

# Silicon surface passivation by static charge

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## Abstract

A properly passivated silicon surface is chemically stable, and all interface properties are constant. The silicon dioxide layers fulfil the chemical stability requirements; however, their surface and interface charges have effect on the silicon surface potential barrier. Positive charge is usually assumed at the oxide–silicon interface, thus depletion or inversion layer develops in the case of p and accumulation in the case of n-type silicon.

The surface of silicon dioxide can be charged macroscopically by corona charger or by conductive rubber stamp, microscopically by a tip of some scanning probe microscope (STM or AFM). The oxide surface usually retains the charges for a long time, however in the case of ultra-thin or other leaky oxide continuous charging it is necessary to keep the constant surface potential.

The main purpose of this work is to summarize the possibilities of charging up the surface, the effect of the surface and interface charge on the surface properties of the silicon. The rearrangement of the surface charges will also be discussed.

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## 1. Introduction

Semiconductor surfaces are extremely sensitive to the environment, thus the passivation of their surfaces is very important. Some aspects (namely the construction and technology of electron devices and integrated circuits, and the characterisation of the silicon surface and bulk properties) as well as some passivation mechanisms (control of the surface potential barrier and lowering the surface and interface trap densities) have been discussed earlier [1], mainly in conjunction with the bare, oxide-covered and porous Si covered [2] silicon surface.

Chemical stability can be achieved by using thermal oxide or other dielectric over-layers. Halogens are used for passivating the bare silicon surface to decrease surface recombination velocity [3]. The properties of the bare and of the oxide covered silicon have been discussed earlier, see Table 1 [1]. The silicon covered by an ultra-thin (tunnelable) insulator (native SiO<sub>2</sub>) layer has some peculiarities, i.e., connection between surface charge and the interface charge carrier density, which result in

depletion or near intrinsic conditions on the silicon surface. Thick insulators usually result in accumulation on n-type, depletion or inversion on p-type silicon, due to positive interface charge on the interface states.

Charging up the insulator surface, the previously discussed surface conditions can be altered, consequently the surface charge may have some passivating effect. This effect has no importance in the device technology, because of short time duration and possible instabilities. However, the ability of surface potential adjustment may help in the characterisation of the silicon surface and bulk properties, see last paragraph of Section 2 for conventional corona oxide semiconductor (COS) methods, and the end of this article, where the effect of the static charge passivation is demonstrated on the lifetime measurements by microwave photoconductive decay ( $\mu$ PCD).

As it has been pointed out, the deposition of static charges [4] (e.g., via corona discharge) is a well-known procedure for manipulating the surface potential and interface band bending [5]. Some aspects of this fact have not been discussed in the literature in conjunction with the surface passivation. For example, there was not an exact method to adjust the surface voltage of insulators. Also, a still-open problem is the general behaviour of the charge on the insulator surface in spite of some previous investigations on that field [6–8].

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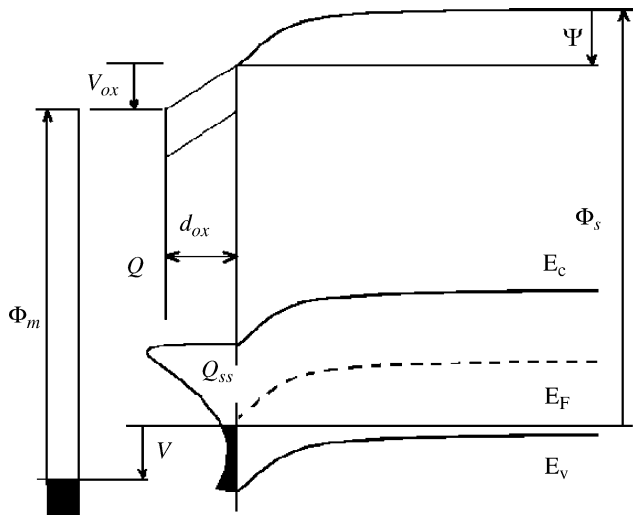


Fig. 1. Band diagram of an oxide covered Si surface with a capacitively coupled reference electrode and positive surface and interface charge ( $Q$ ,  $Q_{ss}$ ).

Novel approaches of this work are the summary and comparison of the different possibilities of charging up the surface, including the macroscopic and the microscopic (electrostatic) charges, self charging by tunnelling, and optical excitation. The lateral and vertical homogeneity and possible rearrangement of the surface charges will also be discussed.

