Laser based manufacturing of channels and improvement of their lifetime with sol-gel coatings

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Abstract

The fabrication of preclinical devices for performing bioassays has aroused a huge interest in the past years due to the fact that some pathologies, like cardiovascular ones, are a main cause of morbidity worldwide and their study in-intro conditions is a key factor for their understanding. We have developed a preclinical device that mimics half blood vessel by using laser technologies. By employing a Nd:YVO_4 laser in Q-switch mode (wavelength 1064 nm and pulse duration 20 ns) a channel has been manufactured over soda-lime glass [1]. Using a CO_2 laser (wavelength 10.6 µm and pulse duration 10 µs) combined with a roller furnace, a thermal treatment has been applied to the channel in order to reduce its roughness and enhance its quality. The glass structure was employed as a master to replicate the channel in polydimethylsiloxane (PDMS) by soft-lithography [2]. To avoid the deterioration of the PDMS when it is exposed to organic solvents during bioassays [3], the channels were coated with three different sol-gel coatings compositions: 60MTES/40TEOS, 70MTES/30TISP and 80MTES/20TISP. Methyltriethoxysilane (MTES) and tetraethylorthosilane (TEOS) were used as silicon dioxide precursors and titanium isopropoxide (TIPS) as titanium dioxide precursor. Human umbilical endothelial cells were cultured over the channels in order to determine the most suitable composition to cell growth and to study cell behaviour in each case.

Fabrication method and sol-gel coating

Master fabrication by laser techniques » Replica procedure by soft-lithography methods » Sol-gel coatings

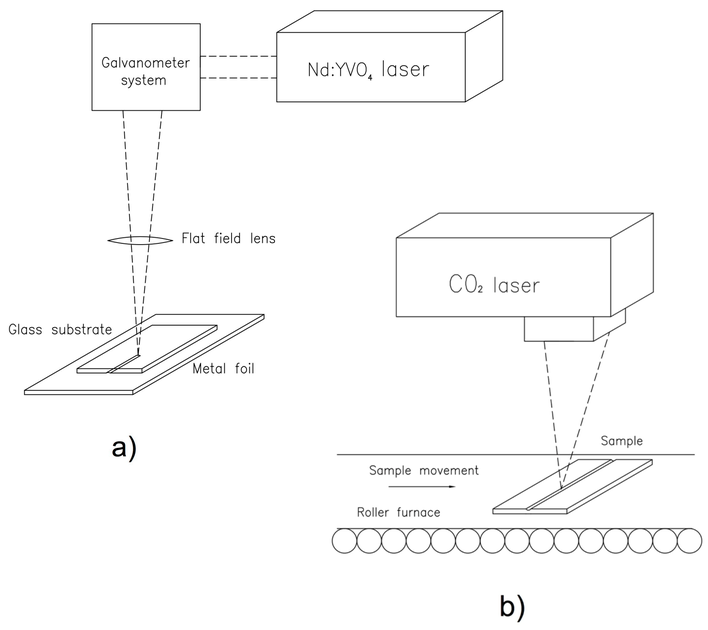

Fig. 1: a) Laser backwriting method employed for manufacturing the master over soda-lime glass. b) Post thermal treatment applied to the master with a laser and a roller furnace.

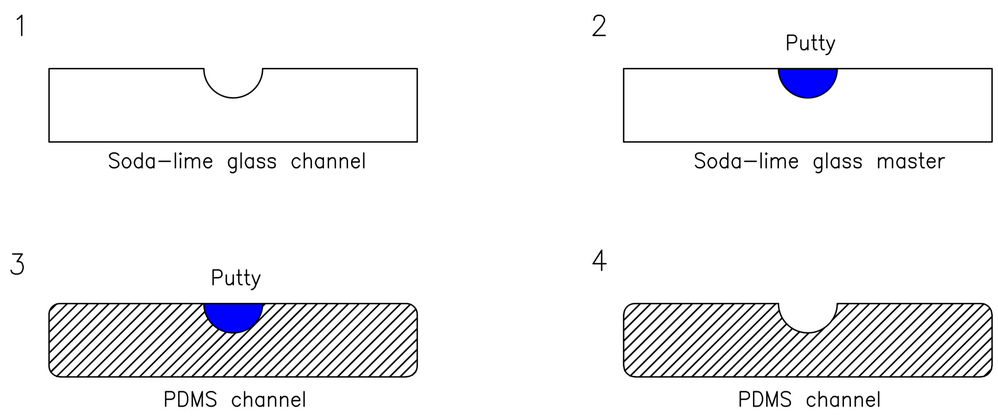

Fig. 2: The master was replicated in PDMS employing soft-lithography methods. First, an inverse mold of the channel was obtained with putty. The putty was covered with PDMS in a ratio 10:1 and the elastomer was cured. Finally, the PDMS was peeled off and an accurate replica of the soda-lime master was achieved.

