

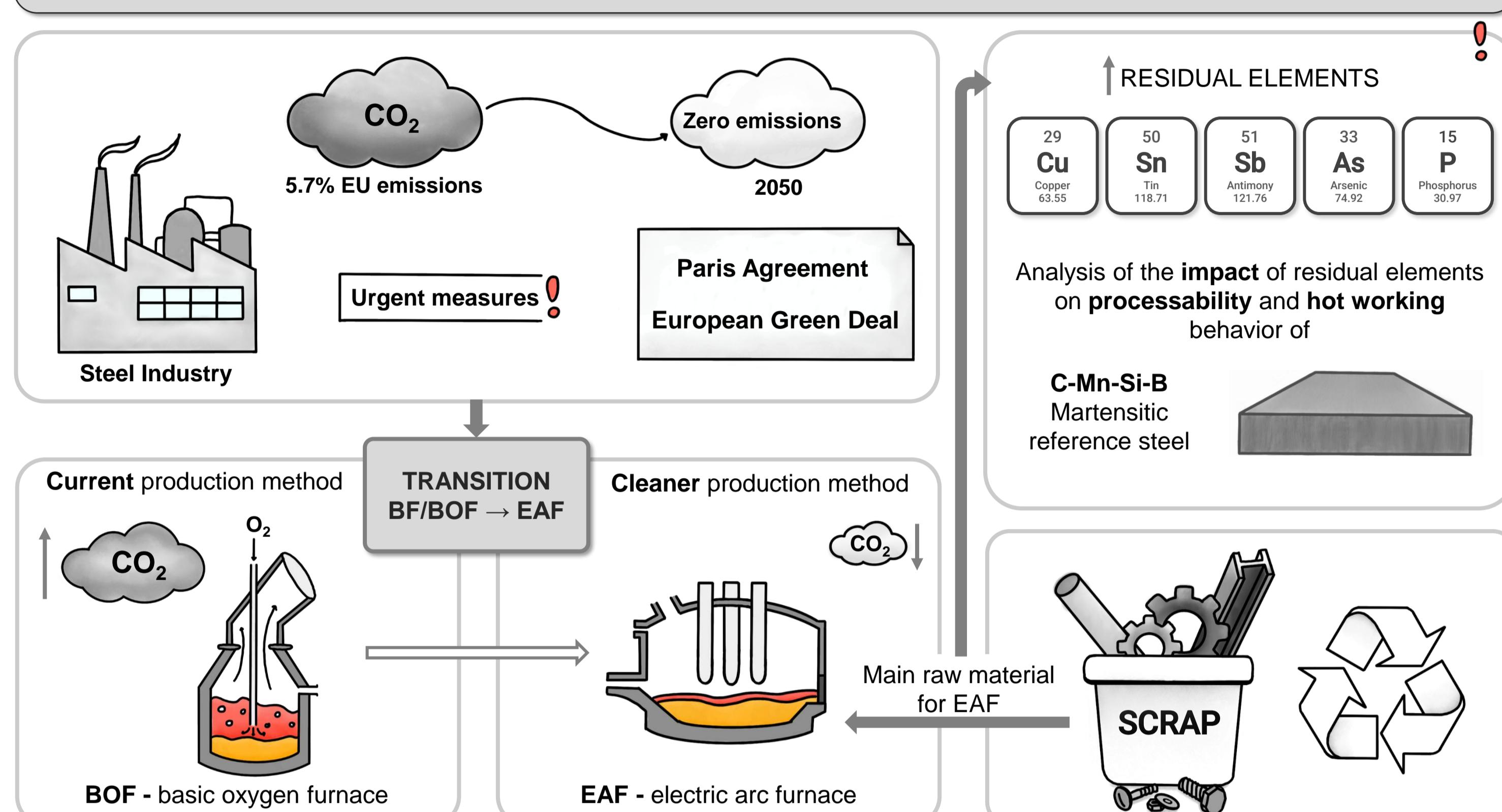
Toward sustainable steelmaking: impact of residual elements on processability and hot working