Appl. Phys. A 84, 369–371 (2006)
DOI: 10.1007/s00339-006-3639-4

Applied Physics A
Materials Science & Processing

Rapid communication

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Etching nano-holes in silicon carbide using catalytic platinum nano-particles

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Received: 12 May 2006/Accepted: 16 May 2006
Published online: 20 June 2006 •

ABSTRACT The catalytic reaction of platinum during a hydrogen etching process has been used to perform controlled vertical nanopatterning of silicon carbide substrates. A first set of experiments was performed with platinum powder randomly distributed on the SiC surface. Subsequent hydrogen etching in a hot wall reactor caused local atomic hydrogen production at the catalyst resulting in local SiC etching and hole formation. Secondly, a highly regular and monosized distribution of Pt was obtained by sputter deposition of Pt through an Au membrane serving as a contact mask. After the lift-off of the mask, the hydrogen etching revealed the onset of well-controlled vertical patterned holes on the SiC surface.

PACS 61.46.+w; 68.37.-d; 81.65.Cf

1 Introduction

Various experimental methods for the synthesis of nanoporous materials are reported in the literature. Mainly based on electrochemistry, porous semiconducting nanostructures can be obtained in silicon [1], silicon carbide [2–4], gallium nitride [5] and gallium arsenate [6–9] in a nearly routinely manner. Most of these porous materials exhibit irregular structures. Regular pore structures have been reported for silicon [10–12], alumina [13, 14] and recently for silicon carbide [15, 16]. These porous materials exhibit interesting new photonic, electronic and mechanical properties. Especially silicon carbide has many favourable properties compared to silicon and the achievement of vertical nanopores and regularly distributed holes in SiC is a research field of increasing interest. A few experimental approaches for SiC have been reported so far. In all these cases, pre-structured holes in the substrate are etched with hydrogen at elevated temperatures in the final process step. Pre-structured holes can be obtained either by focused ion beam etching [15], reactive ion etching through a physical mask [17] or via the revealing of defects in an electrochemical process [18]. As a pre-treatment of the semiconducting surface, hydrogen erosion of SiC is used for the preparation of clean, flat SiC surfaces [19, 20]. In the present paper, we report on the catalytic reaction of platinum nanoparticles during a hydrogen etching process of silicon carbide. The reduction of molecular hydrogen to atomic hydrogen, occurring in the platinum metal, gives rise to a locally enhanced etching process of SiC. Similar studies have been reported for the silver-silicon system [21]. The catalytic reaction of deposited silver particles on a Si(100) surface gave rise to nanoholes when etched in a solution containing HF and H_2O_2. An irregular network of pipes several micrometers deep was obtained.

2 Experimental results

SiC samples were cut from an on-axis, nitrogen-doped, n-type (resistivity 0.03–0.12 $\Omega\,m^{-1}$) silicon terminated 6H-SiC(0001) wafer from SiCrystal [22]. Before the patterning process, the wafer has been etched in a hot wall reactor at 1700 °C for 20 min [23]. This procedure leads to a SiC surface with a well-defined smooth morphology [19, 20, 24]. In a first set of experiments, platinum powder with a grain size between 100 and 450 nm, dissolved in ultra-pure alcohol, was placed on the SiC surface. After drying of the solvent, the obtained Pt clusters revealed an irregular shape and were randomly distributed as investigated with scanning electron microscopy (SEM) (see inset in Fig. 1). The SiC surfaces covered with Pt particles were subsequently etched in hydrogen in a horizontal graphite hot wall reactor [23]. Hydrogen etching was performed at a hydrogen pressure of 13 mbar. The samples were etched in a temperature range between 700 °C and 1000 °C. This temperature is too low to allow significant etching without the presence of the catalyst.

The etching time intervals were varied between 30 and 120 min each. The hydrogen flow was kept at 6 l/min during the whole experiment. Figure 1 shows a typical image of a former irregular Pt particle, obtained with powder, after hydrogen erosion at 800 °C for

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