Collaborative project*

Project acronym: SNM

Project full title: "**Single Nanometer Manufacturing for beyond CMOS devices**"

Grant agreement no: 318804

Deliverable: 3.1 ("Nanopatterns of different chemical compositions by changing the liquid bridge")

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List of participants:

Participant no.	Participant organisation name	Part. short name	Activity Type	Country
1 (Co)	Technische Universität Ilmenau	**TUIL**	HER	Germany
2	EV Group E. Thallner GmbH	**EVG**	IND; End-user	Austria
3	IMEC	**IMEC**	RES	Belgium
4	Mikrosistemi Ltd	**µS**	SME; End-User	Bulgaria
5	Universität Bayreuth	**UBT**	HER	Germany
6	Technische Universiteit Delft	**TUD**	HER	Netherlands
7	Spanish National Research Council	**CSIC**	RES	Spain
8	IBM Research GmbH	**IBM**	IND; End-user	Switzerland
9	École polytechnique fédérale de Lausanne	**EPFL**	HER	Switzerland
10	SwissLitho AG	**SL**	SME; End-User	Switzerland
11	Oxford Instruments Nanotechnology Tools Ltd	**OINT**	IND; End-user	UK
12	Imperial College London	**IMPERIAL**	HER	UK
13	The Open University	**OU**	HER	UK
14	Oxford Scientific Consultants Ltd	**OSC**	SME	UK
15	VSL Dutch Metrology Institute	**VSL**	IND	Netherlands
16	University of Liverpool	**ULIV**	HER	UK

SNM

Work Package 3

Deliverable: 3.1 ("Nanopatterns of different chemical compositions by changing the liquid bridge")

Lead beneficiary number	7	**Nature**	R	**Dissemination level**	PU

Estimated Person-months	12.00									
Person-months by partner for the Deliverable	CSIC									
	15									

Estimated Delivery Date	Month 12	**Delivery Date** December 12th, 2013	Month 12

Description of the Deliverable

Electrochemical SPL: Combination of patterns made of oxides and carbonaceous compounds

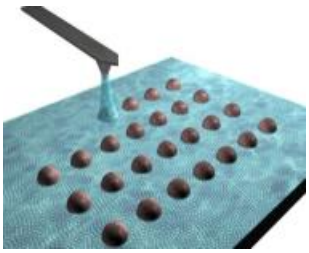

Figure 1. Scheme of the electrochemical SPL

The goal of this deliverable is to demonstrate that scanning probe lithography (SPL) has the capability to fabricate patterns of different chemical compositions and to place them side-by-side on a silicon wafer with a 1-μm separation. The scientific activity is also intended to decrease the feature size of the fabricated structures by electrochemical SPL methods with the objective of approaching the 1 nm resolution. The chemical composition of the fabricated patters is controlled by the composition of the liquid bridge formed between the tip and the surface (Fig. 1). We have used liquid bridges of different chemical compositions, in particular, water, octane and heptane. Figure 2 show the reaction chamber that encloses the AFM head. Some of the gas inlets and outlets are also shown.

To illustrate the achievement of the deliverable D3.1 we have patterned a silicon surface with arrays of dots made of silicon oxide and arrays of dots made of a carbonaceous

compound. In the case of silicon oxide dots, the liquid bridge was made of water while in the case of the carbonaceous dots, the liquid bridge was made of octane.

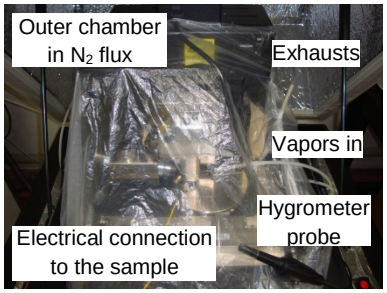

Figure 2. AFM head and reaction chamber to confine organic vapors.

