A New Generation of Light Scattering Device with Real Time Data Analysis for Rheo-optical Measurements

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Abstract:
An apparatus for small angle light scattering (SALS) and light transmission measurements under shear was built and tested at the University of Massachusetts Amherst. As a new development, the polarization direction can be rotated by a liquid crystal polarization rotator (LCPR) with a short response time of about 20 ms. The experiments were controlled and analyzed with a LabVIEW™ based code (LabVIEW™ 7.1) in real time. Quiescent and flow-induced crystallization experiments on isotactic poly-1-butene (iPB) were conducted to demonstrate the instrument and software capabilities. Software was designed with a modular approach, so that further modules can be added to investigate other systems such as polymer blends, colloidal suspensions, solutions with droplets etc. A replica of the SALS apparatus was custom built for ExxonMobil Research in Clinton NJ.

Zusammenfassung:
Eine Apparatur für Kleinwinkellichtstreuung (SALS) und Lichttransmissionsmessungen in Scherung wurde an der University of Massachusetts Amherst entwickelt und getestet. Eine neue Entwicklung stellt die Drehung der Polarisationsrichtung durch einen flüssigkristallinen Polarisationsrotator (LCPR) mit einer kurzen Antwortzeit von 20 ms dar. Die Experimente wurden mit Hilfe einer LabView™-Steuerung kontrolliert und in Echtzeit analysiert (LabView™ 7.1). Kristallisationsexperimente ohne und in Strömung wurden an isotaktischem Poly-1-Buten (iPB) durchgeführt, um die Möglichkeiten der Apparatur und der Software darzulegen. Die Softwaresteuerung ist modular aufgebaut, so dass weitere Module hinzugefügt werden können, um andere Systeme (z. B. Polymerblends, kolloidale Suspensionen, Lösungen mit Tröpfchen etc.) zu untersuchen. Die SALS-Apparatur wurde für ExxonMobil Research in Clinton (NJ) konstruiert.

Résumé:
Un appareil pour des mesures de diffusion de la lumière aux petits angles (SALS) et de transmission de la lumière sous écoulement a été construit et testé à l'université de Massachusetts Amherst. En termes de nouveau développement, la direction de la polarisation peut être tournée grâce à un modulateur de polarisation cristal liquide (LCPR) qui possède un temps de réponse court de 20 ms. Les expériences ont été contrôlées et analisées avec un code LabVIEW™ (LabVIEW™ 7.1) en temps reel. Des expériences de cristallisation au repos et induites par l'écoulement ont été menées avec un poly-1-butène isotactique (iPB) afin de démontrer les possibilités de l'instrument et du programme informatique. Le programme a été conçu avec une approche modulaire, de telle sorte que de futures modules peuvent être additionnés afin d'étudier d'autres systèmes comme les mélanges de polymères, les suspensions colloïdales, les solutions contenant des gouttelettes, etc. L'appareil de SALS a été spécialement construit pour ExxonMobil Research à Clinton NJ

Key words: rheology, light scattering, transmission intensity measurements, liquid crystal polarization rotator

1 INTRODUCTION

Small angle light scattering (SALS) is gaining ample popularity in material industries as a preferred technique to perform real time structural analysis especially as a combinatorial tool with rheometry [1–5]. The fast data acquisition, easy handling, robustness and the ease of integrating with variety of other techniques such as X-ray, optical microscopy (OM) and differential scanning calorimetry (DSC) make SALS an attractive sensor [6, 7] even for incorporating with industrial film extruders and injection molding machines. Here we present a house-built device that can perform light scattering and transmission intensity measurements simultaneously while analyzing the data in real time. The device grew out of an earlier apparatus at the University of Massachusetts Amherst [8, 9] and incorporated a liquid crystal based device to control the polarization direction of a linearly polarized laser beam. Crystal -

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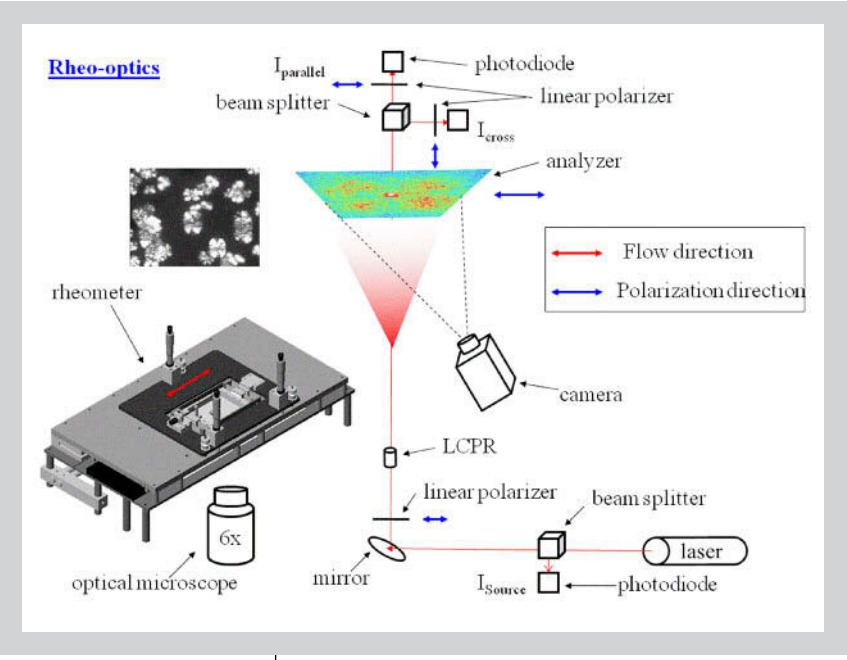

Figure 9:
An inverted SALS set-up combined with a rheometer and an optical microscope to follow the evolution of mechanical and optical properties simultaneously along with the morphology from scattering and optical microscopy images.

6 CONCLUSIONS

The device at UMass Amherst was developed to investigate the crystallization of thermoplastic semicrystalline polymers though it can readily be extended to polymer blends, concentrated suspensions, micellar solutions, crude oil and to variety of other materials [1, 25–28]. A LabVIEW™ based platform provides flexibility to add new modules to the existing code. The house-built small angle light scattering apparatus is able to perform following in real time:

- Transmission intensity measurements under cross and parallel polars
- Record scattering images under cross and parallel polars and their real time analysis to obtain light scattering invariants
- Source intensity measurements
- Controlling polarization direction using a liquid crystal based device for fast response time

As a novel addition a liquid crystal based device is incorporated as a superior substitute of quarter wave plate to control the polarization direction of a linearly polarized laser. The LCPR unit not only provides faster rotation of light but also is less bulky than the traditional quarter wave plate set-up which requires a motor to rotate the plate. The set-up is being combined with a rheometer and an optical microscope.

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