Self-organized pore formation and open-loop-control in semiconductor etching

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Abstract

Electrochemical etching of semiconductors, apart from many technical applications, provides an interesting experimental setup for self-organized structure formation capable e.g. of regular, diameter-modulated, and branching pores. The underlying dynamical processes governing current transfer and structure formation are described by the Current-Burst-Model: all dissolution processes are assumed to occur inhomogeneously in time and space as a Current Burst (CB); the properties and interactions between CB's are described by a number of material- and chemistry- dependent ingredients, like passivation and aging of surfaces in different crystallographic orientations, giving a qualitative understanding of resulting pore morphologies. These morphologies cannot be influenced only by the current, by chemical, material and other etching conditions, but also by an open-loop control, triggering the time scale given by the oxide dissolution time. With this method, under conditions where only branching pores occur, the additional signal hinders side pore formation resulting in regular pores with modulated diameter.
Silicon monocrystals are the most perfect material mankind has ever created since they are essential for high integrated computer circuits. Due to this high degree of perfection, i. e. corrosion is not defect-driven, and "ideal corrosion" is possible: Silicon and other semiconductors can be made porous by electrochemical etching giving an outstanding variety of pore sizes, from nanopores to macropores, and geometries, including disordered nanoporous, dendritic-like sidebranching pores, and pores with modulated diameter. Abstracting from the details of the underlying electrochemical processes, the Current Burst Model together with the Aging Concept, and accounting the interactions between Current Bursts, the generation of different pore geometries, oscillations and synchronization phenomena can be explained including the percolation transition to global oscillations. Based on the time scale derived from the Aging Concept, an open-loop control can be applied to suppress sidebranching of pores in a technologically relevant regime.

1 Introduction

The solid - liquid junction of Silicon and HF - containing liquids exhibits a number of peculiar features, e.g. a very low density of surface states, i.e. an extremely well "passivated" interface [1]. If the junction is biased, the IV - characteristics (Fig. 1) in diluted HF is quite complicated and exhibits two current peaks and strong current- or voltage oscillations at large current densities (for reviews see [2, 3]). These oscillations have been decribed quantitatively by the Current-Burst-Model [4, 5, 6, 7].

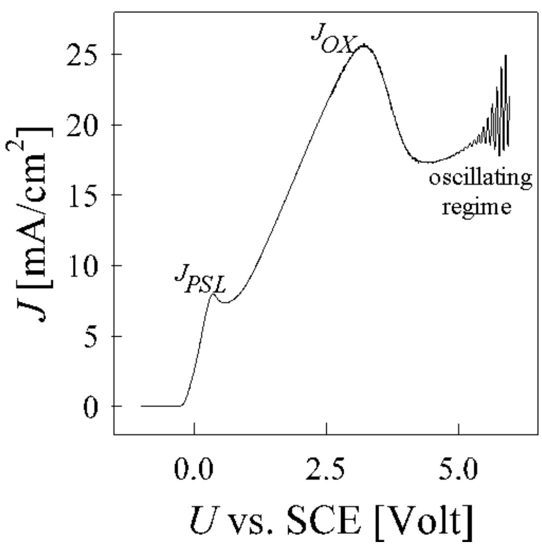

Figure 1: The IV- characteristics of the silicon-hydrofluoric acid contact shows different phenomena from generation of a porous silicon layer (PSL), oxidation and electropolishing (OX) and electrochemical oscillations at higher anodic bias.

Perhaps the most outstanding features are the many different kinds of pores - nanopores, mesopores, macropores, and so on - that form under a wide range of conditions in many HF containing electrolytes, including organic substances [8, 9]. Despite of an intensive research triggered by the finding that nanoporous Si shows strong luminescence [10, 11], neither the intricacies of the IV - characteristics nor the processes responsible for the formation of pores,