Project updated: 03.06.2021

Thermal scanning probe lithography for 2D material-based devices

Semester project / Master project

(Section: microengineering, material science, mechanical engineering, physics microelectronics)

Traditionally, 2D material (2DM) devices are patterned using electron beam lithography. However, electrons can easily damage the delicate 2DM and you typically need to fabricate alignment marks to overlay the patterns with the 2DM buried under the resist.

Here, we propose the use of thermal scanning probe lithography (t-SPL), a lithographic tool that uses a hot sharp tip to create nanometer-sized patterns (see Fig. 1). T-SPL avoids the use of electrons and offers precise overlay and marker-less stitching thanks to its capability of in-situ inspection. Besides, the same tool offers laser direct writing (DLW) to speed up the fabrication of microscale patterns (see Figs. 1c-d). 3D patterning can be also easily achieved by creating a design in greyscale that will translate into different depths of patterning, such as Fig. 1f

In this experimental project, the student will be able to use t-SPL for the fabrication of 2DM devices. The project can be adjusted to the student's interests.

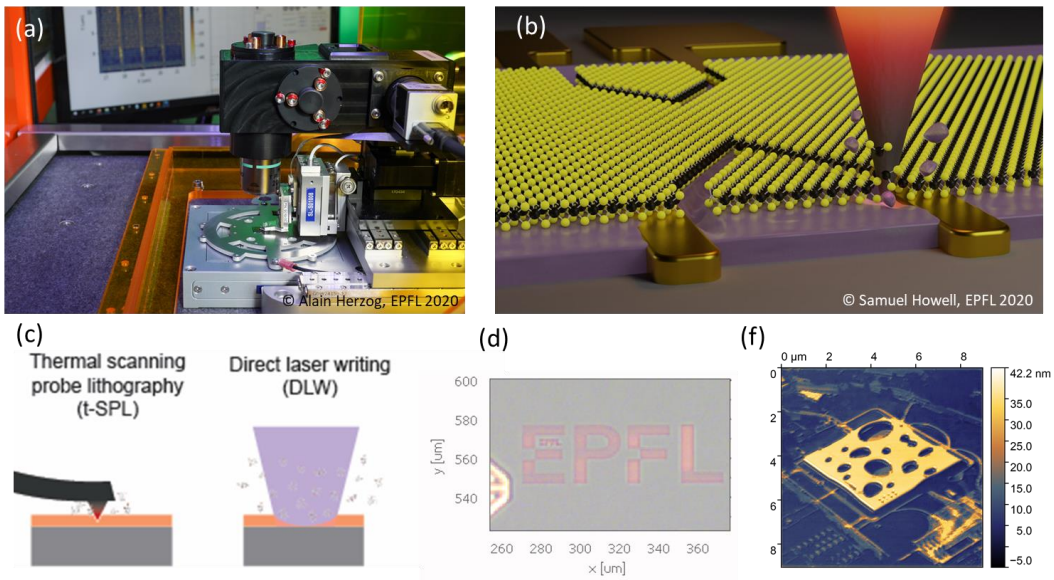

Figure 1. Main idea and scheme of the process.

Work description:

- Use of tSPL to define nanometer scale patterns
- Use of DLW to create microscale patterns
- Combination of tSPL and DLW for a functional device by using pattern transfer (etching) or lift-off (e.g. creation of electrodes)

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Project updated: 03.06.2021

Thermal Scanning Probe Lithography Patterning for Straining 2D Materials

Semester project / Master project

(Section: microengineering, material science, mechanical engineering, physics, microelectronics)

The emerging field of 2D materials (2DM) is growing exponentially thanks to their extraordinary properties that find applications in very diverse fields. For example, it is well known that strain can be used to tune the bandgap and the optoelectronic properties of 2DMs. However, currently, the values for strain reported in literature are still limited which hinders in turn the bandgap tuning. In this project, we propose to transfer 2D materials (monolayer) onto the prepatterned PPA substrate, such as sinusoidal waves in Fig 1 and 2 and other patterns. The PPA substrate is patterned using Thermal Scanning Lithography (t-SPL).

