Surface & Coatings Technology 217 (2013) 88–93

Contents lists available at SciVerse ScienceDirect

Surface & Coatings Technology

journal homepage: www.elsevier.com/locate/surfcoat

Chemical vapor deposition of amorphous silicon carbide thin films on metal surfaces using monomethylsilane gas at low temperatures

Hitoshi Habuka *, Masaki Tsuji

Department of Chemical and Energy Engineering, Yokohama National University, 79-5 Tokiwadai, Hodogaya, Yokohama 240-8501, Japan

ARTICLE INFO

Article history:
Received 23 July 2012
Accepted in revised form 29 November 2012
Available online 7 December 2012

Keywords:
Silicon carbide
Monomethylsilane
Chemical vapor deposition
Room temperature

ABSTRACT

The low temperature chemical vapor deposition process of depositing silicon carbide on a metal surface, such as aluminum and stainless steel, was developed using monomethylsilane gas. In order to prepare the reactive substrate surface, two alternative methods were separately used. The first was the formation of a silicon interlayer containing silicon dimers. The other method was the argon plasma etching for producing dangling bonds. After the reactive surface preparation, the silicon carbide thin film was formed at room temperature using monomethylsilane gas. Because the silicon–carbon bond remained after the deposition, the silicon carbide coating technology is expected to be applicable for various metals.

1. Introduction

Silicon carbide (SiC) is a suitable surface coating material, because the silicon carbide film is robust even in a harsh environment and at high temperatures. The typical application is the coating of the carbon susceptor used in a chemical vapor deposition (CVD) reactor [1]. However, one of the problems of the silicon carbide material is the very high temperature necessary for the CVD film deposition [2–4]. Because the temperatures for depositing the silicon carbide film is often higher than the melting point or phase change temperature of various useful metals, the silicon carbide coating has been limited to only a few materials, such as carbon and silicon [4]. From a different viewpoint for maximizing the advantage of silicon carbide, its chemically inactive and mechanically hard nature should be applied to further improve corrosion-resistant materials, such as stainless steel, which has been insufficient for various chemical processes, such as silicon epitaxial growth process which uses hydrogen chloride gas at high concentration and at high temperature near 1200 °C for the reactor cleaning [1].

For achieving these objectives, the low temperature amorphous silicon carbide film formation technology on a silicon surface using monomethylsilane (MMS) gas [5–9] is considered to be applicable and hopeful. This technology consists of two steps, that is, (A) the reactive surface preparation, and (B) the silicon carbide film formation from monomethylsilane gas at room temperature. In order to apply this technology to various metal surfaces, the key issue is the development of a reactive surface preparation process at low temperatures.

In previous studies [5–7], the reactive surface has been prepared using the following three processes:

(I) The hydrogen annealing of silicon surface at high temperatures, such as 1100 °C, and cooling to room temperature in ambient hydrogen [5,6] in order to prepare the hydrogen-terminated silicon surface containing silicon dimers.
(II) The silicon thin film (silicon interlayer) formation at moderate temperatures, such as several hundred degrees, followed by cooling to room temperature in ambient hydrogen [7] in order to produce the surface condition the same as (I).
(III) The dangling bond formation on the substrate material surface by surface cleaning using an argon plasma at room temperature [8].

Processes (II) and (III) are expected to be applicable to various materials other than silicon.

In this study, the low-temperature process of amorphous silicon carbide CVD film deposition on a metal substrate was developed. Aluminum and stainless steel were used as the substrate, because improving the corrosion-resistant nature of these metals will significantly increase their convenience for various chemical processes.

2. Process design

The CVD process designed in this study is shown in Figs. 1 and 2. Fig. 1 shows the process using the silicon interlayer. This is classified as Process (II). The silicon thin film is formed at 600 °C using trichlorosilane gas at the metal surface, as shown in Fig. 1(b). The substrate is then cooled to room temperature in ambient hydrogen.

* Corresponding author. Tel./fax: +81 45 339 3998.
E-mail address: habuka1@ynu.ac.jp (H. Habuka).

