

## Chemical-etching-based observation on spherulitic and interfacial morphologies of fiber reinforced thermoplastics

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Questions? Remarks?

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### Introduction

- Some compression-molded glass fiber reinforced polypropylene (GF/PP) unidirectional (UD) laminates were manufactured under different cooling rates, and the wedge peel tests on those samples showed a significant difference in the interlaminar bond strength.

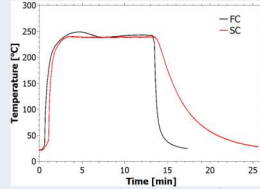
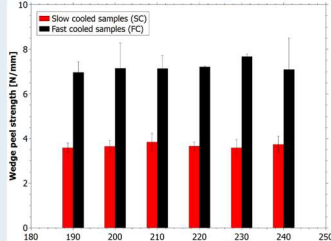


Fig. 2 The temperature profiles

Table 1 The transient cooling rates

|    | at 200 °C | at 166 °C | at 102 °C |
|----|-----------|-----------|-----------|
| SC | 51 K/min  | 42 K/min  | 23 K/min  |
| FC | 604 K/min | 484 K/min | 206 K/min |

Fig. 1 Wedge peel strength of UD GF/PP laminates manufactured under different cooling rates

- Related characterization indicated the effect of crystallization: lower crystallinity, smaller crystallite size, fine  $\alpha$ -PP, and the existence of  $\beta$ -PP...

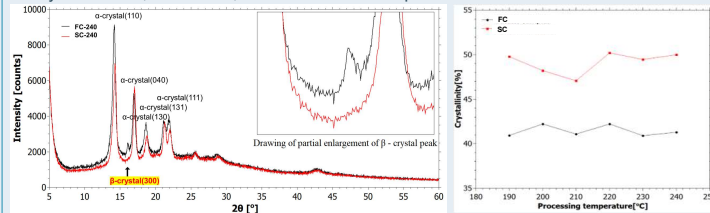


Fig. 3 The XRD profile (left) and the degree of crystallinity of the FC and SC samples

### Experiments and results

#### Chemical etching (CE)

- The permanganic acid solution preferentially etches the amorphous part of the PP in the spherulites, in such a way that the lamellae then clearly appear under SEM.

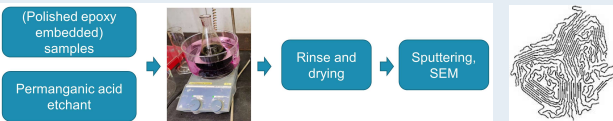


Fig. 4 The flowchart of CE and subsequent SEM observation (left) and schematic of semi-crystalline structure (right)

#### PP spherulitic morphology

- Central radial lamellae, sheaf-like structures, with two perpendicular lamellae branches
- Mostly immature spherulites, and FC samples have smaller spherulitic sizes.

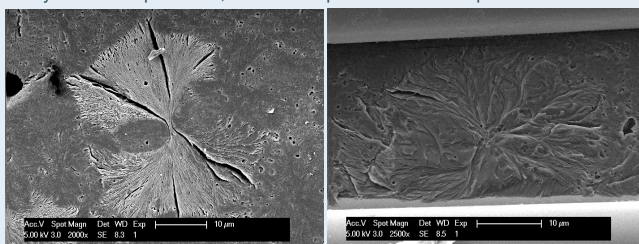


Fig. 5 Typical PP spherulitic morphologies

#### Fiber nucleation

- FC: Lamellae can grow along/spreading the GF surface (better F/M contact) as well as toward the matrix area due to relatively sufficient growing space;
- SC: Lamellae grow perpendicularly to the GF surface (limited contact at lamellae edges) due to suppression by their neighborhoods.

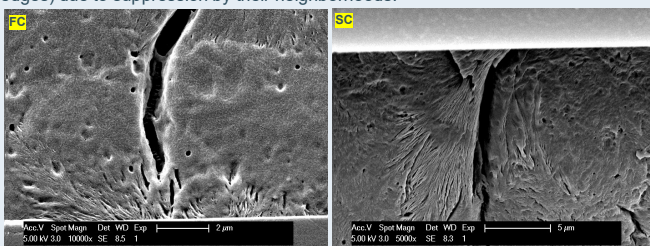


Fig. 6 Fiber-nucleation phenomenon in FC samples (left) and SC samples (right)

#### Fiber/matrix morphology

- Less nucleation and crystal growth time under FC;
- FC: Semi-spherulites on GF surface, with more amorphous PP and fewer spherulites;
- SC: (like-) transcrystalline structures on GF surface.