## 2. Theoretical background

In the case of metal–oxide–silicon (MOS) structure the potential of the electrode is well defined by the charge and the capacitance of the system. The measuring methods ( $C$ – $V$ ) are well developed and commercial equipment is available in the market [9].

The surface voltage is not so well defined on the insulator (oxide) covered silicon. Assuming zero electric field above the surface, the surface voltage can be expressed with oxide surface charge ( $Q$ ) and the  $\text{SiO}_2$ –Si interface charge ( $Q_{ss} = Q_f + Q_{it}$ ),

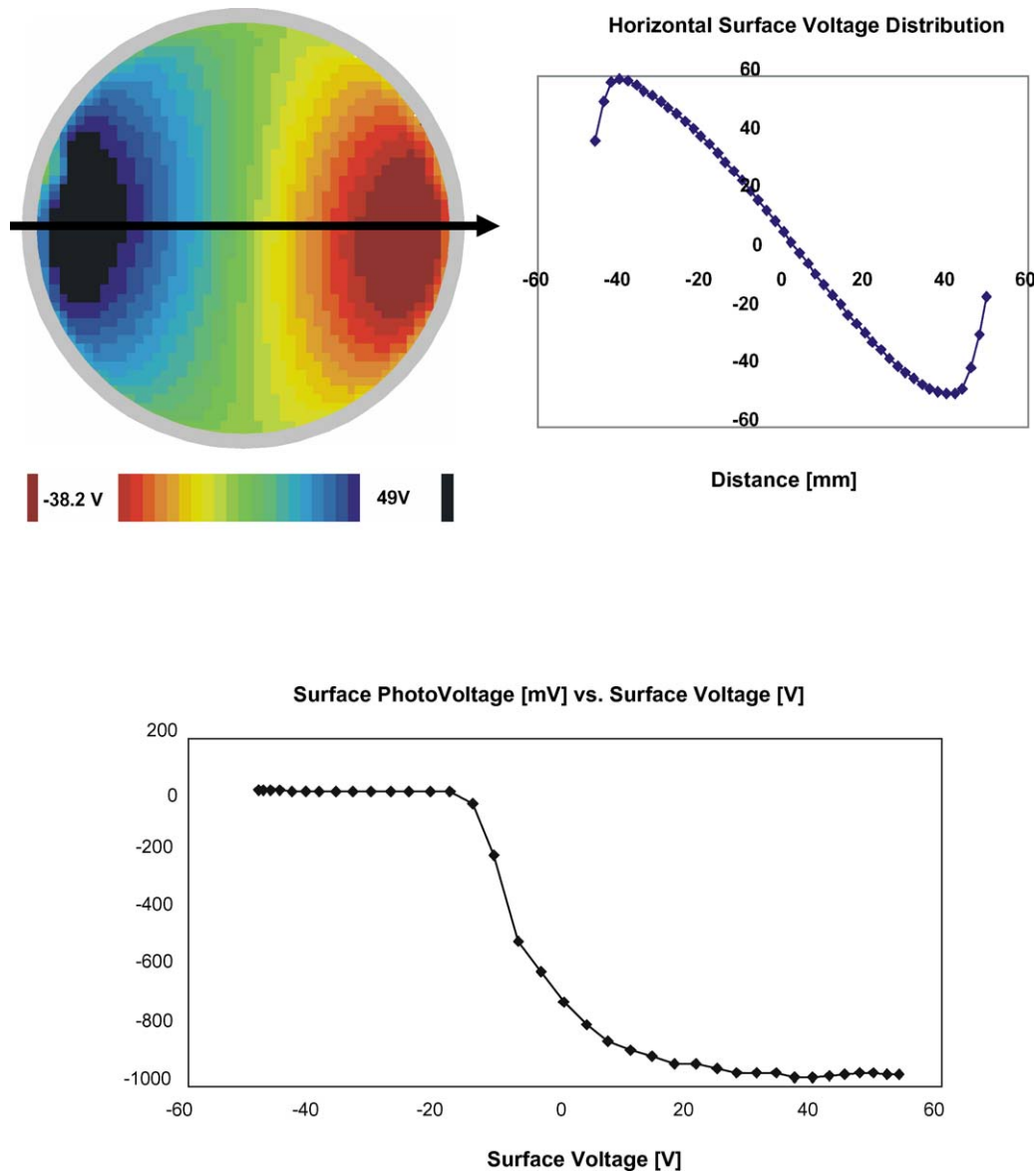


Fig. 2. Corona charged (400 nm)  $\text{SiO}_2$ –Si system: surface voltage map, surface voltage (charge) distribution, surface photovoltage (saturated SPV) vs. surface voltage.

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