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Diagnosis of injection-molded weld line in thermoplastic polymer by terahertz reflective imaging and scanning acoustic microscopy

Min Zhai,^{1,2} Esam T. Ahmed Mohamed,^{1,3} Alexandre Locquet,^{1,2} G. Schneider,⁴ R. Kalmar,⁴ M. Fendler,⁴ N. F. Declercq,^{1,3} and D.S. Citrin^{1,2}

¹Georgia Tech-CNRS IRL2958, Georgia Tech Lorraine, 2 Rue Marconi, 57070 Metz, France

²School of Electrical and Computer Engineering, Georgia Institute of Technology, Atlanta, Georgia, 30332-0250 USA

³School of Mechanical Engineering, Georgia Institute of Technology, Atlanta, Georgia, 30332 USA

⁴CEA Tech, 5 Rue Marconi, Bâtiment Austrasie, 57070 Metz, France

Abstract—Terahertz (THz) reflective imaging and scanning acoustic microscopy (SAM) were utilized to material characterization as well as quality control of the injection-molded thermoplastic electrical receptacle plate. V-notched weld lines that degrade the mechanical strength of injection-molded products significantly, are observed in both SAM and THz results. Micro-elastic heterogeneity resolved in acoustic micrograph validates the location-dependent birefringence observed in THz results.

I. INTRODUCTION

Weld lines in injection molding are introduced when two melt streams meet, degrading the mechanical properties at the weld. To date, the most common approach used to identify the location of weld lines is destructive mechanical testing. Owing to the nature of THz waves, it presents the potential of monitoring the quality of injection-molded thermoplastic products and characterizing the weld-line in a nondestructive and contactless manner.

II. RESULTS

Fig. 1. (a). THz C-scans based on the peak reflected signal arrival time as the contrast mechanism. (b). SAM micrographs operating at center frequency $f=420$ MHz.

The surface morphology of the injection-molded plastic samples was characterized using THz reflective imaging and SAM, shown in Fig. 1. V-shaped weld lines are observed in THz results. The width as well as depth of V-shaped notches were estimated, based on the arrival time of the echo reflected from the surface, to be $\sim 400 \mu\text{m}$ and $\sim 10 \mu\text{m}$, respectively. These values are close to SAM results.

Spatially dependent THz birefringence Δn is observed in Fig. 2. We find that enhanced THz birefringence is localized around the weld line at 6 mm gradually decreasing on the length scale of 2 mm with distance from the weld. Moreover, a large discrepancy in the Rayleigh surface acoustic waves (V_R) found in SAM results, demonstrates the

Fig. 2. Birefringence Δn along section perpendicular to weld line.

variation in the micro-elastic properties between areas close to and distant from the weld lines. The spatial variation in birefringence and V_R indicates an anisotropic propagation of polarized THz and ultrasonic waves. Anisotropy at the weld might relate to the frozen-in molecular orientation and internal stress, which are more isotropic away from the weld. The locations of these features are consistent with injection conditions and mechanical failure under stress.

III. SUMMARY

In this work, THz reflective imaging and SAM are carried out to characterize the injection-mold weld lines in an acrylonitrile butadiene styrene (ABS) electrical receptacle plate. V-shaped notches are found in the surface morphology by THz imaging and SAM. An enhanced THz birefringence close to the weld lines indicates the anisotropy state due to the fountain flow, and the birefringence drops as locations move away from the weld lines with the material exhibiting more THz isotropy. THz results are also supported by SAM measurements and mechanical failure tests, demonstrating that THz techniques in conjunction with SAM, is capable of providing information for nondestructive reliability assessment and a characterization of local mechanical properties for injection-molded thermoplastic components.

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