behavior of martensitic steels

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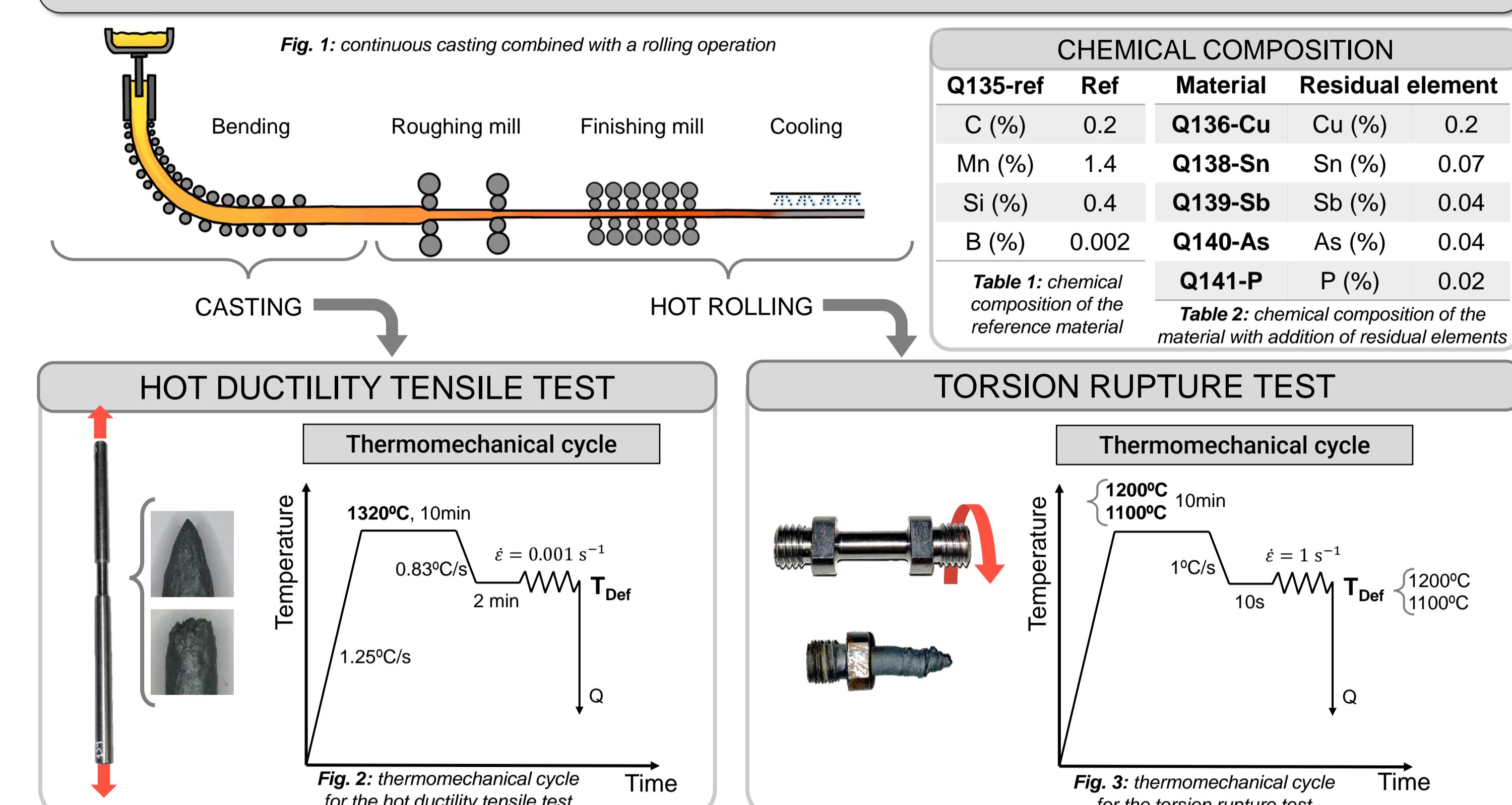
