Gradienten der chemischen Zusammensetzung abgeschieden. Die Untersuchungen solcher Schichten mit jeweils zwei unterschiedlichen Ausgangskonzentrationen von Titan bzw. Silizium zeigen, dass mit Hilfe dieser kontinuierlichen Gradienten der chemischen Zusammensetzung gut haftende Kohlenstoffbasisschichten mit hoher Härte abgeschieden werden können.

Die Kombination der Gradierung in Aufbau und Eigenschaften mit einem Gradienten der chemischen Zusammensetzung führt im System Kohlenstoff/Siliziumcarbid zu harten und sehr gut haftenden Schichten.

Insbesondere werden für alle Kohlenstoffschichten mit hohem Anteil an Silizium signifikant niedrige Reibwerte (0,08 bis 0,05) im Stift-Scheibe-Modellversuch zur ungeschmierten Gleitreibung gegen 100Cr6 ermittelt. Diese geringen Werte wurden sowohl an homogenen Einlagenschichten als auch an gradierten Schichten nachgewiesen. Im Gegensatz zu den Reibwerten (0,39 bis 0,15) von homogenen und gradierten Einlagenschichten der anderen untersuchten Systeme (Kohlenstoff und Kohlenstoff/Titancarbid) steigen die minimalen Reibwerte der Kohlenstoff/Silizium-Schichten nicht mit zunehmender Ionenenergie an.

Abstract

Superhard PVD carbon films deposited with different gradients with and without additions of titanium and silicon

This work focusses on thin carbon-based films, deposited by magnetron sputtering with additional argon ion bombardment (0 eV to 800 eV) without extra adhesive layer on hard metal inserts. As one possibility of increasing the reduced adherence of hard carbon films the deposition of films with additions of titanium and silicon is studied. The aim of this work is to examine the influence of a modification of the transition between substrate and film by realizing three different types of deposition gradients. The gradient in structure and properties is made by stepwise increasing ion energy during the deposition process. The continuously gradient in chemical composition is realized by using segmented targets, with a steady movement of the substrates from the carbide-rich half to the carbon-rich half during deposition. Additionally the continuous gradient in chemical composition is combined with the gradient in structure and properties. The ion flux to atom flux ratio is for all deposited films between 0,02 and 0,21 and is influenced by the ion energy.

The pure carbon films are amorphous, the dominant network of atoms is formed by sp^2 bonded atoms. The amount of sp^3 bonded atoms is up to 30 % and is influenced by the bombarding argon ion energy. Carbon films with additions of silicon are amorphous, only in films with a high amount of titanium (approx. 20 at%) nanocomposites of titanium carbide crystals with diameters of less than 5 nm in an amorphous carbon matrix were found.

The mechanical properties and the behavior of single layer carbon films strongly depend on the argon ion energy. An increase of this energy leads to higher film hardness and higher residual stress and results in the delamination of superhard carbon

films on hard metal substrates. The adhesion of single layer films for ion energies of more than 200 eV is significantly improved by additions of titanium and silicon, respectively. The addition of 23 at% silicon and titanium, respectively leads to a high reduction of the residual stress.

Different gradients in structure and properties by stepwise increase of argon energy are suitable for reducing the residual stress and to improve adhesion and hardness of the films. It is possible to deposit thick (9,3 μm) pure carbon films with a good adhesion (critical load of failure in scratch test: 31 N), extremely low residual stress (-0,7 GPa), and very high hardness (5300 HV0,05). Especially for carbon/titanium carbide films these gradients in structure and properties lead to a significant improvement of the critical load of failure in the scratch test from 14 N to 39 N.

In a non-reactive PVD process thin films were deposited with a continuously gradient in chemical composition. The results of the investigations of the films with two different concentrations of titanium and silicon, respectively show that carbon-based films with a good adhesion could be deposited.

The combination of the two gradients in structure and properties and in chemical composition leads in the system with carbon and silicon carbide to hard and very adhesive films.

Especially for carbon films with a high amount of silicon very low friction coefficients (0,08 to 0,05) were found by investigations in the pin-on-disc arrangement for unlubricated sliding friction against AISI 52100. These low friction values were found for single layer films and also for films deposited with a gradient. In contrast to the friction coefficients of single layer films and of graded films in the other systems (pure carbon and carbon/titanium) the small friction coefficient of the films in the system carbon/silicon does not rise for increasing ion energy.