Accepted Manuscript


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PII: S0040-6090(18)30092-0
DOI: https://doi.org/10.1016/j.tsf.2018.02.013
Reference: TSF 36475

To appear in: *Thin Solid Films*

Received date: 8 July 2017
Revised date: 6 February 2018
Accepted date: 6 February 2018

# Preparation of nickel-containing conductive amorphous carbon films by magnetron sputtering with negative high-voltage pulsed substrate bias

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**Abstract**

Nickel-containing amorphous carbon (a-C-Ni) films were deposited by magnetron sputtering of graphite and nickel. Graphite magnetron sputtering power was 1500 W. Nickel magnetron sputtering power changed from 0 W to 1000 W, allowing control of the Ni concentration in the films from 0 to 58 at.%. Growth rates of a-C-Ni films were 1.4–2.5 μm/h. High-voltage negative pulsed bias voltage of -3 kV amplitude, frequency of 1 kHz, and pulse duration of 50 - 250 μs was applied to a substrate. The chemical composition of the films was determined using Auger electron spectroscopy. The surface morphology was observed by atomic force microscopy (AFM). The film structure was characterized by Raman spectroscopy and X-ray diffractometry (XRD). The resistivity of the films was measured by a four-point probe method. Film properties that are changed by the added metal, such as structure, electrical resistivity, and hardness, were evaluated and compared with those of pure a-C films as well as with literature values for a-C-Ni films. It is shown that the resistivity of a-C films depends on the duration of the bias voltage pulses and varies from 3.4 to $7.6 \cdot 10^{-2}$ Ohm·cm at pulse duration 50 and 250 μs, respectively. In the case of Ni doping, the a-C-Ni film resistivity can be reduced to $6.7 \cdot 10^{-4}$ Ohm·cm. Where Ni is included in the film in the form of $Ni_3C$ carbide, which has hexagonal (hcp) modification, the crystallite size averages 12 nm. The film has a columnar structure and carbon is also present as a graphite-like interlayer 3 nm thick between the $Ni_3C$ crystallites. At sputtering power of 600 W of nickel magnetron, a-C-Ni film with resistivity of $5.3 \cdot 10^{-3}$ Ohm·cm is obtained, which can be used as a barrier layer in thermoelements based on bismuth telluride.

**Keywords:** Metal-containing amorphous carbon; Sputter deposition; Substrate bias; Ion bombardment; Nano-particles

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