Polarization-Sensitive Full Field Optical Coherence Tomography in Use for Structural, Birefringence and Stress-Strain Imaging

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Abstract. We will discuss polarization-sensitive full field optical coherence tomography as an imaging technique applicable in the field of material testing and stress-strain imaging. It provides interesting abilities and features for investigation of semi-transparent materials with respect to their internal birefringence properties.

Introduction

Polarization–sensitive full field optical coherence tomography (PS-FF-OCT) represents an imaging technique, which shows potential for photo-elastographic measurements as well, both in biological and material sciences fields, [1].

Similar to classical photo-elasticity (PE) measurement techniques birefringent properties of specimens can be visualized, which may be induced by internal stress-strain fields of the sample under load or also can be inherent.

Similar to full field imaging techniques the imaging can be performed as *en-face* area imaging with recordings taken perpendicularly to the optical axis of the system, [2].

And similar to optical coherence tomography, the measurement can be performed in a depth–resolved way, using low-coherence interferometric technique therefore, [3].

Method and Results

Tuning the interference region within the sample by scanning the mirror over depth (or the light source over wavelength) the structural and functional knowledge about interfaces or internal structures can be obtained, as long as (strong) scattering and depolarization effects can be neglected.

For birefringent sample these insights can be gained in a three-fold way, as reflectivity, retardation and optical axis information. Therefore, the magnitude, ratio and phase difference of both signal amplitudes are considered in a two-channel detection scheme, with respect to both orthogonal polarization directions, [4]. So, a qualitative characterization of local birefringence is possible and performed in an accumulated way, as long as retardation and axis orientation are not altering simultaneously. By means of the stress-optical coefficient these quantities can be related to the in-plane stress fields, in case of photo-elastic materials. By exploiting in particular birefringence material properties, PS-(FF)-OCT techniques are slightly distinguished from elastographic OCT methods, which exploit rather correlative features on deformation and conventionally are used for stress-strain characterization within materials [5].

Nowadays, broad band light sources, as super-continuum light sources offer more and more the possibility to extend the spectral range for probing, also from the near towards the mid infrared region [6]. In particular for technical samples, showing usually a low water content, a higher penetration is allowed in these spectral regions. So, novel application scenes come into the realm of possibilities and visions. Investigating diverse polymer and compound components, so beyond structural insights, also information with respect to their birefringence behaviour, which might partly result from the manufacturing process can be called as an example [7]. But also the development of the scanning or full field version of PS-OCT towards investigating materials and components, like silicon wafers, for a characterization of their structural defects or getting insights about stress distributions might be a possibility for future.

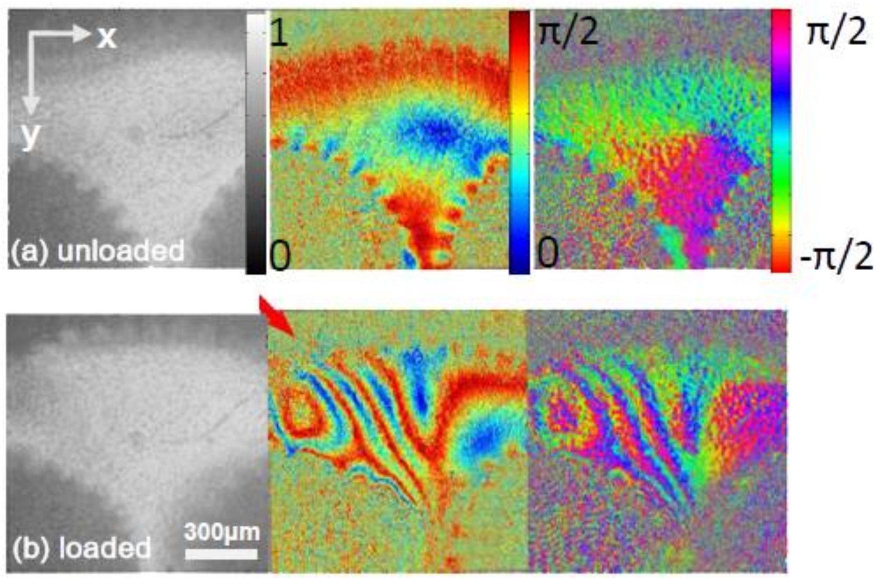

Fig. 1 PS-FF-OCT imaging: *en-face* reflectivity (left), retardation (middle) and axis orientation (right) excerpts, exemplified for a polymer test sample, subjected alternatingly to a (a) load and (b) unloaded state.

Conclusion

We have illustrated how PS-FF-OCT can be applied for monitoring dynamic loading scenes in semi-transparent specimens and performs the imaging in a depth-resolved way. Beyond polymer testing also investigation of novel technical and bio-materials are envisaged.

References

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