Laser micromachined Moiré pattern strain sensors on polymer membrane

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Abstract

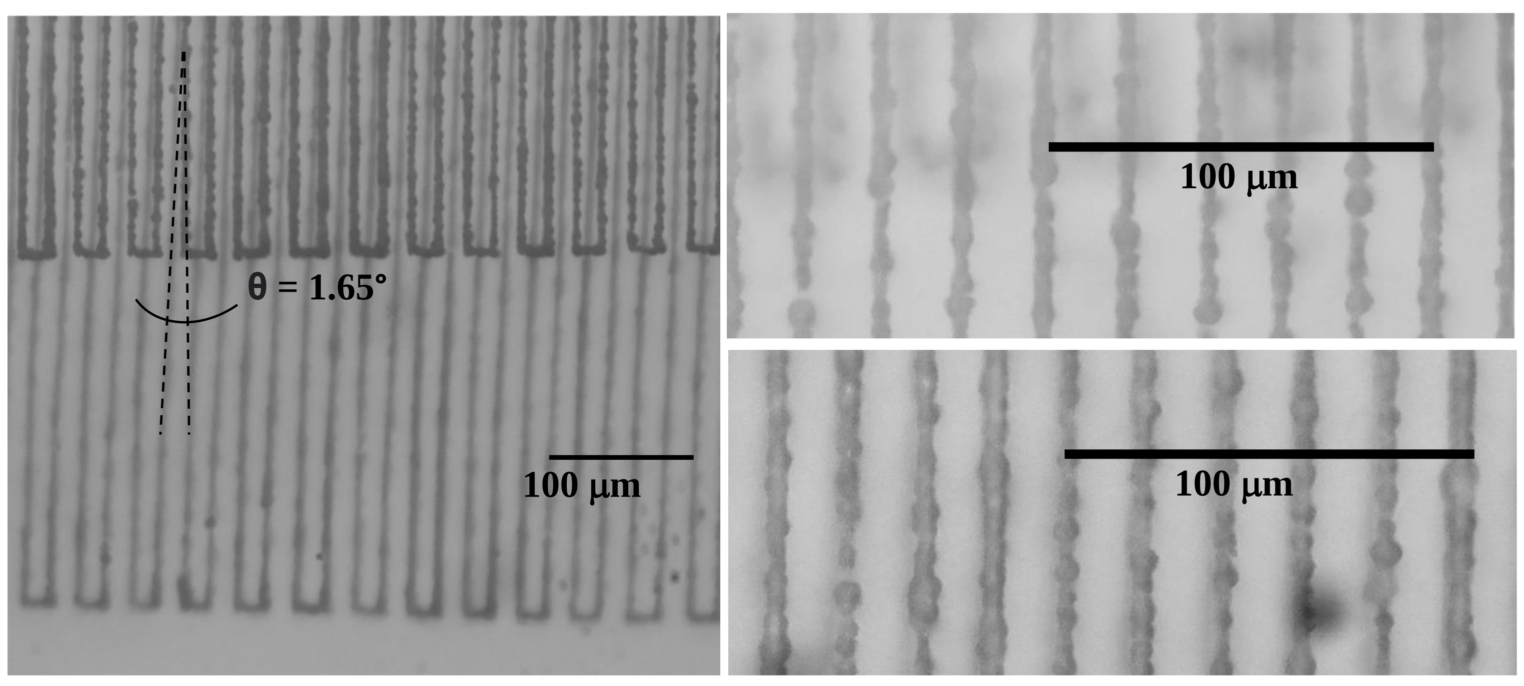
- Moiré technique is one of the highly sensitive non-contact method to measure surface deformations due to strain. .
- In literature, Moiré patterns are made using holographic photolithography, electron beam lithography, focused ion beam (FIB) lithography and nanoimprint lithography (NIL).
- Some of these techniques need very expensive and precise equipments like vibration isolation platform, nano stage, which makes fabrication and mass manufacturing difficult.
- Here, we propose picosecond laser micromachining as a reliable technique for embedding optical microstructures such as gratings at various depths of a material. The proposed membranes can be used as strain sensors for health monitoring of various structures, importantly in underground mines wherein all-optical sensors are in great demand

