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Review

A perspective on the optimisation of hard carbon and related coatings for engineering applications

Stephane Neuville [a], Allan Matthews [b,*]

[a] 1 rue du Gal de Gaulle, F-77 165 CUISY, France
[b] Department of Engineering Materials, Sheffield University, Mappin Street, Sheffield S1 3JD, UK

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Abstract

Hard carbon coatings hold the key to improved performance for many types of products. However the achievement of these improvements requires the selection of the appropriate type of carbon coating and therefore the correct process and appropriate deposition parameters. The huge range of properties achievable in carbon coatings is mainly due to the ability of carbon to form different types of interatomic bonds, to take up different sites, and to adopt different structures. In addition to intrinsic material properties, other factors must also be considered for each application, such as the adhesion level achievable and coating cost. This complex situation explains why the number of applications for hard carbon films is still more limited than originally expected. Despite the considerable progress achieved during the last decade in hard coating technologies, practical results often appear conflicting, with differences in properties occurring even within the same types of coatings. Furthermore, the many different deposition systems and processes which have been developed introduce further complications in regard to (for example) achievable coating uniformity and deposition rates. Thus, there is often confusion in the use of certain fundamental principles, especially regarding the growth mechanisms and the effects which produce more dense homogeneous and stable coating materials. This is especially true for the improved properties of tetrahedral amorphous carbon films, which are different from previously reported diamond-like carbon materials, and can be created by adapting and improving existing industrial processes, to offer advantages compared to earlier coatings, and hence possibilities for important new applications. This paper discusses issues relating to intrinsic material properties, and practical aspects such as adhesion, to provide a framework for the development, selection and use of hard carbon coatings in practical situations.
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Keywords: Carbon; Diamond; Diamond-Like-Carbon; Hardness; Adhesion; Bonding

Contents

* Corresponding author.
E-mail addresses: stephane.neuville709@orange.fr (S. Neuville), A.Matthews@sheffield.ac.uk (A. Matthews).

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1. Introduction

The wide range of equipment of producing carbon-based coatings equipment, and the very large differences in intrinsic film properties, adhesion, growth rates and throughputs, can be a source of confusion among potential users [1,2]. The last two decades have seen the emergence of several new hard carbon deposition processes (e.g., see Refs. [3–7]). However, despite this activity, many expected applications have yet to see fully optimised solutions. Examples include hard discs, high volume automotive engine parts, high speed cutting tools, and electronic applications. In all of these areas, there is a continuing search for better technical solutions (often related to the need to reduce substrate and processing costs).

An empirical approach to coating improvement has often been used, apparently driven by a general opinion that only minor differences exist between the different coatings of similar composition and that inadequate performance is the consequence of the coating process or material adopted. However, a lack of performance can sometimes be the consequence of only one coating characteristic among many. For instance, when the adhesion is good, the wear rates are not necessarily optimal, and when the friction coefficient is low, then the thermal and mechanical stability may not be sufficient, leading to reduced lifetimes. The surface temperature during wear processes is strongly dependent on the frictional energy released, which depends on the contact pressure, speed and friction coefficient, and on mechanical properties which can degrade in operation.

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