Ink-jet printing of polymeric dampers for MEMS applications

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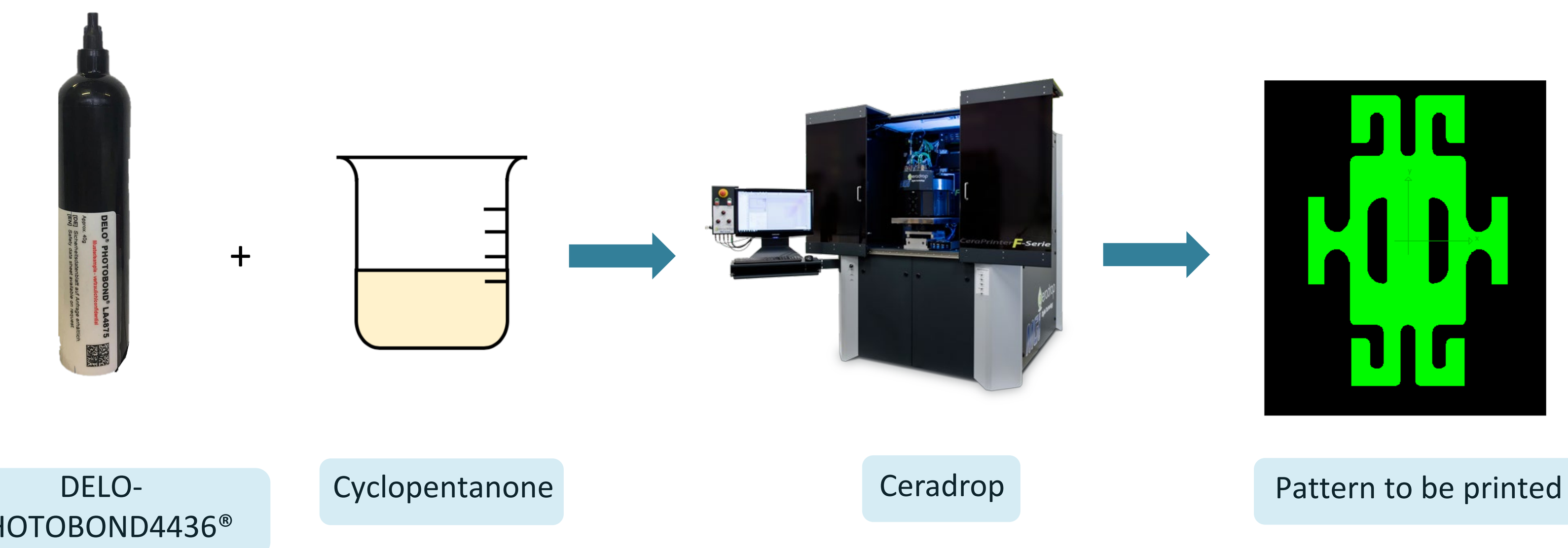
Abstract & purpose

Over years, additive manufacturing has gained growing interest and attention in applications where customization and cost-effectiveness are strategic features [1]. In this frame, ink-jet printing has emerged as a potential process to be flanked by traditional microelectronics material deposition methods [2], where non-critical restraints on resolutions are required [3]. This is true, for example, in the case of polymeric materials that can find application in MEMS microdevices production. Here it is proposed a successful ink-jet printing of a commercial product belonging to this family (DELO-PHOTOBOND 4436®) on silicon oxide substrate, whose final application will be a mechanical bump and damper. A jetting characterization was performed to assess the optimal printing parameters: the applied voltage, frequency and drop velocity. Physical ink properties need to be considered to guarantee an operative jetting, i.e. viscosity (< 20 cP) and surface tension (< 35 mN/m) [4]. After printing, pattern characterization was carried out to understand the final morphology and thickness, respectively.

