The Definition of Semiconductors Nanowires using Ga^+ Focused Ion Beam Lithography with Mask of Hydrogenated Amorphous Silicon Film

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This work presents the formation of silicon nanowires (SiNWs), with sub-400 nm wide, and III-V nanowires (III-VNWs), with sub-120 nm wide, using the Ga^+ focused ion beam (FIB) lithography with the protective layer of hydrogenated amorphous silicon (a-Si:H) film. Previous work has demonstrated the formation of fins for FinFETs prototypes fabricated using the Ga^+ FIB lithography directly on the Si substrate, which results in the gallium incorporation and implantation on the transistor channel. [1] This can change the electrical and optical properties of the device.[1] Therefore, we propose to deposit a a-Si:H thin layer (60 nm thick) on the substrates (Si and III-V semiconductor) to avoid the interaction of the gallium ions with the substrate. Thus, the local and shallow implantation of gallium ions occurs in the a-Si:H film, as shown in Figure 1, forming a non-volatile mask when exposed to a fluorinated plasma. The quality and integrity of the SiNWs are studied through the electrical measurements carried out on the pseudo-MOS transistors as is shown in Figure 2.

SiNWs were fabricated on SOI substrate, with a 340 nm thick silicon (Si) layer. III-VNWs were fabricated on III-V semiconductor substrate (GaAs-n^+ (10 nm)/GaAs Buffer (300 nm)/GaAs). The source and drain regions were covered with a 50 nm thick aluminum (Al). The multiple nanowires, with length of 2 μm and 9 μm, were defined using the Ga^+ FIB, with energy of 30 kV and current of 30 pA and 300 pA. In this step, the ion beam was used only for a shallow cut of the a-Si:H thin layer of the fin structure, as shown in Figure 1. Figure 3 presents the 30 SiNWs after the etch step. The a-Si:H layer and Si substrate etch were done using SF_6/C_4F_8 inductively coupled plasma (ICP) after the FIB step. Figure 4 presents the 3 III-VNWs after the etch step. The III-V substrate etch was done using Cl_2/Ar ICP.

Our method for the formation of semiconductors nanowires is effective and avoids the gallium incorporation and implantation on the substrates.

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[1] Leonhardt, A.; Santos, M. V. P.; Diniz, J. A.; Manera, L. T.; Lima, L. P. B. Journal Vaccum Science & Technology B 34, 06KA03 (2016).

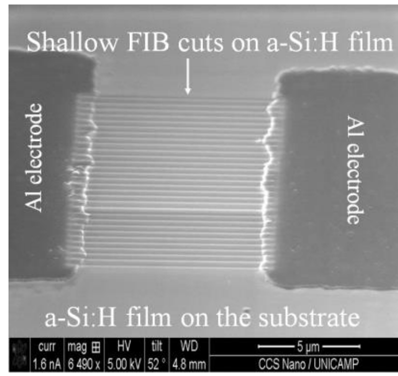

Figure 1: The shallow FIB cuts of 50 lines on the a-Si:H film.

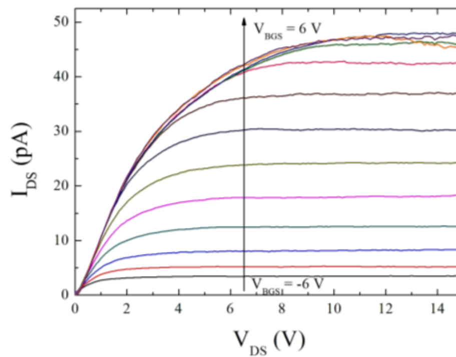

Figure 2: I_{DS} x V_{DS} curves of Pseudo-MOS transistors.

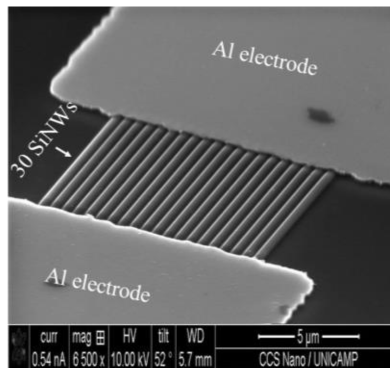

Figure 3: 30 SiNWs after the etch step for SF_6:Ar ICP.

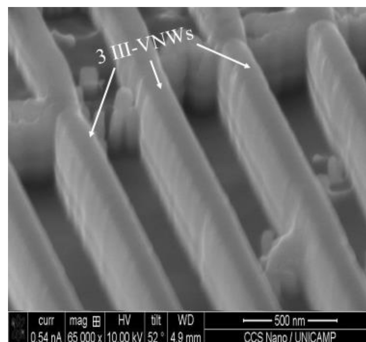

Figure 4: 3 III-VNWs after the etch step for Cl_2:Ar ICP.