OXIDATION OF SILICON SURFACE BY DCSBD

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Abstract
In the present work plasma oxidation of crystalline silicon (c-Si) surface in diffuse coplanar surface barrier discharge (DCSBD) generated at atmospheric pressure has been studied. Silicon surface has been oxidized in oxygen and argon plasma. The surface properties have been studied by means scanning electron microscopy (SEM) and energy dispersive X-ray (EDX) analyses. It was found that thin layer of amorphous silicon dioxide during the short treatment time was formed. Oxidation by DCSBD could represent new alternative of a low cost and fast oxidation process.

Keywords:
Coplanar DBD, silicon dioxide, oxidation, atmospheric pressure plasma

1. INTRODUCTION

Silicon and silicon dioxide represent fundamental elements in the semiconductor industry [1]. At the present time, several methods for formation SiO$_2$ layer have been developed. In order to decrease the manufacturing costs and improve the production efficiency, low pressure plasma processes tend to be replaced by atmospheric pressure one. Nowadays, various plasma sources using to formation of silicon oxide films have been developed [2-5]. Disadvantage of many of these methods is necessity of precursors which are almost toxic of volatile [5-7].

In this contribution we investigated oxidation of crystalline silicon (c-Si) surface by means of low temperature atmospheric pressure plasma in pure oxygen and argon atmosphere. As a plasma source diffuse coplanar surface barrier discharge (DCSBD) has been used. In comparison with other atmospheric pressure plasma sources, DSCBD generate large area of diffuse highly non-isothermal cold plasma in ambient air [8,9]. Surface morphology of such oxidized c-Si surface has been studied by scanning electron microscopy (SEM), chemical composition of oxidized layers has been investigated by energy dispersive X-ray (EDX). It was found that after relatively short treatment time in the scale of minutes, DCSBD operated in oxygen or argon created thin amorphous oxidized layer on the c-Si surface.

2. EXPERIMENTAL

2.1 Plasma source

Diffuse Coplanar Surface Barrier Discharge (DCSBD) operating in oxygen and argon at atmospheric pressure near room temperature has been used to oxidation of Si surface [9-11]. This type of discharge provides the large area of thin layer of atmospheric non-isothermal low temperature plasma on the surface of dielectric barrier. The dielectric barrier is made of Al$_2$O$_3$ ceramics with embedded metallic electrodes (Fig. 1).
2.2 Samples and pretreatment
The silicon wafers used in this study were one-side polished p- type, doped with boron, crystallographic orientation (100) having resistivity (6-12) $\Omega \text{cm}^{-1}$ purchased by ON Semiconductor, Czech Republic,s.r.o. Before plasma treatment samples were cleaned by isopropyl alcohol and then immersed in 1% HF solution at room temperature for 45s to remove native oxide layer [12].

2.3 Surface characterization
Surface morphology of the oxidized Si surface was observed by high resolution scanning electron microscope (MIRA3 FEG SEM, TESCAN) with embedded Energy Dispersive X-ray (EDX) analyser. The resolution of microscope is 1.2 nm for accelerate voltage of 30 kV and 2.5 nm for accelerate voltage of 3 kV.

3. RESULTS
The structure of layers oxidized in oxygen plasma was studied by scanning electron microscopy (SEM). Electron channelling patterns (ECP) for clean and oxidized surface at accelerated voltage 30 kV, 10 kV, 5 kV and 3 kV are illustrated from Fig.2 to Fig. 6. Apparently, clean Si surface before plasma treatment is characterized by strong ECP, while ECP of plasma treated surface is attenuated depending on the accelerated voltage. In case of accelerating voltage 3 kV ECP of plasma treated surface is almost invisible, which confirms the presence of thin amorphous oxidized layer on the surface.
Fig. 2 Electron channelling pattern at accelerating voltage 30 kV for a) untreated sample Si(100) and b) 30min plasma treated sample Si(100).

Fig. 3 Electron channelling pattern at accelerating voltage 10 kV for a) untreated sample Si(100) and b) 30min plasma treated sample Si(100).

Fig. 4 Electron channelling pattern at accelerating voltage 5 kV for a) untreated sample Si(100) and b) 30min plasma treated sample Si(100).

Fig. 5 Electron channelling pattern at accelerating voltage 3 kV for a) untreated sample Si(100) and b) 30min plasma treated sample Si(100).
The effect of oxidation has been observed also in argon plasma. After HF cleaning the Si (100) surface was partially masked and this masked part of the surface was not in contact with plasma. Consequently, surface was treated for 30 minutes in argon plasma. Chemical composition obtained by EDX and inserted SEM image is shown in Fig. 6. Evidently, visible borderline of treated and untreated surface was observed. In case of oxidized surface, increased O peak demonstrated the increase of oxygen on the treated surface.

![EDX spectrum and SEM image](image)

**Fig. 6** EDX spectrum of untreated and plasma treated sample Si(100) and 30min plasma treated sample Si(100) and inserted SEM image with visible borderline of oxidized and untreated surface.

4. **CONCLUSION**

DCSBD operating in oxygen or argon at atmospheric pressure plasma can be successfully used to create thin layer of amorphous oxide layer on the Si(100) surface. By means of electron channelling patterns the presence of thin amorphous oxidized layer after exposure time of 30 minutes has been proven. Also the increased amount of oxygen on the plasma treated surface by EDX spectrum has been confirmed. In the future, DCSBD could be a cheap and easy solution of fast and low cost plasma oxidation technology of Si surfaces.

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**LITERATURE**