Introduction

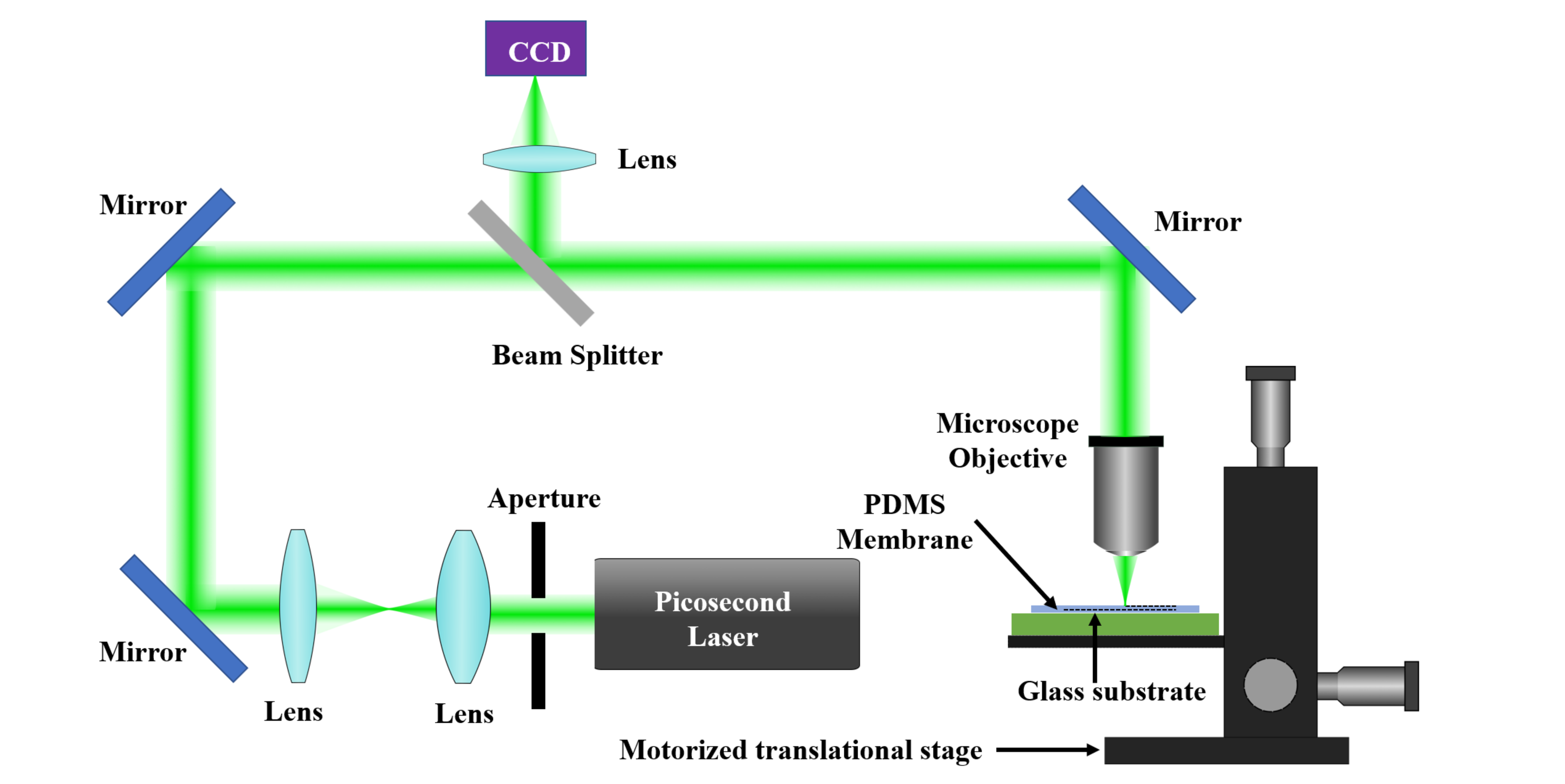
- Direct laser writing or laser micromachining by laser ablation on polymer membrane can be an alternative way of producing micro structures like grating at different depths of a membrane.[3]
- Laser direct ablation is a low-cost and versatile process in which by tweaking the parameters such as energy of the pulses, pulse repetition rate and pulse duration, fabrication of tracks and complex 2D/3D structures is possible.
- One such polymer used widely in research is PDMS(polydimethylsiloxane). PDMS is a silicon-based polymer exhibiting tunable mechanical, chemical and optical properties which is non-toxic and biocompatible.

Design/Other information

- PDMS membranes were fabricated using Sylgard™ 184 silicone elastomer kit procured from Dow. The base and the curing agent were mixed in a 10:1 ratio and spin-coated on a cleaned glass substrate and at 500 rotations per minute (rpm) for 40 seconds, and then cured at 75 °C for 1 hour.
- The lab built motorized 3-axis stage were used to move the sample in X and Y directions according to a CAD drawing, using stepper motors driven by microcontroller. The Z-axis translational stage was used to focus the laser beam on to the substrate by using the feedback data from CCD camera.
- In the setup, a picosecond laser is used of 532 nm wavelength with pulse duration less than 500 ps and pulse repetition rate at 2 kHz.
- The microscope objective of 20x was used to focus the beam on to the sample.

