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Structure and Properties of Co-C-Pd Thin Film Obtained by Magnetron Sputtering

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ABSTRACT

The article investigates Co-(C-Pd) multilayer coatings produced by magnetron sputtering, focusing on their structure and magneto-optical behavior. Film thickness was controlled by the number of layers, and X-ray diffraction was used to analyze structural features. Magneto-optical properties were measured by the transmission line method. Impedance spectroscopy (50 Hz–100 MHz) showed decreasing phase angle at high frequencies, indicating dielectric losses. Charge accumulation was influenced by crystallite boundaries, bulk resistance, and surface effects. Very high ε' and ε'' values were observed, with low-frequency growth explained by Maxwell–Wagner polarization. Frequency dependence of dielectric loss and conductivity confirmed electromagnetic absorption. Thicker multilayers demonstrated enhanced magneto-optical characteristics, underscoring the potential of Co-C-Pd coatings for spintronic and data-storage technologies.

KEYWORDS

Co-C-Pd Thin Film, Magnetron Sputtering, Magneto-Optical Properties, Microstructure, Multilayer Coatings

INTRODUCTION

Coatings based on transition metal alloys such as cobalt (Co) and palladium (Pd) have become widely used in research due to their unique properties (Tsunashima et al., 1991). In recent years, researchers' interests have also been attracted to the addition of carbon (C) to such coatings, which can significantly affect their structural and magneto-optical properties as well as improve mechanical stability (Sobczak et al., 2012). This field is actively studied, and publications show that improving magnetron-sputtering parameters and adding C can significantly enhance material properties. This is especially important for magnetic and optical devices and for developing new C-Pd catalytic thin films (Lijewski et al., 2017). Studies of the magneto-optical properties and structure of Co-C-Pd coatings obtained by magnetron sputtering are of great interest since such coatings are used in modern memory devices, sensors, and magneto-optical systems (Sebastiani-Tofano et al., 2025).

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Co-C-Pd coatings exhibit the Kerr effect, when reflected light changes its polarization under the influence of a magnetic field (Maximenko et al., 2017). Measuring this effect depending on the layers' thickness and composition allows for fine tuning of the coating's magneto-optical characteristics. With a constant increase in magnetic recording density, the sizes of memory cells move into the submicron and nanometer range. In this regard, in recent years, nanostructures' magneto-optical properties have been the subject of various research groups (Hellman et al., 2017).

Co's ferromagnetic properties allow the coating based on it to exhibit strong magnetic properties. By adding Pd and C, the magnetic characteristics of the coating can be changed, influencing such parameters as coercivity and residual magnetization (Grundy, 2001). These properties are especially important for the development of highly sensitive magnetic sensors and data storage devices. Adding Pd to the coating helps improve the material's optical characteristics, including its reflective properties and ability to absorb light. These features can be used to create magneto-optical devices that respond to changes in the magnetic field by changing their optical response (Jamali et al., 2013). Interactions in perpendicularly magnetized Pt-Co-Pt thin films are actively studied to control magnetization in ferromagnetic metal systems through current-induced spin-transfer torque in metallic spin valves and tunneling structures (Hrabec et al., 2014). Spintronic devices use the electron's spin to generate and control charge currents as well as to convert electrical and magnetic signals (Hirohata et al., 2020). These effects enable the creation of magnetic-memory devices that combine high capacity, low power consumption, excellent performance, and an almost unlimited lifetime (Apalkov et al., 2013; Bendra et al., 2025).

C is added to stabilize the structure and improve the mechanical properties of the coating. The addition of C promotes the formation of an amorphous structure, which helps to prevent cracking and increases the coating's heat resistance (Babbar et al., 2025). C can slow down grain aggregation and change the structural morphology, which opens the possibility of using such coatings at elevated temperatures. Adding C to the Co-Pd alloy can also improve the coating's magneto-optical properties by stabilizing its structure and enhancing anisotropy's control. The most important process parameters affecting film morphology are the substrate temperature and the surface free energy of both the substrate and the film (Wasniowska et al., 2007).

Magnetron sputtering is one of the current methods for producing thin films, including multilayer systems such as Co-C-Pd (Arzac et al., 2021). This method ensures high precision in depositing layers of varying thickness, which is critical for controlling magnetic and optical properties (Garg et al., 2024). Different targets are used in the sputtering process, controlling the sputtering parameters to obtain coatings with specified characteristics (Prokhorenkova et al., 2024).

The structure of the Co-C-Pd coating is formed during the film growth process and can be affected by deposition conditions such as pressure, magnetron power, substrate temperature, and deposition rate (Nayak et al., 2024). Studies show the influence of layer thickness and number on coercive properties, which are useful for data storage applications (M'hid et al., 2025; Wu et al., 2021).

Co and Pd tend to form different phases, such as face-centered cubic (FCC) or hexagonal lattice, which determine the coating's magnetic properties (Harumoto et al., 2021). By varying the thickness of each layer (especially the Co and Pd layers), it is possible to control the coating properties, such as magnetic anisotropy, which allows achieving specific values of magnetic coercivity and remanence (Lin et al., 2020).

The coating thickness plays an important role in the formation of its structure and phase composition. Thin Co-Pd films exhibit a high degree of crystallinity at a thickness of less than 10 nm, while an increase in thickness leads to the formation of a coarser-grained structure. This allows for considering the thickness an important parameter in the design of multilayer structures and combined coatings for various applications (Bieloshapka et al., 2017).

The magnetic properties of Co-C-Pd coatings depend on the combination of Co and Pd as well as on the spacing between them. By adjusting the composition and layer thickness, it is possible to achieve high magnetic anisotropy, which is important for the development of magneto-optical

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