Workshop on Scanning Probe Nanotechnology

Experimental Physics Department - University of Torino, Italy
16-17 December 2002

Local anodic oxidation of hydrogenated diamond surface using scanning probe methods

Chiara Paolini, *Experimental Physics Department, University of Torino, Italy*
paolini@to.infn.it

Abstract

Wide bandgap semiconductors attract attention as high temperature, high-power, high-frequency device materials. Among them, diamond exhibits peculiar properties, such as high breakdown field, maximum thermal conductivity, superb radiation hardness, low dielectric constant and high carrier mobility, that make it a very promising candidate for electronic applications. Moreover, diamond surface properties are quite different between hydrogen-terminated and oxygen-terminated surfaces. A hydrogen-terminated surface induces strong p-type surface conduction even in undoped diamond (1), exhibits hydrophobicity and it is characterised by a negative electron affinity (NEA). Since undoped diamond is basically an insulating material, hydrogen-terminated diamond has then a semiconductor-on-insulator structure. On the other hand, an oxygen-terminated diamond surface is strongly insulating, hydrophilic and has a positive electron affinity (PEA). This means that diamond has an advantage over other semiconductor materials in the fabrication of a surface nanostructure using a scanning probe microscope (SPM)-based processing technology. In the case of Si for example, special extra techniques such as SIMOX are required to fabricate the electrically isolated thin conductive layer. In diamond, an electrically isolated surface conductive layer is easily obtained by hydrogen termination; this layer shows excellent properties for the channel and the source/drain junctions of a field-effect transistor, the possibility of realising which has already been demonstrated (2). The electrical properties of the conductive area can be controlled at nanometer scale by changing surface hydrogen-termination to oxygen-termination. This is possible by means of local anodic oxidation (LAO), that we performed using both an atomic force microscope in contact mode and a scanning tunnelling microscope, with a grounded metal-coated tip and a few volts positive bias applied to the sample. The phenomenon depends not only on the applied bias, but also on the ambient humidity and the scanning speed used in LAO.
Lateral MOS structures have already been realised in this way (3); they are characterised by a 60 nm wide "oxidised" line, through which Fowler-Nordheim tunnelling current was observed. Future purposes are addressed to the realisation of "single hole transistors" in which the oxidised surface works as double tunnelling barrier. Morever, the possibility of realising transparent ohmic contacts using hydrogenation processes opens the way to exploit not only diamond electrical properties, but also optical ones at the same time.

References:

(1) F.Maier, L.Ley et al., Physical Review Letters 85 (2000) 3472.

(2) H. Umezawa, H. Kawarada et al., Japanese Journal of Applied Physics 38 (1999) L1222.

(3) M. Tachiki, H. Kawarada et al., Applied Surf. Science 159-160 (2000) 578.