1.78}P$ sample. The hysteresis loops for the Fe_2P(-Mn) thin films show a two-step magnetic reversal with one part belonging to an amorphous phase fraction and the other to the Fe_2P(-Mn) phase. A maximum coercivity of 0.36 T was measured for the Fe_2P(-Mn) phase fraction also at the composition of $(Fe_{0.97}Mn_{0.03})_{1.78}P$. Furthermore, electrochemical properties of FeP_2(-Mn) thin films as hydrogen evolution catalysts (HER) are studied. FeP_2(-Mn) shows a HER onset potential about 200 mV lower than that of Pt. Chronoamperometric testing at -10 mA/cm^2 for over 3500 s revealed no obvious decay in current density, suggesting good stability under typical working conditions in a photoelectrochemical device.

1. Introduction

Fe-P-based materials were investigated with regard to different functional properties such as magnetic [1] or photocatalytic [2] properties. Previous thin films were fabricated using evaporation [3], chemical [4] or electrochemical [5] deposition processes, whereas the thin films of this work were deposited by magnetron sputtering. The aim was to produce a composition gradient in the thin films, using a combinatorial materials research approach [6,7], in order to characterize the structural and functional properties depending on the composition. Compositions around the Fe_2P and FeP_2 phases, which show different functional properties (magnetic and electrochemical), were studied. To the best of the authors' knowledge no findings on magnetron-sputtered Fe-P(-Mn) thin films have yet been published. Therefore, the investigation of the thin films in this work shall reveal their properties in comparison to bulk material and investigate how these properties change with variations around the stoichiometric compositions of the mentioned phases.