Open-Loop-Control of Pore Formation in Semiconductor Etching

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Abstract

Electrochemical etching of semiconductors gives rise to a wide variety of self-organized structures including fractal structures, regular and branching pores. The Current-Burst Model and the Aging Concept are considered to describe the dynamical behavior governing the structure formation. Here the suppression of side-branching during pore growth is demonstrated by an open-loop-control method, resulting in pores with oscillating diameter.

1 Introduction and Setup

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 described quantitatively by the Current-Burst-Model [4, 5, 6, 7].

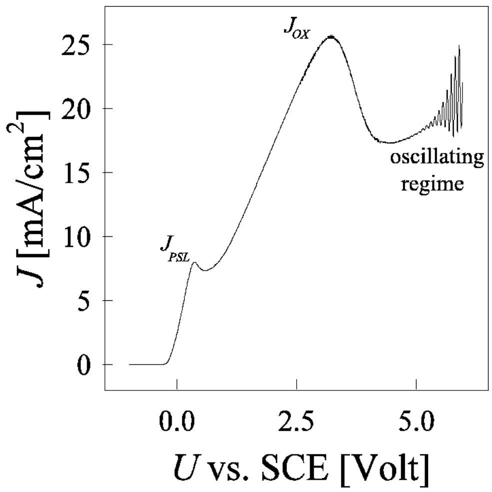

Figure 1: The IV - characteristics of the silicon-hydrofluoric acid contact shows different phenomena from generation of a porous silicon layer (PSL), oxidation and electropolishing (OX) and electrochemical oscillations at higher anodic bias.

Perhaps the most outstanding features are the many different kinds of pores - nanopores, mesopores, macropores, - 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, including their rather peculiar dependence on the crystal orientation, are well understood.

Replacing Si by III/V-compounds, a variety of different pore morphologies can be etched; due to different properties of the A- and B-surfaces one finds e.g. tetrahedron-shaped pores instead of octahedron-shaped pores. For an overview over recent results see [12]. But again most of the phenomena can be well understood within the framework of the Current-Burst-Model which seems to reflect a number of quite general properties of semiconductor electrochemistry.

The basic setup is shown in Fig. 2. Using a four electrode arrangement a potentiostat/galvanostat is contacting the sample and the electrolyte, allowing for a well defind potential resp. current for the electrochemical dissolution reactions. Since the potentiostat/galvanostat as well as the temperature are PC controlled, all relevant etching parameters can be controlled in detail. While the principal setup remains the same in all experiments, backside contact, front- and/or backside illumination and electrolyte pumping can be varied as well as cell size (from under 0.3 cm up to wafers of 6 in) and semiconductor material (Si, InP, GaAs, GaP) including various doping levels and crystallographic orientations. In addition, the electrolytes (e.g. HF, HCl, H_2SO_4) and their concentration and temperature can be varied.

2 The Current-Burst Model

The Current Burst Model [4, 5, 6, 13, 14] states that the dissolution mainly takes place on small spots in short events, starting with a direct Si-dissolution, and possibly followed by an oxidizing reaction (see Fig. 3).

After these two short processes, the oxide hump undergoes dissolution, a time-consuming process which ensures at the location of the current burst a dead-