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# *Polyolefins warpage in material extrusion additive manufacturing*

***A.Zerriouh,*** *S.Liparoti, M.L.DI Lorenzo , D.Cavallo*

*University of Genoa, Department of Chemistry and Industrial Chemistry*
*alii.zerriouh@gmail.com*

## Introduction

Material Extrusion Additive Manufacturing (MEAM) is gaining importance due to its ability to produce complex, customized parts while reducing costs, waste and production time. However, this technique faces technical limitations, notably warpage, caused by uneven layer shrinkage due to temperature variations during the deposition [1]. Infrared cameras has enabled a better understanding of thermal fluctuations like temperature peaks caused by neighboring layer deposition and crystallisation, showing how the printing condition affects temperature distribution and layer solidification [2]. This study investigates the effect of crystallisation rate on the warpage of polypropylene homo- and copolymers. In situ infra-red camera temperature measurement is used to gain insight into the actual temperature profile of the printed parts. The crystallization kinetics of the different polymers are taken into account by considering a parameter, defined as the distance between crystallization temperature and bed temperature, which shows a good correlation to the measured warpage.

## Materials & method

Table 1: Material properties of used polymers

| Sample Code | Type | Ethylene content (wt%) | Tm (°C) | Tc (°C) | Xc (%) |
|---|---|---|---|---|---|
| **PPH** | PP homopolymer | 0 | 166 | 116 | 51 |
| **PPC 2.1** | Random P/E copolymer | 2.1 | 149 | 103 | 37 |
| **PPC 3.5** | Random P/E copolymer | 3.5 | 143 | 95 | 33 |