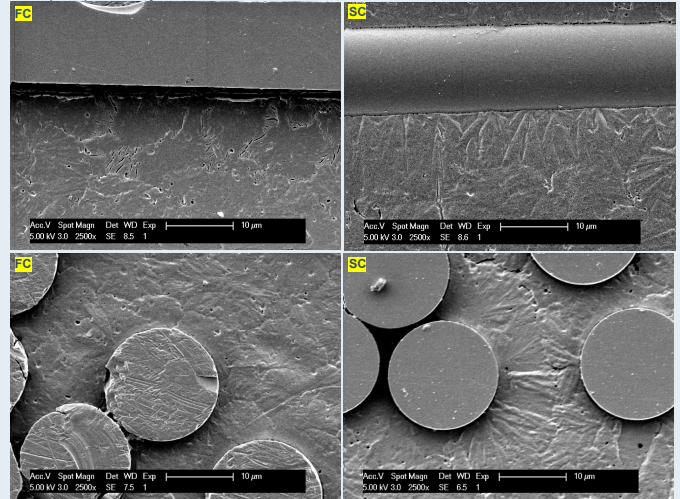


Fig. 7 Different fiber-matrix morphologies in FC samples (left) and SC samples (right)

- The delamination is dominated by (near GF surface) matrix failure, along grain boundary!

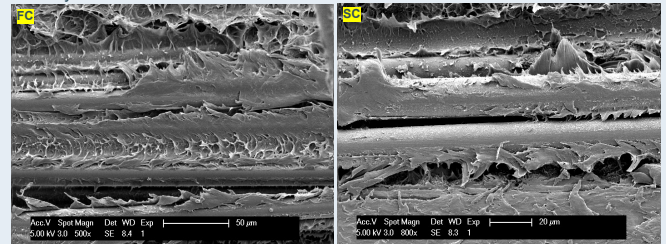


Fig. 8 (near GF surface) matrix failure in FC samples (left) and SC samples (right)

- FC: Interlocked grain boundary, with more amorphous PP in between spherulites, higher F/M adhesion.
- SC: Relatively flat and straight grain boundary parallel to GF surface (also to wedge peel direction), poor F/M adhesion.

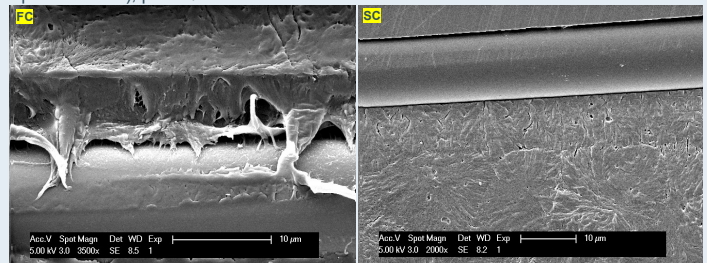


Fig. 9 Different grain boundaries in FC samples (left) and SC samples (right)

### Conclusion

- With CE, spherulitic and interfacial morphologies of GF/PP delaminated samples were directly revealed.
- Different cooling rate makes differences in fiber-matrix morphologies, resulting in different (near GF surface) interphases/structures and fracture propagation paths, and thus a different level of wedge peel strength, as well as bond strength.

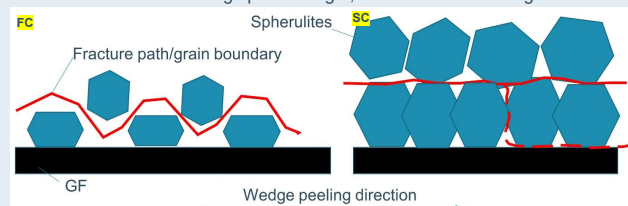


Fig. 10 Schematic of different fracture paths in FC samples (left) and SC samples (right)