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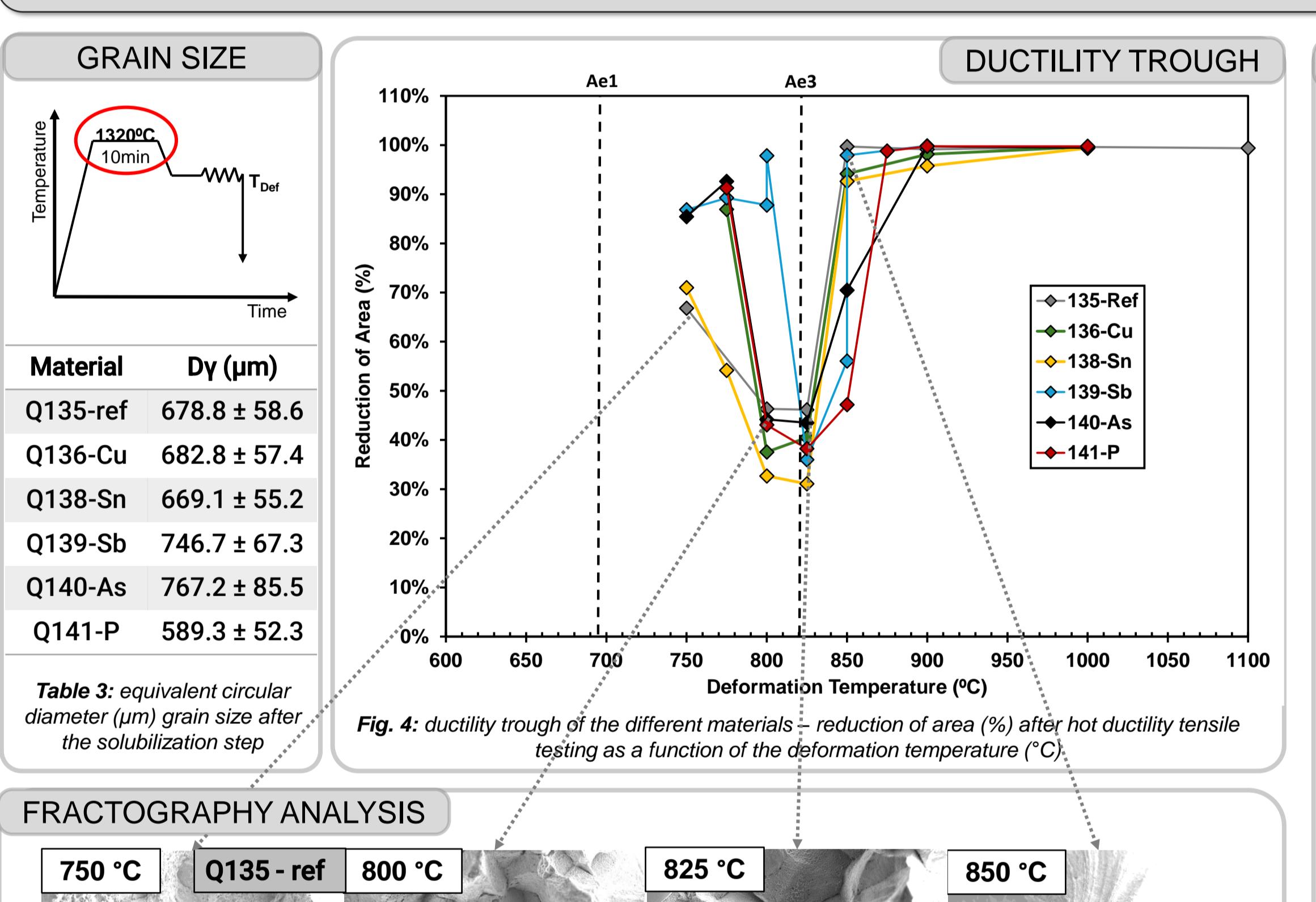
INTRODUCTION



MATERIALS AND PROCEDURE



HOT DUCTILITY: CASTING RELATED



