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On the mechanism of β-WC→α-W_2C transformation under annealing in magnetron-sputtered tungsten carbide films

*O.V.Sobol, E.A.Sobol, L.I.Gladkikh, A.N.Gladkikh**

National Technical University "Kharkiv Polytechnical Institute", 21 Frunze St., 61002 Kharkiv, Ukraine
*The Wolfson Applied Materials Research Center, Tel-Aviv University, 69978 Tel-Aviv, Israel

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The annealing temperature effect on the elemental and phase composition, lattice parameters, stress state, and substructure characteristics of tungsten carbide films obtained by α-WC target magnetron sputtering at a high deposition rate (1.8 nm/s) has been studied. It has been found that the as-deposited thermodynamically non-equilibrium β-WC phase becomes transformed into equilibrium α-W_2C one within a narrow temperature range of 755 to 760°C. A mechanism is proposed for the diffusion-stimulated β-WC→α-W_2C phase transformation being realized via formation of strain-induced subtractive stacking errors in the β-WC lattice.

Исследовано влияние температуры отжига на элементный и фазовый состав, период решетки, напряженное состояние и субструктурные характеристики пленок карбида вольфрама, полученных с высокой скоростью осаждения (1.8 нм/с) при магнетронном распылении α-WC мишени. Установлено, что в узком температурном интервале 755–760°С осуществляется переход термодинамически неравновесной фазы β-WC, формируемой при конденсации, в равновесную α-W_2C. Предложен механизм β-WC→α-W_2C диффузионно-стимулированного фазового перехода, осуществляемого через образование в решетке β-WC фазы деформационных дефектов упаковки типа вычитания.

According to the W-C phase diagram [1], it is just the β-WC phase (NaCl type structure) that is stable at high temperatures (over 2500°C) while at lower temperatures, either α-W_2C (hexagonal close-packed structure with c/a ratio 1.58) or α-WC (single-layer stacking, c/a = 0.98) is, depending on the carbon content. This feature distinguishes tungsten carbide from most other inclusion phases based on transition metals which form mainly NaCl structure type phases within the temperature range of 100 to 500°C [2]. The β-WC phase can be obtained at mentioned temperatures by superfast quenching [2]. In this connection, it is just the ion-plasma deposition methods that are of highest interest. In these techniques, the high energy of particles being deposited provides not only superfast quenching under cooling but also formation of high-strength nanocrystalline materials [3–5]. The magnetron sputtering technique makes it possible to obtain nanocrystalline films of β-WC phase at room temperature [5]. The heat stability of β-WC condensate structure as well as mechanisms of its possible transformations into equilibrium α-W_2C and α-WC phase are still scarcely studied at present an require a more detailed investigation.

In this work, the micrometer range thick tungsten carbide films were obtained by