Formation of micro-plumes at a planar solid/liquid interface in a temperature gradient

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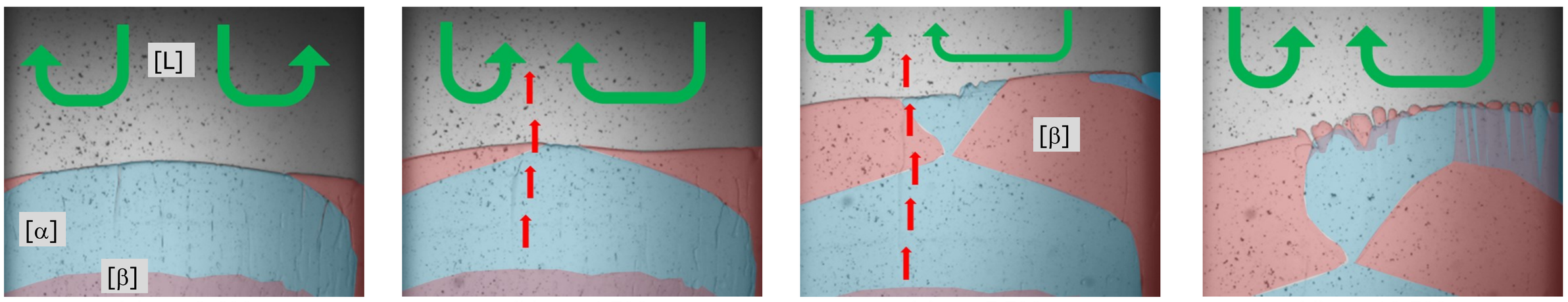
Investigations on peritectic layered structures [1] were carried out by using the Bridgman-technique and the organic model system TRIS-NPG. Such solidifcation pattern are not only highly influenced by the thermo-solutal convection ahead of the solid/liquid interface but also by the macroscopic mass transport within the solid matrix due to the temperature gradient zone melting [2]. These circumstances was observed during the alteration of the peritectic layered structure from bands to peritectic coupled growth (PCG).

Experimental set-up

In order to visualize the flow pattern hollow glass spheres seeding particles (11 ± 9 µm) were added to the organic substances (x = 0.52 NPG) [3]. Once the sample was put in place it was moved with a relativly high velocity of V = 15.7 µm·s^{-1} for 50 minutes for homogenization, then remainrd still for 60 minutes to obtain a planar solid/liquid interface before the solidification experiments for several hours was carried out (V = 0.174 µm·s^{-1}) .