1 Methodology



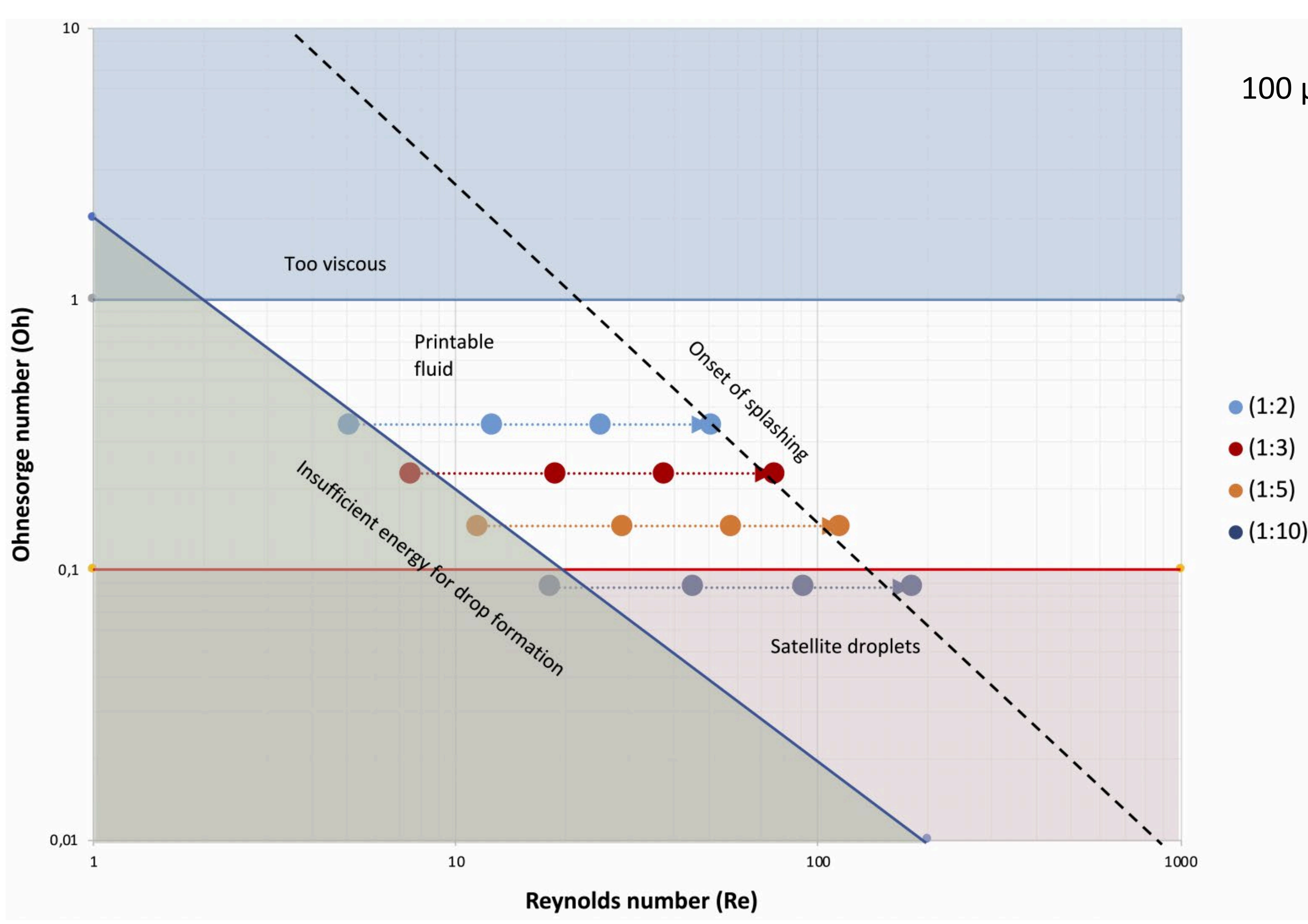
Dilution (1:3 by weight) was necessary to process the material. Cyclopentanone was chosen as diluent as it exhibits a sufficiently low viscosity (η=1.075 cP) and a not too high boiling point (T_{eb}=130°C). The solution was transferred in a 10 pL Dimatix cartridge and mounted in the Ceradrop printhead.

