FIB Technology

E. Bertagnolli, H. Langfischer, A. Lugstein, H.D. Wanzenböck

Institut für Festkörperelektronik, Technische Universität Wien, Floragasse 7, A-1040 Vienna, Austria

1. Focused Ion Beam technology — a new approach for the sub 100nm microfabrication regime

(A. Lugstein, H.D. Wanzenböck, E. Bertagnolli)

1.1 Analytical

Cross-sectioning exposes device structures for direct examination but conventional sample preparation procedures are difficult, time consuming, and grossly destructive. Cross sections formed by focused ion beam (FIB) milling are easier and much faster than the conventional sample preparation process provided by cleaving, polishing, and etching. Using exemplary microelectronic devices, the analytical feasibilities of FIB were exploited revealing an imaging resolution down to 5 nm (Fig. 1).

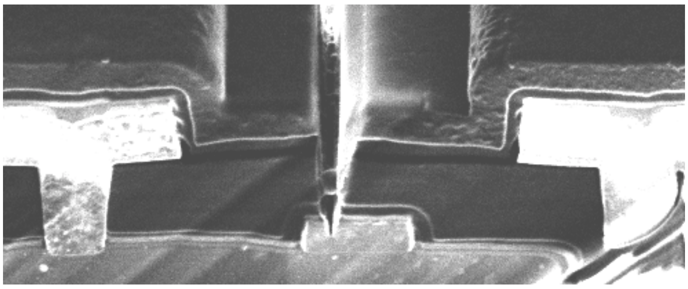

Fig. 1: Cross section of an inhomogeneous channel device.

1.2 Novel QCL-Laser Device

In collaboration with the QCL-Laser group (L. Hvozdara, G. Strasser), a successful modification of GaAs/AlGaAs mid infrared quantum cascade lasers has been demonstrated. By a single step maskless focused ion beam modification a novel monolithic mid infrared quantum cascade laser with self-aligned focused ion beam was generated. This tunable device was named FIB cut coupled cavity laser (FIBC3) and due to its novelty, a patent thereof is already pending.

By the same way a QCL integrated with monolithic one-dimensional photonic bandgap mirrors has been fabricated. The mirrors are composed of two precisely defined grooves trenched across the laser ridge (Fig. 2).

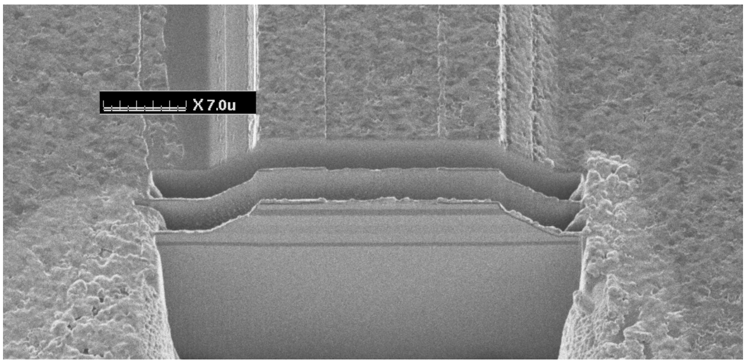

Fig. 2: FIB Image of the QCL with monolithic one dimensional photonic bandgap.

1.3 Inhomogeneous channel devices

In order to overcome the leakage/IDSAT tradeoff of sub-100 nm devices, recent investigations focus on an optimized MOSFET incorporating a sharp sublithographic dopant peak preferably on the source side of the channel. In cooperation with the Simulation Group of Siegfried Selberherr (Institute for Microelectronics, Technical University Vienna), we started the exploration of this device family by using localized ion implantation beams to fabricate laterally tailored doping profiles along the channels. First results show the feasibility of modifying the channel by FIB. Proper post-treatment reduces the defect levels to an insignificant level, thus opening the way to do basic work on these novel devices.

1.4 In situ diagnostic

In order to quantify the solid-beam interaction (charging, heating, defect generation etc.) and the residual damage done by the ion beam impinging the surface, the influence of focused ion beam on device performances will be studied in situ. Therefore the focused ion beam system has been enlarged by a new setup, enabling electrical parameterization of devices during beam exposure.

2. FIB-based tungsten metallization

(H. Langfischer, A. Lugstein, H. D. Wanzenböck, E. Bertagnolli)

Objective of the work is the development of a direct write metallization scheme enabling to contact and to interconnect sub-100 nm devices.