Results and Discussion

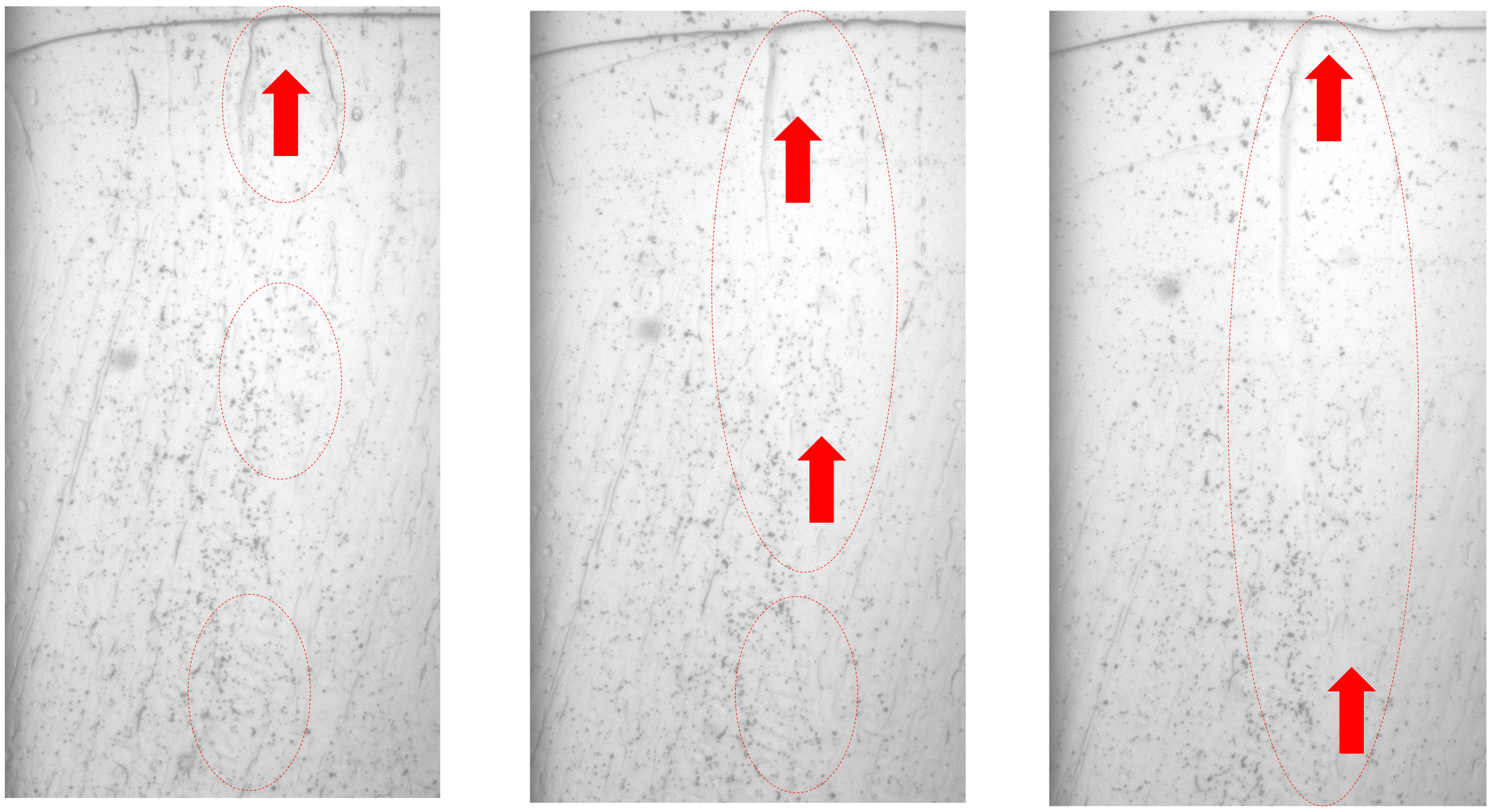
During the formation of bands, a strong upward flow in form of a micro-plume near the center of the sample was observed. It strength was sufficient to change the flow direction in the sample and hampered the lateral band growth on the left side, whereas, PCG was formed on the right side (Fig. 1).



(a) t = 3,600 s (b) t = 4,500 s (c) t = 7,500 s (d) t = 10,500 s

Figure 1: Formation of island bands which leads to peritectic coupled growth effected by a severe micro plume. The width of the picture is 2,000 µm.

Due to connection and migration of liquid films within the temperature gradient, a channel (Fig. 2) deep in the solid phase formed with a length of approx. 1,500 µm. Obviously, the liquid channel was fed from the mushy surrounding so that the high NPG-enriched liquid shot upwards towards the melt and influenced the flow pattern in the bulk and the formation of peritectic layered structures.



(a) t = 2,670 s (b) t = 3,870 s (c) t = 5,970 s

Figure 2: Formation of a long channel by connecting several liquid films (circles). Particle within the liquid channel are moving upwards (arrows) into the bulk melt. The width of the picture is 1000 µm.

Conclusion

The trapped liquid merged to one liquid channel connected to the s/l interface. Due to the density difference and feeding from the mushy surrounding , the enclosed liquid flowed upwards towards the bulk melt and formed a micro plume. This phenomenon change the convection pattern in the bulk melt and influenced the solidification pattern of peritectic layered structures.

References

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[2] Pfann W G 1955 ,*J. Minerals, Metals & Materials Society* ***7****(9)* 961–964
[3] Mogeritsch J P, Pfeifer T, Ludwig A 2018, *7th Int. Conf. on Solidification and Gravity*, Miskolc 319-324