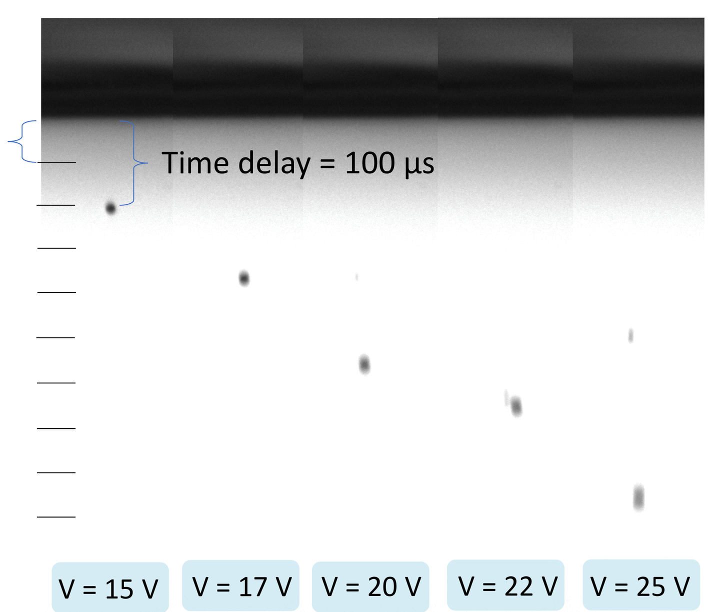
2 Ink & Jetting characterization

$$Oh = \frac{\eta}{\sqrt{\sigma \rho d}}$$

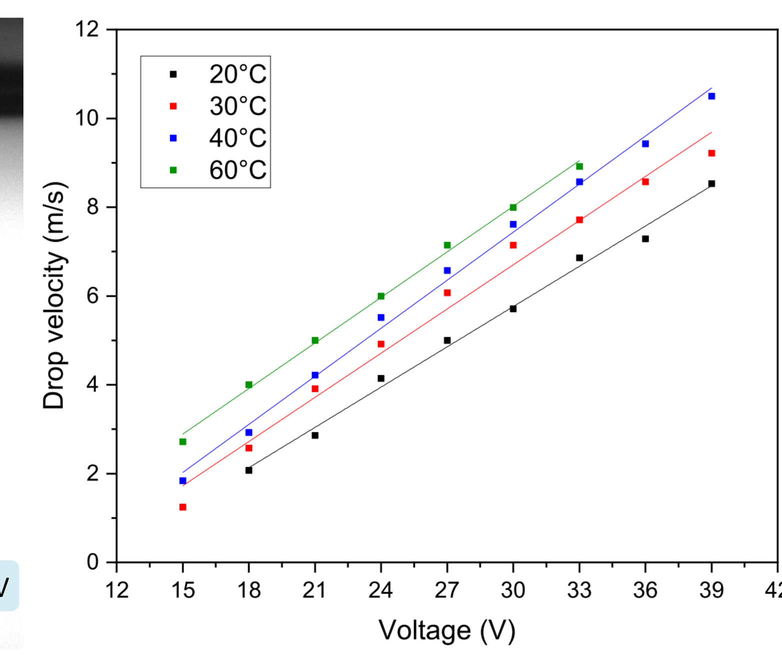
$$Re = \frac{\rho d V}{\eta}$$

A specific combination of Re and Oh numbers allows to define a printability area





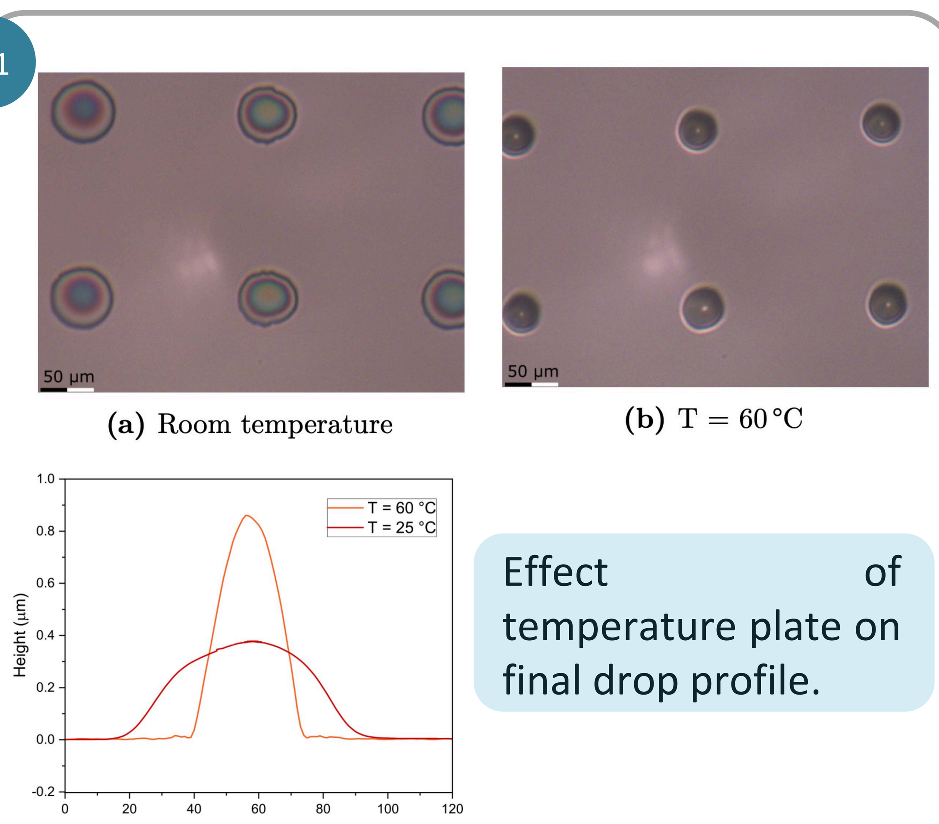
Each photogram was taken with a 100 µs time delay.
By increasing the applied voltage spherical drop shape is progressively lost.



