ICNDT 2026 Conference
The 1st International Online Conference on Non-Destructive Testing
1–3 July 2026 | Online
MDPI

Birefringent properties of 3D printed and other polymers

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Introduction & Aim

- Birefringence describes the optical properties of optically anisotropic or chiral materials
- Linear birefringence, in which the optical properties do not depend on light intensity, is an easily measurable indicator of anisotropy in the structure of a glass or a polymer; thus, stresses induced in glasses or polymers can be detected using stress birefringence
- This effect can also be found in 3D printed materials, such as fused deposition modeling (FDM) printed models of different layer orientation and thickness [1] or stereolithography (SLA) printed objects containing liquid crystals or nanofibers [2,3].

→ Here we report birefringence measurements on 3D printed translucent objects after different curing / thermal post-treatments [4], performed using a microscope with crossed polarizers as well as large-scale crossed polarizers.

Materials and methods

Transparent 3D printed materials:

- HD-glass (Filamentworld, Neu-Ulm, Germany)
- HT-PLA (Filamentworld)
- Clear Basic 3D printing UV sensitive resin (Anycubic)

3D printing:

- FDM printer I3 MK3 (Prusa Research AS Prague, Czech); nozzle diameter 0.4 mm, layer height 0.15 mm, three perimeters, linear filling pattern, infill 100%
- SLA printer Anycubic Photon Mono X SLA printer (Anycubic, Shenzhen, China), layer height 50 µm, 8 bottom layers, exposure time 8 s, bottom exposure time 60 s, light-off delay 1 s, lift after print 8 mm, lifting speed 1 mm/s, lowering speed 3 mm/s, infill 100%
- Sample dimensions 4 mm × 10 mm × 100 mm (according to DIN EN ISO 178)

Thermal treatment:

- Climate chamber CTC256 (Memmert, Schwabach, Germany)
- Thermal cycling between -15 °C and + 85 °C (2 cycles, ~ 21 h/cycle) and between -15 °C and + 185 °C (4 cycles, ~ 38 h/cycle)

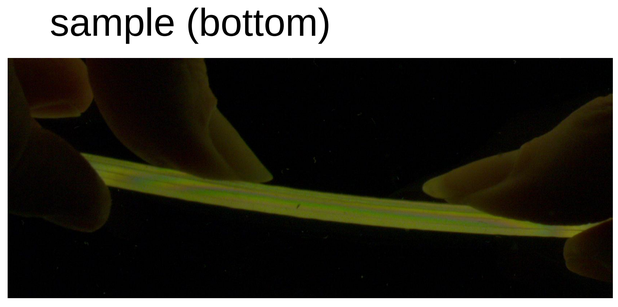
Characterization:

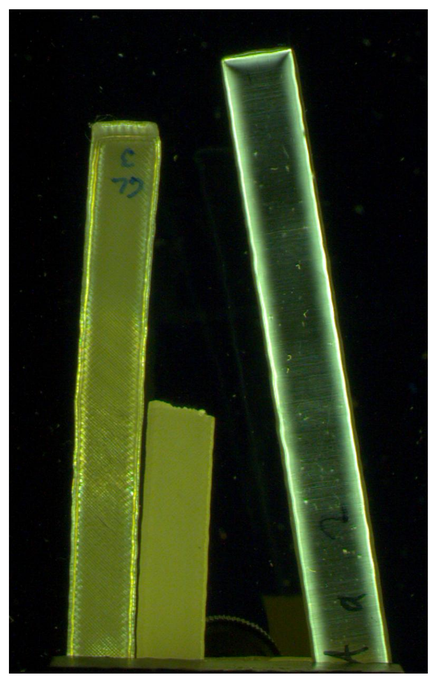
- Microscopic investigation: inverse microscope Axio Observer 7 (Carl Zeiss, Göttingen, Germany) using transmitted light with crossed polarizers, objective 1.25x
- Macroscopic investigation: samples between crossed polarizer sheets (Astromedia, Waltrop, Germany), illumination by a flat light FL-4x8 with 32 W diffused along an area of 200 mm x 308 mm (Georg Ronge Lichtquellen), camera Basler ace - acA2500-14uc with an objective Basler Lens C125-1218-5M f12mm

Results

Macroscopic investigation

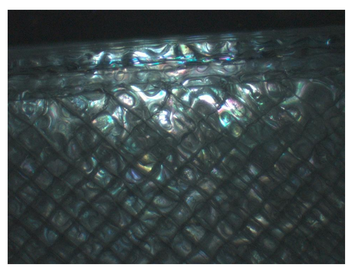
- Birefringence (white transmitted light) in as-printed HD-glass (left) and HT-PLA (middle)
- Birefringence mostly visible along the edges of SLA printed samples (right)
- Color visible in bent HD-glass sample (bottom)

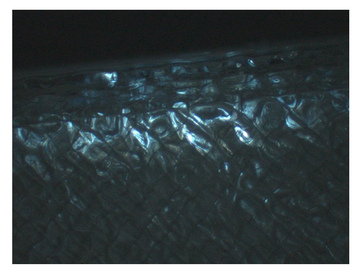




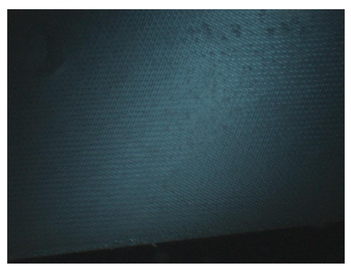
Microscopic characterization

White or colored (wavelength-dependent) transmission, depending on material and temperature treatment:


HD-glass as-printed


after 85 °C


after 185 °C (molten)


Clear resin as-printed


after 85 °C


after 185 °C

→ FDM printing shows partly colored birefringence and a significant color change after melting
→ SLA printing reveals UV diode matrix pattern and color change thermal treatment at high temperatures

Conclusion and Outlook

- Stress birefringence mainly visible in transparent FDM printed samples and along the edges of SLA samples
- Significant changes after heat treatment (185 °C)
- More microscopic birefringence images of these and other 3D printed materials after treatment at different temperatures will be shown in the conference proceedings

References

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