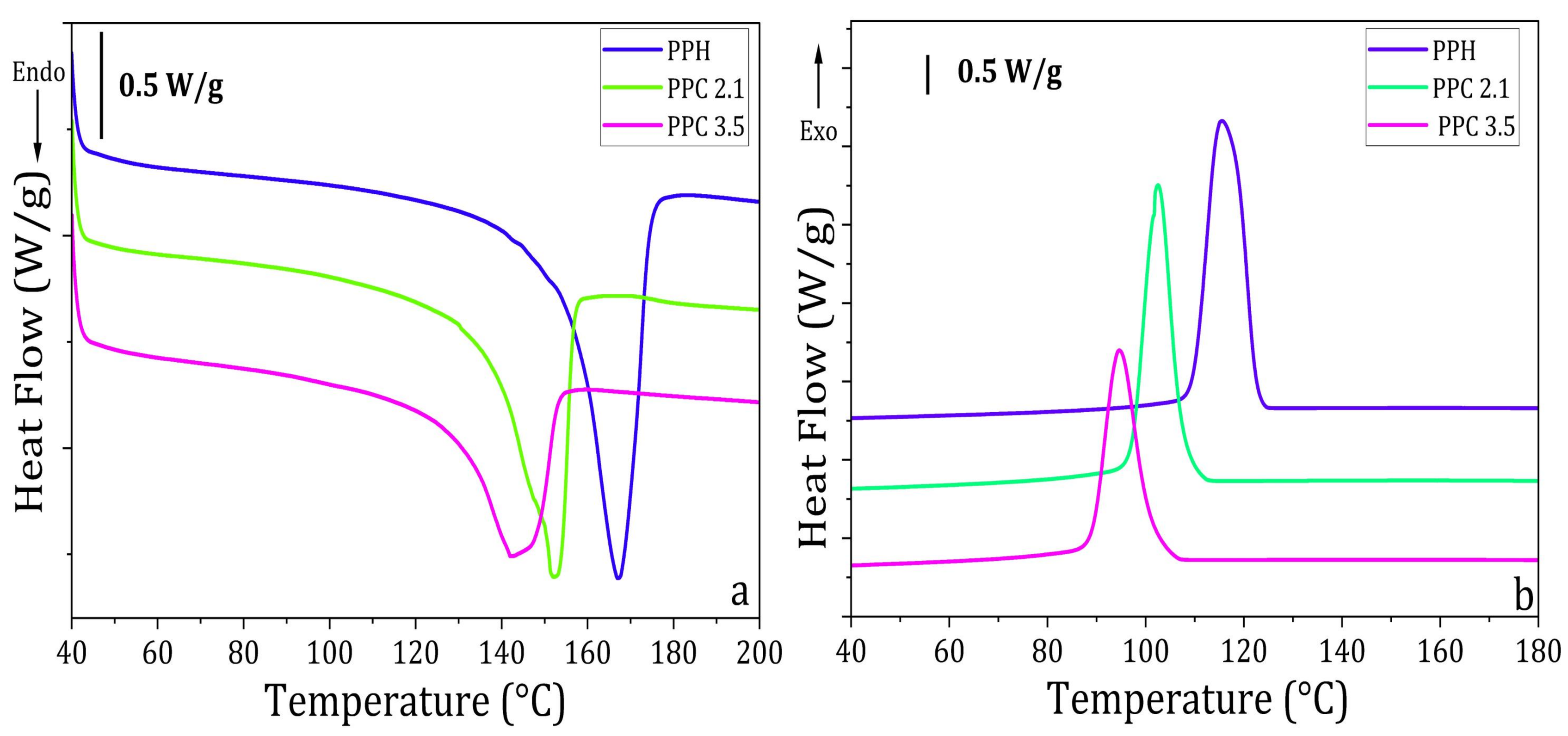


Figure 1: DSC a) heating- and b) cooling-curves for all printed materials

## Warpage Analysis

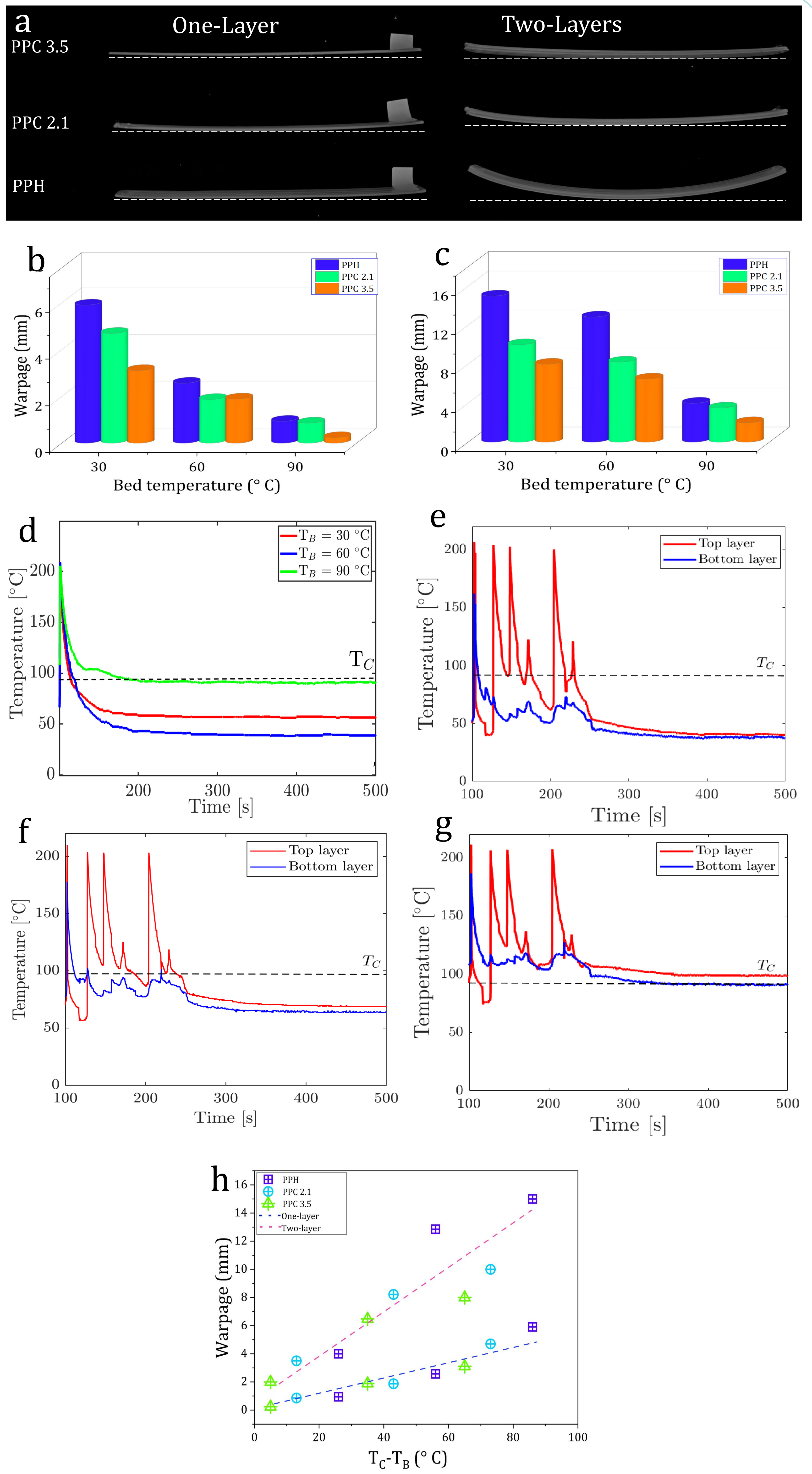


Figure 2: a) Front view of one-layer and two-layer printed samples at a $T_B$ of 60 °C for the indicated materials, Warpage for b) one- and c) two-layer at $T_B$ of 30, 60 and 90 °C, Temperature versus time profiles for d) one-layer PPC 3.5 printed at a $T_B$ of 30, 60 and 90 °C.; Points measured in bottom and top layer, in two-layers PPC3.5 sample printed at a e) $T_B$ of 30 ,f) a $T_B$ of 60°C and g) at $T_B$ of 90 °C., h) Warpage as a function of $T_C$ - $T_B$ for one- and two-layers prints

## Conclusion

- Higher ethylene content reduces crystallinity and significantly decreases warpage.
- Adding a second printed layer increases warpage due to non-uniform crystallization.
- Warpage correlates with the $T_C - T_B$ gap, highlighting the role of crystallization kinetics.

## References

[1] W. Ju, X. Gao, Y. Su, F. Luo, D. Wang, , J. Polym. Sci. 61 (2023) 2665–2676.
[2] A. Antony Samy, A. Golbang, E. Harkin-Jones, E. Archer, A. McIlhagger, CIRP J. Manuf. Sci. Technol. 33 (2021) 443–453.