Drop velocity has a linear dependence on voltage applied to the piezo element. Temperature increases drop velocity, fixed a voltage.

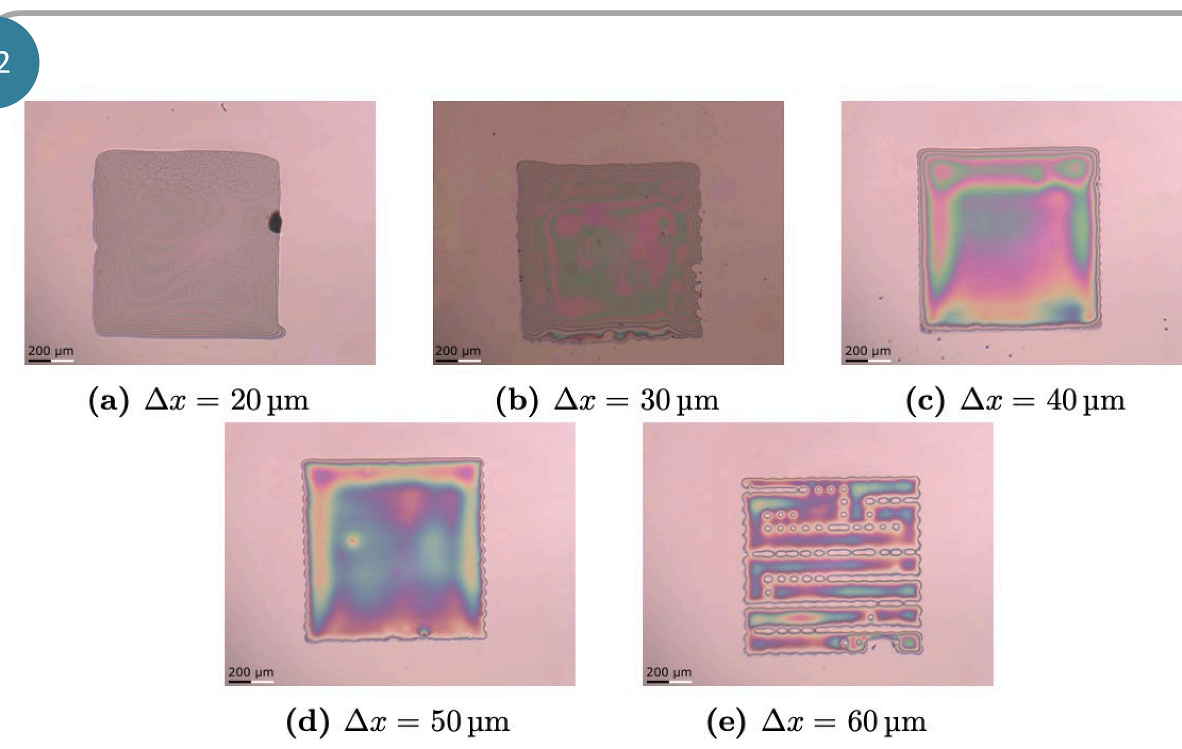
3 Printed pattern characterization

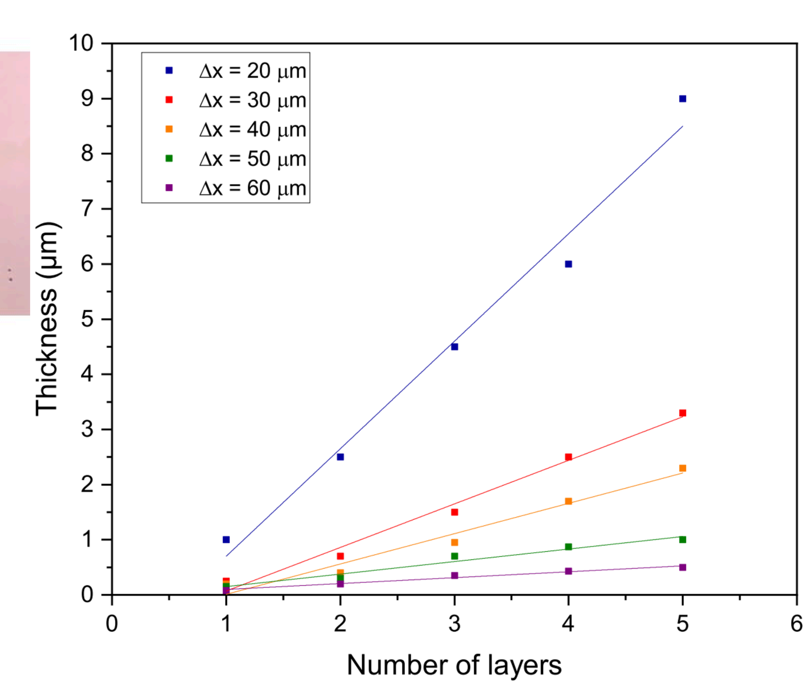
3.1



Effect of temperature plate on final drop profile.