0257-8972/$ – see front matter
http://dx.doi.org/10.1016/j.surfcoat.2012.11.078

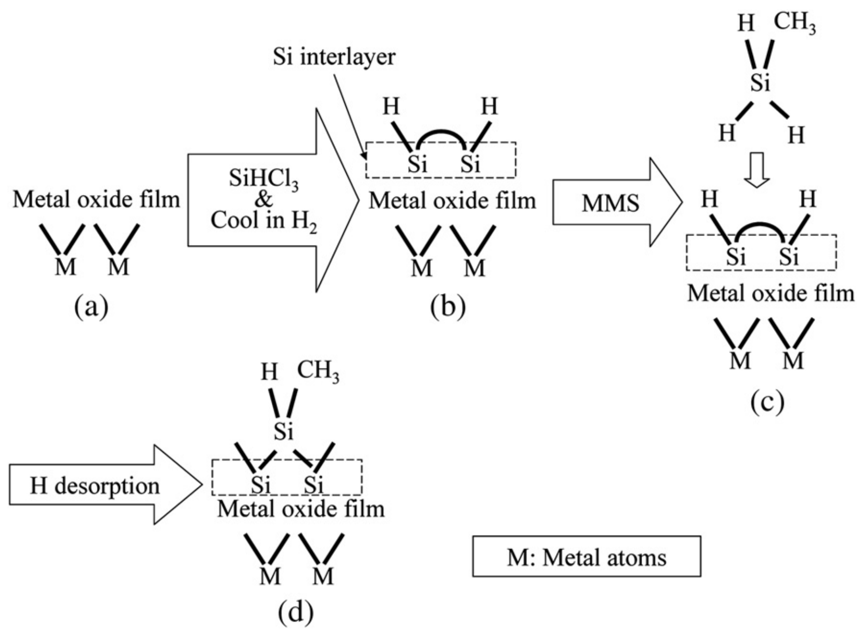

Fig. 1. Silicon carbide film deposition process using silicon interlayer (Process (II)).

Because the silicon interlayer surface has silicon dimers as shown in Fig. 1(b) and (c), the amorphous silicon carbide film can be produced using the MMS gas, as shown in Fig. 1(c) and (d).

The alternative process involves argon plasma etching, as a modified Process (III). The argon plasma slightly etches the metal substrate surface in order to produce dangling bonds, as shown in Fig. 2(b). The dangling bonds are expected to be active for easily forming chemical bonds with the MMS molecule, as shown in Fig. 2(c). After the hydrogen desorption, the silicon–carbon pair remains on the substrate surface, as shown in Fig. 2(d).

These two processes were applied to both aluminum and stainless steel in this study.

3. Experimental

3.1. Substrate

The substrates used in this study were plates of aluminum and stainless steel (SUS430), which are low cost materials for various handicrafts. The dimensions of the samples were 10 mm wide and 10 mm long, cut from a large 0.1–0.3 mm-thick plate. Because of their sufficiently long time exposure to air, the surfaces of these plates were covered with a native oxide film. The sample surface was simply cleaned by ethanol without any additional wet cleaning. Thus, the native oxide film was not removed.

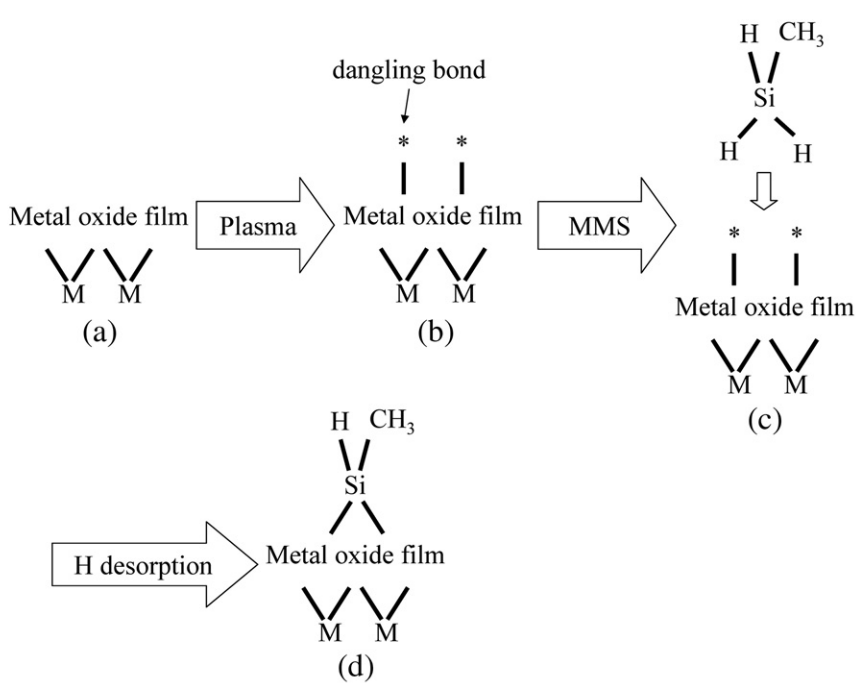

Fig. 2. Silicon carbide film deposition process using the argon plasma etching (Process (II)).