2DHG on H-terminated Diamond for FET Applications

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1. Introduction

The study investigates the hydrogen-terminated diamond surface is in both poly- and single-crystalline diamond using X-ray photoelectron spectroscopy (XPS) and Hall effect measurements. Two surface capping mechanisms, air and Al_2O_3 deposited using atomic layer deposition (ALD), are analyzed. The results show that the two-dimensional hole gas (2DHG) on the H-terminated diamond surface remains stable for several weeks, making it a promising candidate for use in surface channel FETs.

2. Experimental Results

Six poly-crystalline and one single-crystalline diamond samples were treated with hydrogen plasma in a microwave plasma chemical vapor deposition (MPCVD) system. The samples, all of which had dimensions of 5mm × 5mm, were exposed to hydrogen plasma for 30 minutes at 800℃, with a hydrogen gas flow rate of 200 sccm. Quarter-circle metal contacts of Cr(20nm) / Au(80nm) were deposited using e-beam evaporation immediately after the hydrogen termination to form Van der Pauw structures. X-ray photoelectron spectroscopy (XPS) analysis was performed on the single-crystalline diamond sample to confirm the hydrogen coverage, with the C1s and O1s peaks analyzed. Figure 1 displays the survey and C1s spectra of the single-crystalline diamond before (a), (b) and after (c), (d) hydrogenation. Since XPS cannot detect hydrogen bonds directly, the hydrogen-termination was confirmed indirectly through the reduction of the relative intensity of the O1s peak, which represents C-O bonds on the diamond surface.

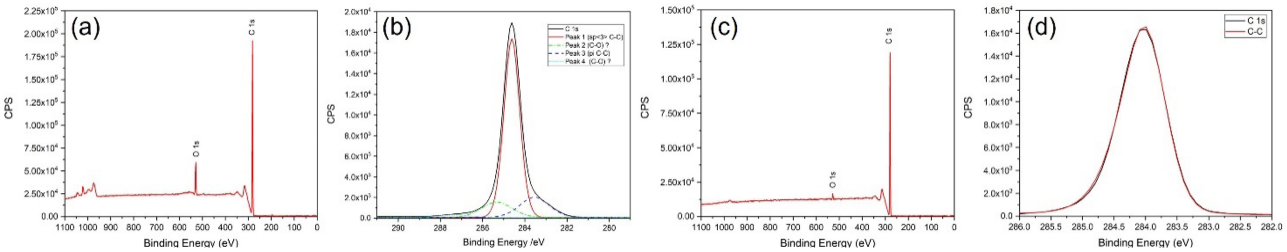

FIG. 1. (a) Survey spectrum of single-crystalline diamond sample before H-termination; (b) C1s spectrum before H-termination; (c) Survey spectrum after H-termination; (d) C1s spectrum after H-termination

Hall effect measurements were used to characterize carrier mobility and sheet carrier concentration of both poly- and single-crystalline diamond samples, and the measurements were monitored over a period of three weeks. Neither sample type showed discernable degradation in 2DHG sheet resistivity within this period. The poly-crystalline samples showed an average sheet resistance of 1.57×10^5 Ω/□, while the single-crystalline sample measured a sheet resistance of 1.82×10^4 Ω/□. Figure 2 plots the carrier mobility and sheet carrier concentration of six samples capped by air adsorbates over time. It has been proven that Al2O3 can effectively induce 2DHG for H-terminated diamond and improve the stability of 2DHG based field-effect transistors (FETs). To investigate the effect of Al_2O_3 coverage, the same hydrogenation process was repeated on a single-crystalline sample with a fine-polished surface, which had an RMS surface roughness less than 1nm. Metal contacts were deposited using e-beam evaporation in the Van der Pauw configuration, followed by the deposition of 20nm of Al_2O_3 using ALD. Electrical measurements showed a low sheet resistance of 1.22×10^3 Ω/☐ for this sample, which is more than one order of magnitude lower than the sample exposed to air.

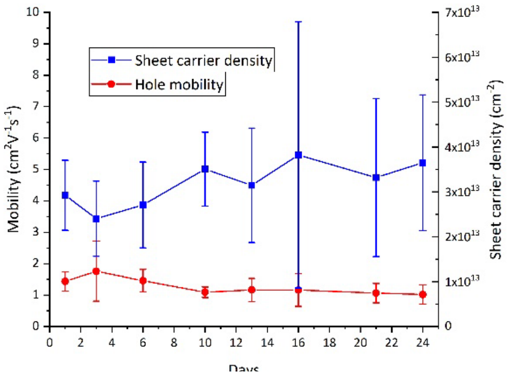

FIG. 2. Carrier mobility and sheet resistance of six poly-crystalline diamond samples