The main goal of the project is experiments including fabrication, characterization, etc. The project can be adjusted to the student's interest, eventually.

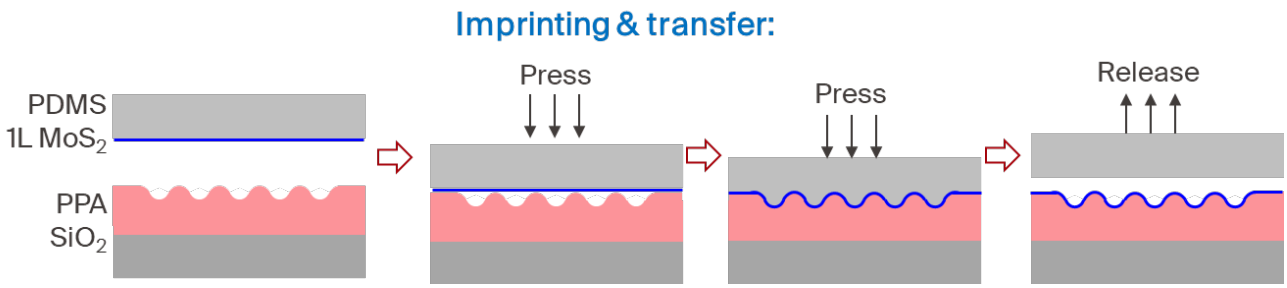

Figure 1. Main idea and scheme of the process.

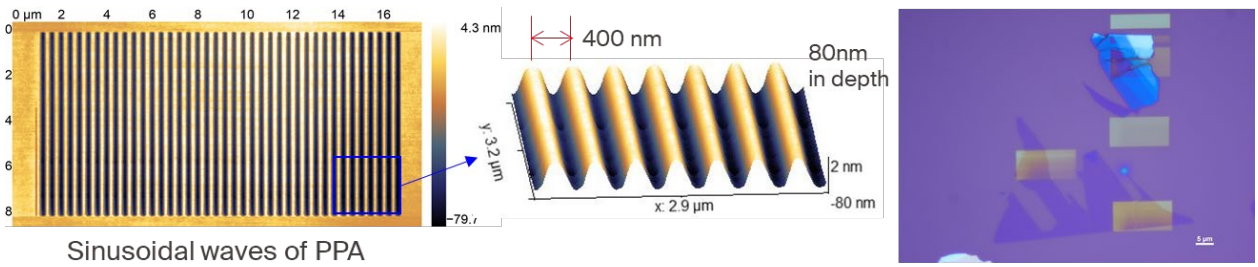

Figure 2. Preliminary results about t-SPL pattern and the 2D transfer.

Work description:

- t-SPL pattern
- Preparation of 2D material flakes
- characterization of strain in the 2D material

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Project updated: 04.06.2021

Spontaneously Formed Surface Micro-Wrinkles for Applications in Pattern Masks or Straining 2D Materials

Semester project / Master project

(Section: microengineering, material science, mechanical engineering, physics, microelectronics)

Methods for spontaneously forming periodic micro-/nanostructures have received considerable attention for lithography-free patterning applications. Self-organizing patterns with micrometer-scale features are promising for applications in photonics and bioengineering. Their spontaneous formation reduces the number of required processing steps. Previously, we developed an approach to spontaneously form stochastic patterns in thin skin layers on top of thermosensitive resist and an approach to align the micro-wrinkles. What's next, some demonstrations using the method will be interesting, for example, in the applications of fabrications of complex pattern masks, or straining atomically thin materials.

The main goal of the project is experiments including fabrication, characterization, modeling, etc. The project can be adjusted to the student's interest, eventually.