3.2

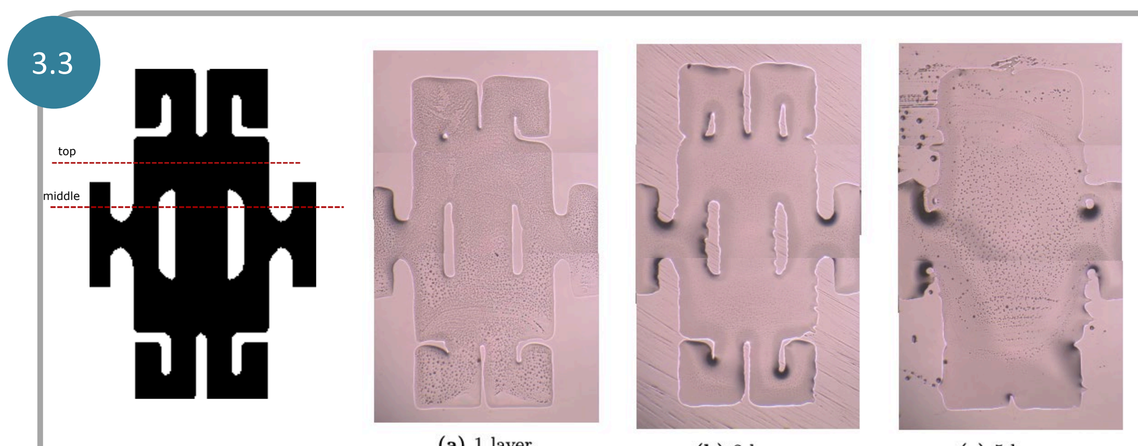




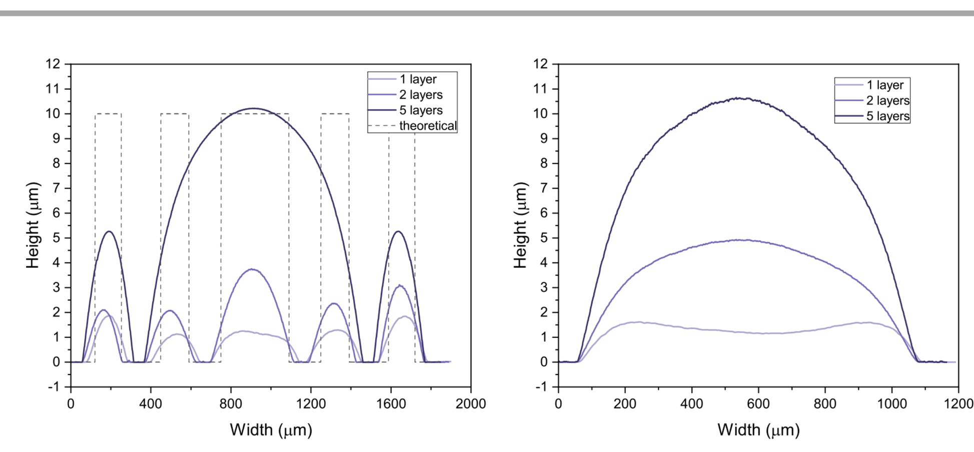
Drop spacing (Δx) is the distance between the centers of two adjacent drops.

Increasing Δx above a certain value will cause drops to not overlap → not continuous layer is obtained.

3.3



Printing of the final pattern with Δx = 20 µm @60°C, by varying the number of printed layers.

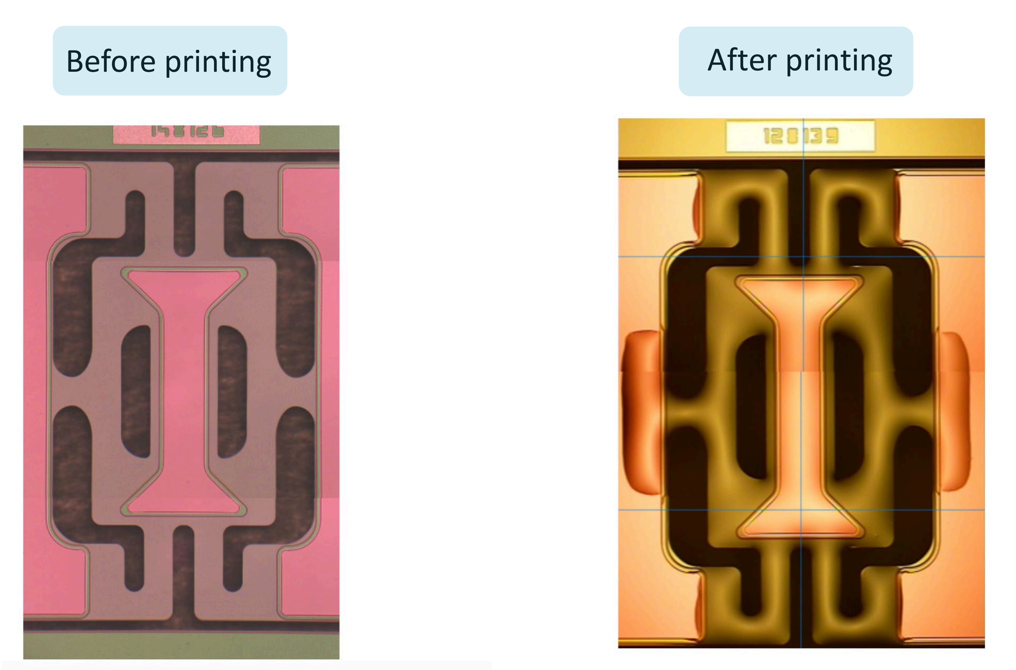


Pattern profilometry in correspondence of top/middle part.

3.4

Before printing

After printing



Conclusions

A successful printing of a solution comprising commercial product DELO-PHOTOBOND4436® and cyclopentanone (1:3) on silicon oxide substrate was demonstrated. The optimal voltage to be applied was found to be 20 V. Final printed material presented the desired mechanical properties. Further studies are necessary to improve morphology uniformity of the final pattern.

References

[1] Müller, M., Huynh, QU., Uhlmann, E. et al., *Study of inkjet printing as additive manufacturing process for gradient polyurethane material*, Prod. Eng. Res. Devel. (2014).
[2] T. Huanga and W. Wu, *Scalable nanomanufacturing of inkjet-printed wearable energy storage devices*, . Mater. Chem. A. (2019).
[3] G. Lau and M. Shrestha, *Ink-Jet Printing of Micro-Elelectro-Mechanical Systems (MEMS)*, Micromachines (2017).
[4] Stephen Hoath, *Fundamentals of ink-jet printing*, Wiley (2016).