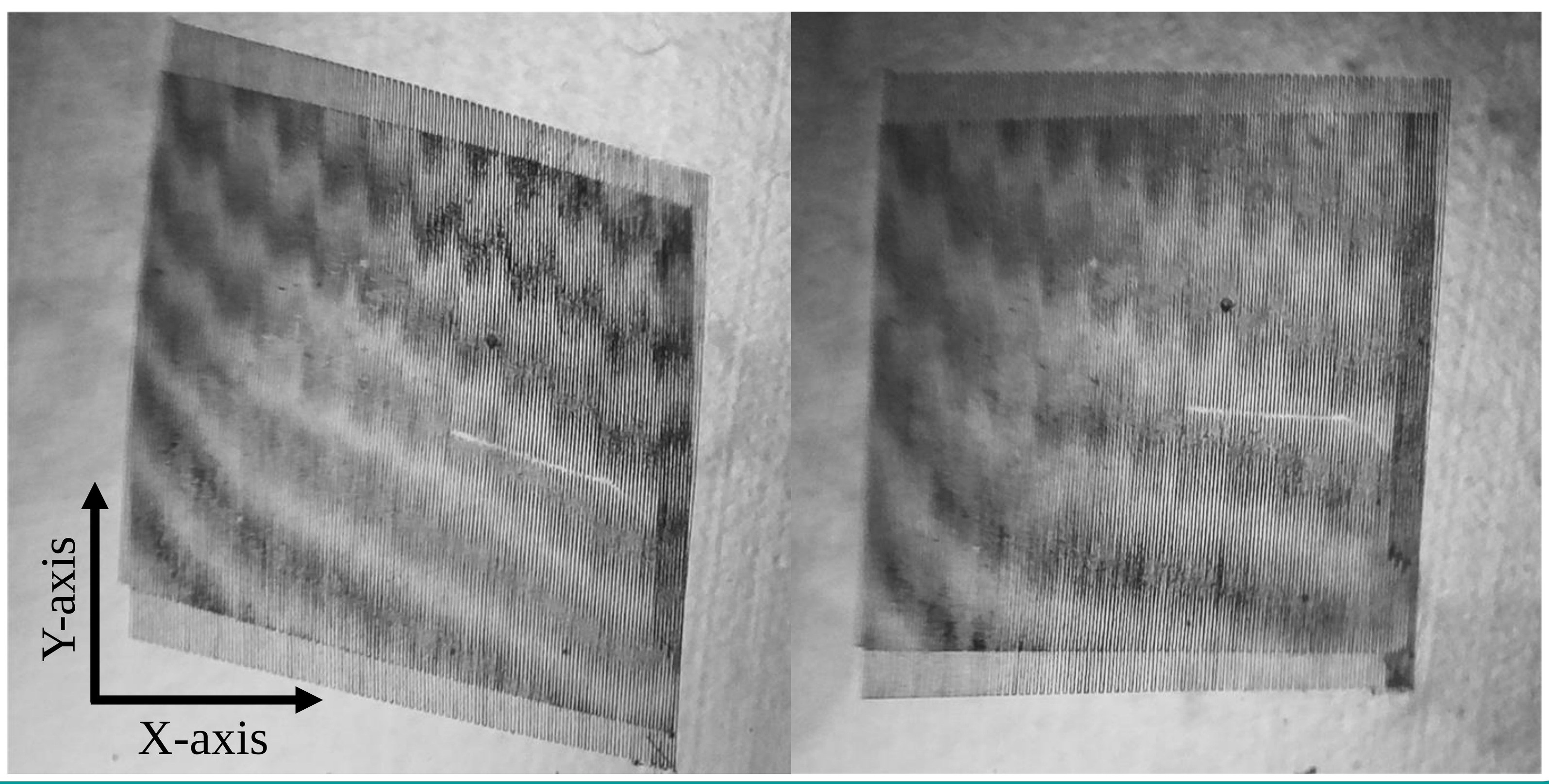


Set up



Results

- The thickness of the PDMS membrane prepared was ~ 100 µm.
- Two line gratings, whose planes are separated in depth by 40 µm, placed at an angle of 1.65° were imprinted on elastic PDMS membrane.
- The grating lines formed on PDMS were 3 mm in length. At the surface the width of the grating lines was 6 ± 0.8 µm and at 40 µm depth the width of the grating lines was 5.6 ± 0.3 µm.
- Visual change in Moiré Patterns in terms of intensity, shape and number of fringes was observed when PDMS membrane was under shear force induced by 1 mm displacement



Conclusions

- The proposed membranes can be used as strain sensors for health monitoring of various structures
- Strain sensitivity generated using the above-mentioned technique can be increased with optimized line width, line spacing and angle between the structures.

Acknowledgement

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