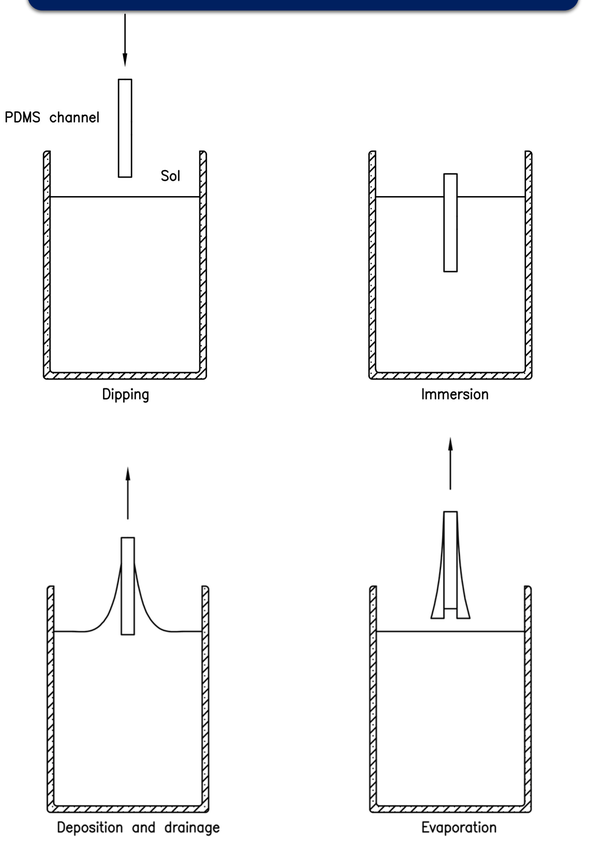

Fig. 3: Scheme of the sol-gel dip-coating process.

Cell culture and biocompatibility study

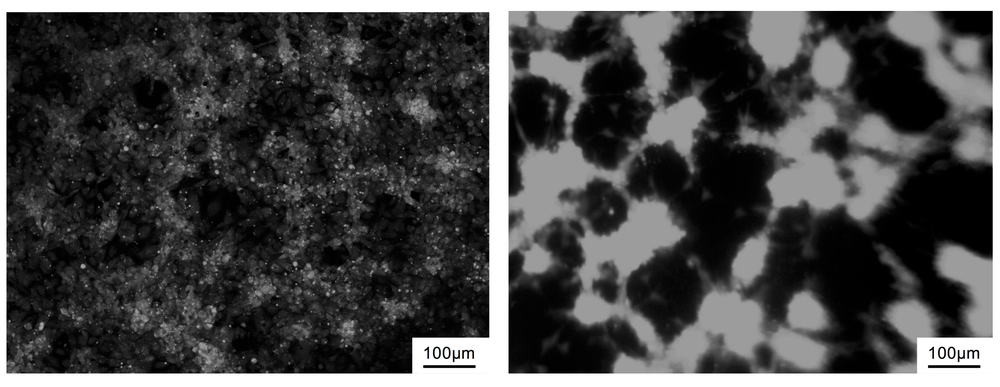

Fig. 4: Fluorescence images of PDMS degradation problem when it is exposed to organic solvents. a) Endothelial cells in the first use of the chip and b) abnormal growth after washing the device with ethanol.

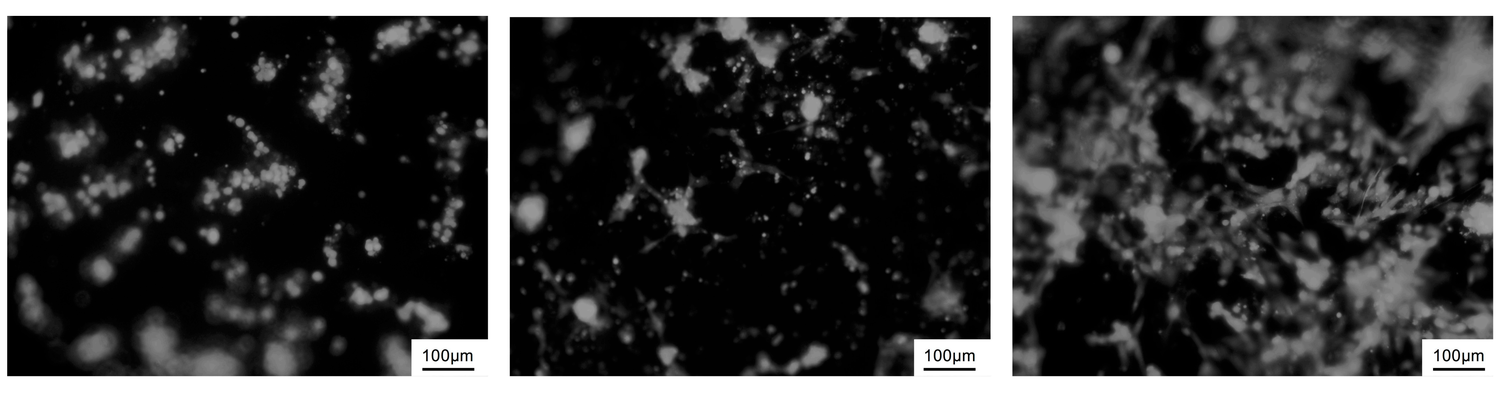

Fig. 5: Fluorescence microscopy images of the endothelial cells over the PDMS device with different sol-gel coatings after one day culture. Important differences in cell growth can be appreciated when channels were coated with a) 60MTES/40TEOS, b) 70MTES/30TISP and c)80MTES/20TISP sol-gel compositions.

Conclusions

PDMS devices for preclinical applications were fabricated. By using a laser indirect writing technique, a master of the structure was manufactured over commercial soda-lime glass. A post-thermal treatment with a CO_2 laser combined with a roller furnace was applied to enhance the quality of the master and channels with 1 mm depth were achieved. Then, the master was replicated in PDMS by using soft-lithography methods. The final channels were coated with three different sol-gel compositions (60MTES/40TEOS, 70MTES/30TISP and 80MTES/20TISP) to avoid PDMS degradation when it is exposed to organic solvents. Endothelial cell behaviour over the coated channels was evaluated, determining that the 80MTES/20TISP sol-gel composition was the most suitable one for cell proliferation.

References

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