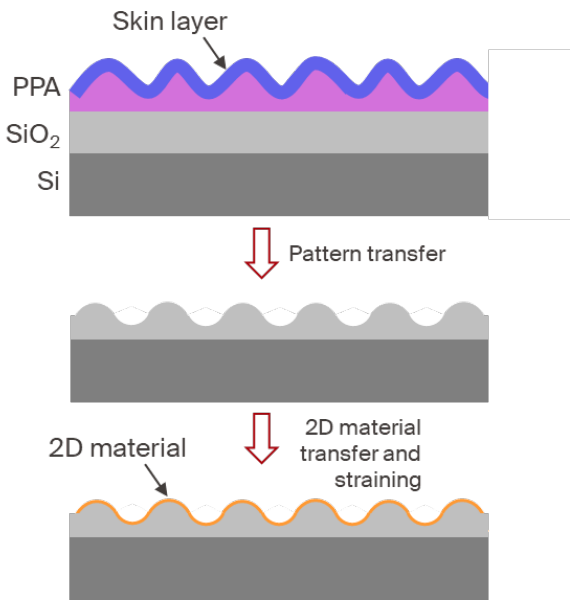

Figure 1. Main idea and scheme of the process.

Work description:

- Fabrication of wrinkles on other materials using plasma etching
- Preparation of 2D material flakes
- Characterization of strain in the 2D material

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Project updated: 03.06.2021

Inducing strain in 2D materials with nanoimprint lithography

Semester project / Master project

(Section: microengineering, material science, mechanical engineering, physics microelectronics)

The emerging field of 2D materials (2DM) is growing exponentially thanks to their fascinating properties that find applications in very diverse fields. For example, it is well known that strain can be used to tune the bandgap and the optoelectronic properties of 2DM. However, currently, the values for strain reported in literature are still limited which hinders in turn the bandgap tuning and some methods used for inducing strain are limited in terms of scalability and others cannot properly control the induced strain. In this project, we propose the use of nanoimprint lithography to induce strain in 2DM in a controllable and scalable way.

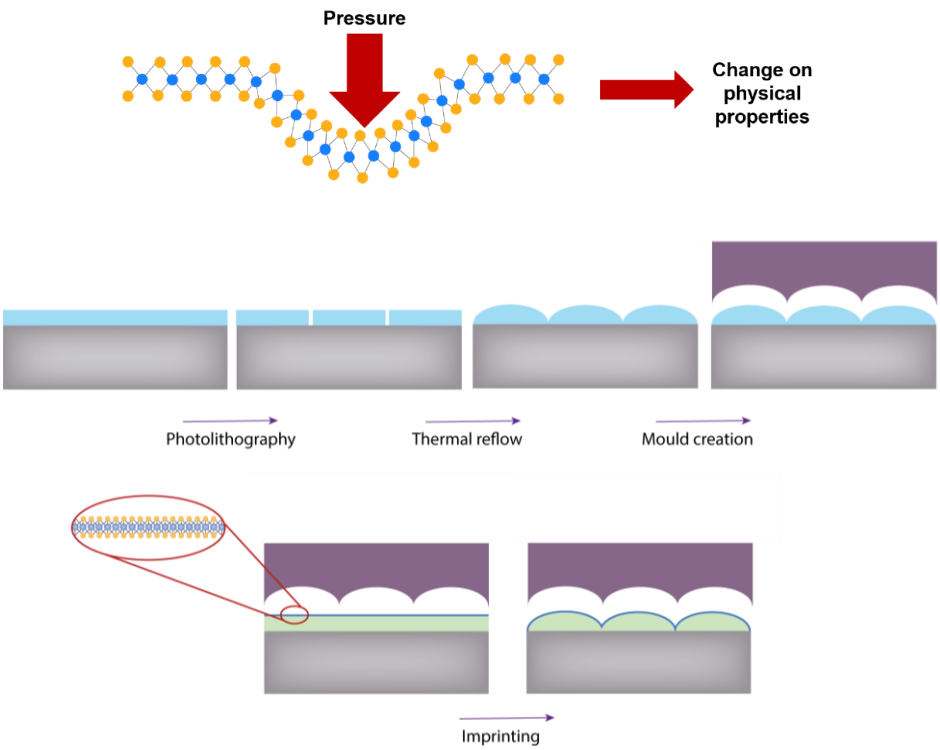

Figure 1. Main idea and scheme of the process.

Work description:

- Fabrication of stamps for NIL with wavy structures
- Use of the fabricated stamps for NIL to induce strain in 2D materials
- Characterization of the strain in 2D materials by Raman spectroscopy

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