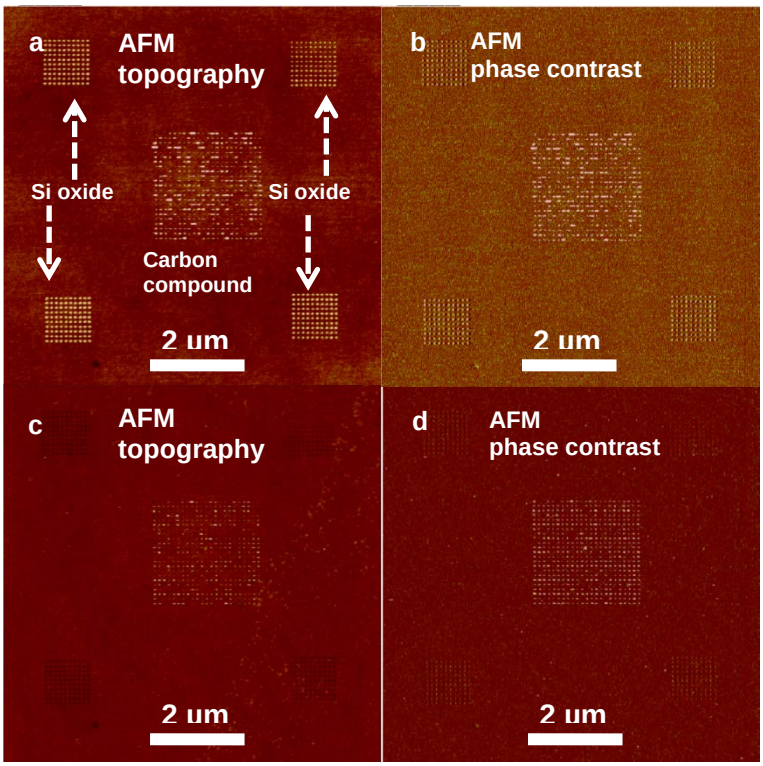

Figure 3. (a) AFM topography image of patterns with organic vapors (central) and oxidation SPL (corners). (b) AFM phase image (compositional contrast). (c) AFM topography image of the same patterns after 10 s etching in HF and sample cleaning. (d) AFM phase image of the patterns after etching in HF.

We have designed a pattern made of five regions. Four regions are made of an array of 10x10 silicon oxide dots. The dots are separated 100 nm and are obtained by applying voltage pulses of 21 V (top patterns) and 22.5 V (bottom patterns) for 500 μs, while the reaction chamber was kept at a relative humidity of 42-44%. The silicon oxide arrays surround a central region made of an array of 23x23 dots fabricated in an octane atmosphere (Figs. 3a and 3b). In the latter case, the pattern was fabricated by applying voltage pulses of 28.5 V and 500 μs separated by 100 nm. The nanolithography sequence first involved the patterning of the array of carbonaceous dots and then the patterns made of silicon oxide dots. The full width at half maximum (FWHM) of the oxide dots is of 30 nm while the FWHM of the carbonaceous compounds is of 20 nm.

In order to illustrate the differences in the chemical composition of the patterns

	fabricated with either water or octane liquid bridges, the sample was exposed to HF vapors for 10 s, and cleaned with several ultrasonic bath cycles in water, isopropanol, acetone, toluene, chloroform, NH_3:H_2O_2:H_2O mixture. It is known that the etching rate of silicon oxide in HF is much faster than the one of silicon. Consequently the exposure of the sample to HF vapours will lead to holes in the regions patterned with silicon oxide dots while the rest of the regions will remain practically unchanged. Figures 3c and 3d show that after HF etching, the oxide patterns have disappeared. In their place appear holes, one for each oxide dot. The holes are barely visible in the images. On the other hand, the organic pattern is left unchanged. The compositional contrast provided by the AFM phase image (Fig. 3d) does not show any contrast between the silicon surface and the region previously occupied by the silicon oxide dots. This confirms that the silicon oxide dots have been removed. The central array of dots generated in an octane environment remain visible in both AFM topography and phase contrast images. In short, Figure 4 shows the ability of electrochemical SPL to pattern side-by-side regions of silicon dioxide and carbon compounds. Figure 3 demonstrates that the deliverable D3.1 has been fully achieved.
Explanation of the Differences between Estimation and Realisation	D3.1 has been achieved in its totality.