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The effect of Si incorporation on the properties of boron carbide sputtered coatings

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Boron carbide is one of the hardest materials ever known and it takes the primacy over other ceramic materials concerning dynamic elasticity. These properties, along with its high melting point, low mass density, high wear resistance and high thermal stability, explain the great interest in depositing this material as thin protective coatings. Doping hard coatings with different elements, such as Si-doping of hard ta-C coatings, can lead to significant improvements in their fracture toughness ability.
The aim of this work was to deposit boron carbide based coatings with increasing Si contents (B-C:Si). All the films were sputtered from B4C and Si targets in an Ar discharge gas at 0.5 Pa. The substrate bias was varied between 0 and -120 V and heated up to 1000 ºC. The body of work published in the literature about the deposition of boron carbide coatings by sputtering shows that heating of the substrates during the deposition process to at least 950 ºC is necessary in order to achieve crystallinity. This result was confirmed in this work, as all the coatings deposited without substrate heating and with 200 and 800 ºC heating were amorphous as characterized by X-Ray diffraction and Micro Raman Spectroscopy. On the other hand, all the coatings deposited with a substrate heating of 1000 ºC were crystalline regardless of the other deposition parameters values.
The incorporation of Si in the films was achieved by co-sputtering both targets at the same time. Higher amounts of Si were deposited by using higher deposition powers at the Si target. In this way, boron carbide films with a maximum Si content of 8 at. %, as measured by Electron Microprobe Analysis (EPMA), were deposited. The incorporation of more than 4 at. % Si in the boron carbide coating leaded to the collapse of the crystalline structure and to the deposition of amorphous films. This conclusion is clearly supported by the evolution of the Micro Raman spectroscopy results as the characteristic peaks associated to the vibration of the icosahedra present in the boron carbide structure are much broader and badly defined at higher Si contents.
The results concerning structure, chemical composition, morphology and hardness will be presented as a function of the annealing temperature as well as the Si content. Further results obtained X-ray Photoelectron Spectroscopy (XPS) will also be presented for understanding both compositional and thermal effects on boron carbide-based coatings.

Keywords

Boron carbide
Si doping
Sputtering
Structure
Composition