In a first step, the process windows and the fundamental mechanisms of deposition and etch reactions are under investigation. Therefore, pattern transfer, pattern alignment, layer formation, and layer characterization are primary concerns. Patterned W-layers were deposited on thermally grown silicon oxide via local decomposition of adsorbed molecular layers of volatile metal organic tungsten precursor gases (e.g. $W(CO)_6$) by focused Ga^+ ion beams. Primary effects are substrate intermixing and substrate erosion underneath the tungsten line, consuming tens of nanometers of substrate material. The chemical composition of the layers was evaluated by secondary ion mass spectroscopy (SIMS) measurements of as-grown metal pads. In Fig. 3, the SIMS depth profiles of W and C ions and W-Si molecule ions, acting as an indicator for the Si substrate, are depicted showing a homogeneous composition of the deposited metal layer. Approaching the interface, however, a clear pile-up is seen, suggesting atomic mixing with the substrate due to recoil effects.

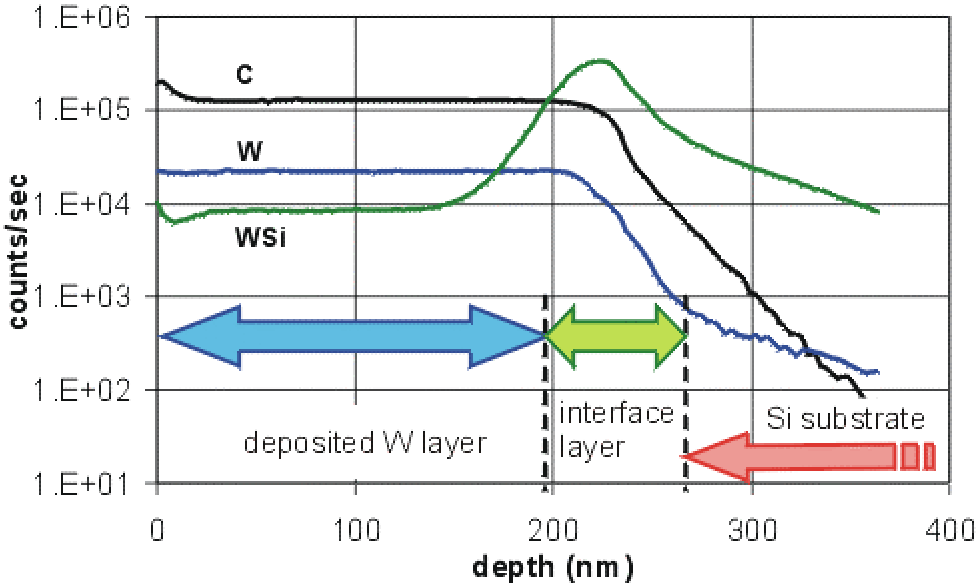

Fig. 3: SIMS depth profile of C, W and WSi. The pile-up in the WSi concentration indicates the atomic mixing at the interface layer.

In order to perform electrical measurements, tungsten squares are connected to Al contact pads (60 x 60 µm^2) in a van der Paw arrangement, allowing electrical probing (Fig. 4).

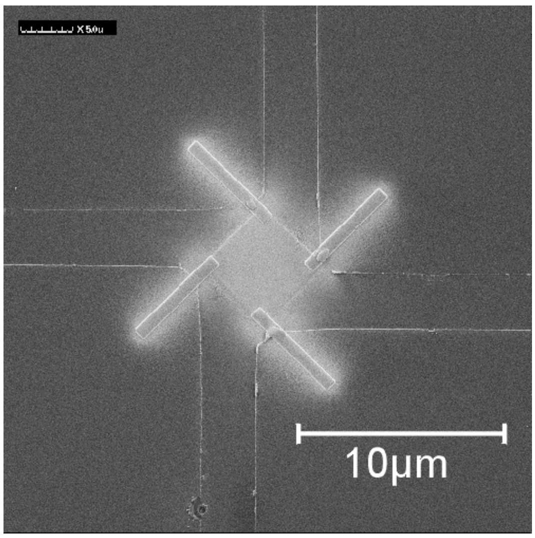

Fig. 4: SEM picture of a FIB tungsten test device.

The electrical and analytical characterization of the FIB induced metallization allowed to corroborate the dependence of the material properties on the variation of the deposition parameters. The sheet resistance of the layers amounts typically to 3 Ohms per square. The resistivity of the metal was calculated to be in a typical range of 200 – 300 $\mu\Omega$cm.

The maximum current densities, indicating the robustness of the material, were estimated to 3.5 10^6 A/cm^2. As expected, the electrical properties of the material were found to correlate with the composition of the tungsten layer, hosting Ga, C, Si and O. Auger spectra of the W-layer on SiO_2 indicated a significant presence of C and Ga and trace levels of Si and O. By balancing the pulse rate of the impinging beam with the adsorption efficiency, the relative Ga contamination of the layers could be drastically reduced.

The obtained results demonstrated that FIB based metal layers of W are a promising choice for local front-end metallization regarding layer homogeneity, sheet resistance, and maximum current density. Most crucial from the point of view of contact metallization is the incorporation of Gallium and the substrate mixing effect due to the high energy of the impinging ions.