

### Thermal Diffusivity of 3D-Printed PLA Filaments: Influence of the Print Orientation

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#### Introduction

Additive manufacturing – particularly fused deposition modeling (FDM) – has become a widely used technique for the fast and flexible production of polymer-based components. In addition to mechanical properties, the thermal behavior of printed parts is becoming increasingly important. Especially for functional components, thermally stressed housings, application-oriented prototypes or components exposed to local heat generation, knowledge of the thermal diffusivity is essential for evaluating the material behavior under real operating conditions.

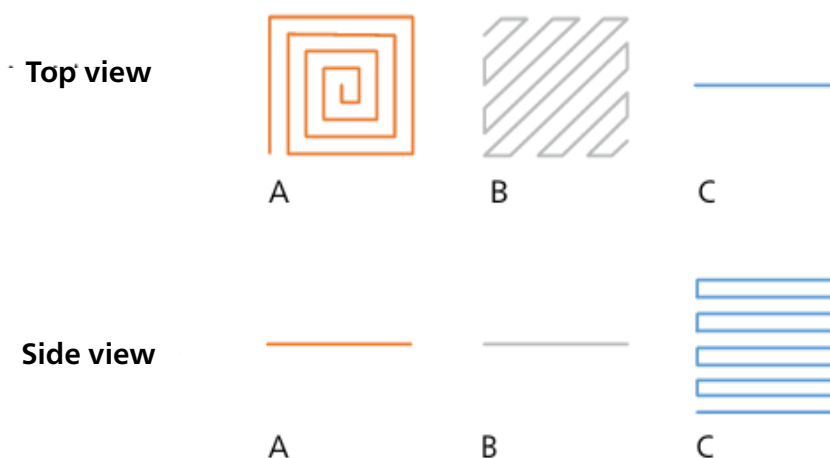
Poly lactides (PLA) are among the most commonly used materials in FDM 3D printing. Due to the layer-by-layer deposition of this material, however, direction-dependent thermophysical properties may occur within the print structure. The orientation of the filaments,

the cooling conditions and the fusion between adjacent strands influence how quickly heat is transported through the printed component.

#### Measurement Task

In this study, the thermal diffusivity of PLA samples printed as shown above was analyzed. The samples were manufactured at the same printing speed but in different orientations. The aim was to investigate the influence of print orientation and the resulting filament arrangement on heat propagation within the material.

The samples were printed at a speed of 60 mm/s. Two variants represent individual filament layers deposited flat directly onto the print bed – one with a linear and one with a spiral filament path. A third sample was built perpendicular to the print bed and exhibits vertical filament fusion.



- 1 PLA printed in three different orientations: A) flat on the print bed, spiral filament path; B) flat on the print bed, linear filament path; C) perpendicular to the print bed with vertical filament fusion.

## Method and Measurement Conditions

The thermal diffusivity was determined by means of Light Flash Analysis (LFA) using the NETZSCH LFA 717 *HyperFlash*®. In the flash method, the front side of a plane-parallel sample is heated by a short energy pulse. The resulting temperature rise on the rear side of the sample is recorded contact-free by an infrared detector. The thermal diffusivity of the PLA sample is calculated from the time-dependent signal curve.

The Standard Model\* was employed for the evaluation. The essential measurement conditions are summarized in Table 1.

\*The Standard Model considers the two dimensional (z-axis and radial) heat loss similar to the former Cape-Lehman [1] model.

**Tabelle 1** Measurement conditions

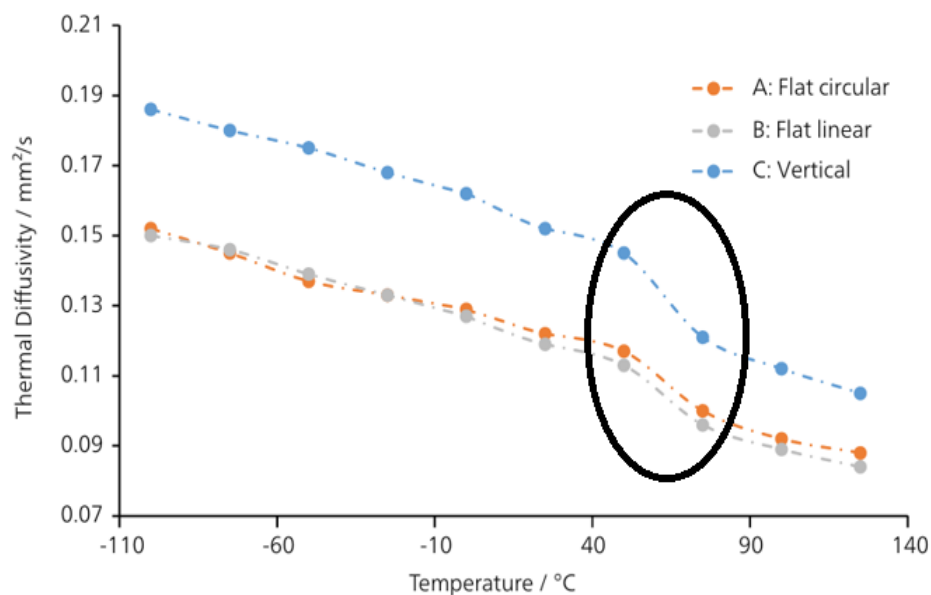
| Parameter         | Setting                     |
|-------------------|-----------------------------|
| Sample            | Poly lactide (PLA)          |
| Instrument        | LFA 717 <i>HyperFlash</i> ® |
| Detector          | MCT                         |
| Sample holder     | 4 samples, square           |
| Heating rate      | 10 K/min                    |
| Temperature range | -100°C to 125°C             |
| Sample dimensions | 10 mm x 10 mm x 09 mm       |

## Measurement Results

The direct comparison of the thermal diffusivity curves of the three PLA samples shows a clear influence of the print orientation. The samples printed horizontally on the unheated print bed with linear or spiral filament paths exhibit comparable thermal diffusivities. The vertically printed sample with vertical filament fusion, however, shows higher values over the temperature range investigated.

This higher thermal diffusivity indicates more efficient heat propagation along the vertically connected filament structure. One possible reason is a higher degree of intra- or interfilament fusion, promoted by the vertical layering and heat transfer to already extruded, cooling PLA.

In all data sets, a distinct jump in thermal diffusivity is observed at around 60°C. This effect is characteristic of the glass transition of PLA. The transition marks the change from a glassy to an increasingly rubber-like material state and correspondingly affects the molecular mobility of the polymer and thus its heat transport properties.



**2** Thermal diffusivity of PLA filaments printed horizontally on an unheated print bed and vertically onto freshly extruded and cooled PLA.

### Summary

The measurement results show that the print orientation has a significant influence on the thermal diffusivity of FDM-printed PLA. In particular, the vertically built sample with vertical filament fusion exhibits higher thermal diffusivity than the horizontally printed variants.

Light Flash Analysis with the LFA 717 *HyperFlash*® enables reliable characterization of such orientation-dependent thermophysical properties. This makes it possible to quantify process-related differences in the thermal behavior of additively manufactured materials and use the results to optimize printing parameters, component geometries and manufacturing strategies.

### References

[1] Cape, Lehman (1963): "Temperature and finite pulse time effects in the flash method for measuring thermal diffusivity," J. Appl. Phys., 34(7), 1909–1913.