HOT SHORTNESS AND DUCTILITY: HOT ROLLING RELATED

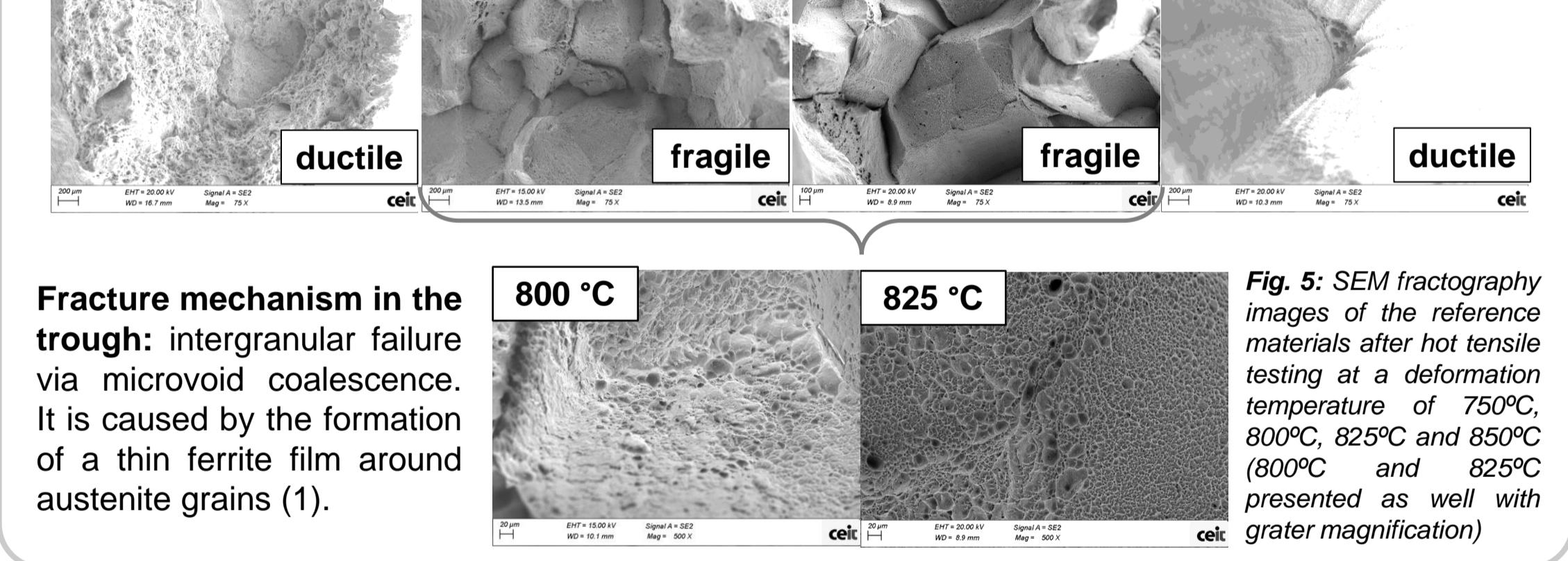
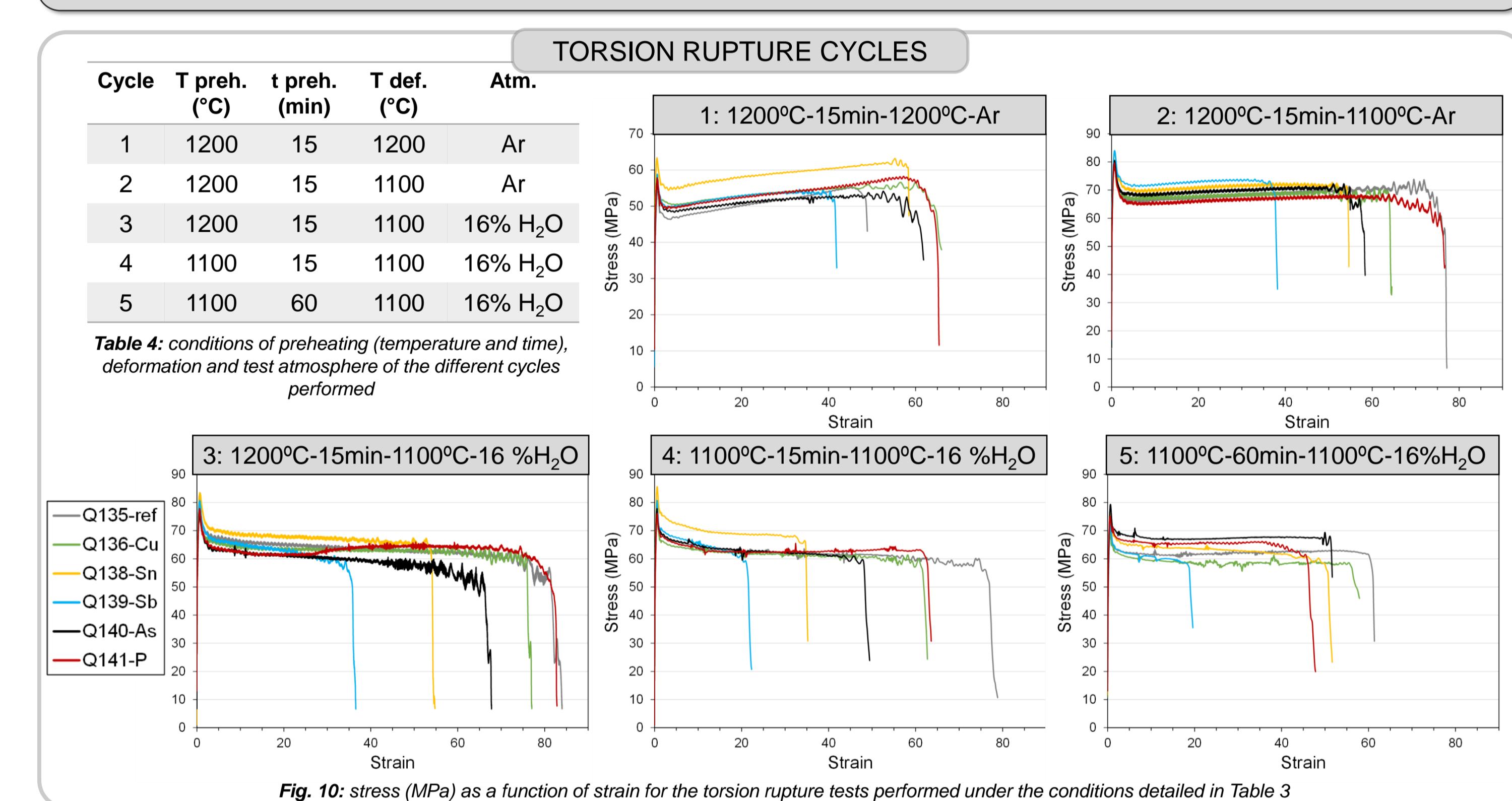
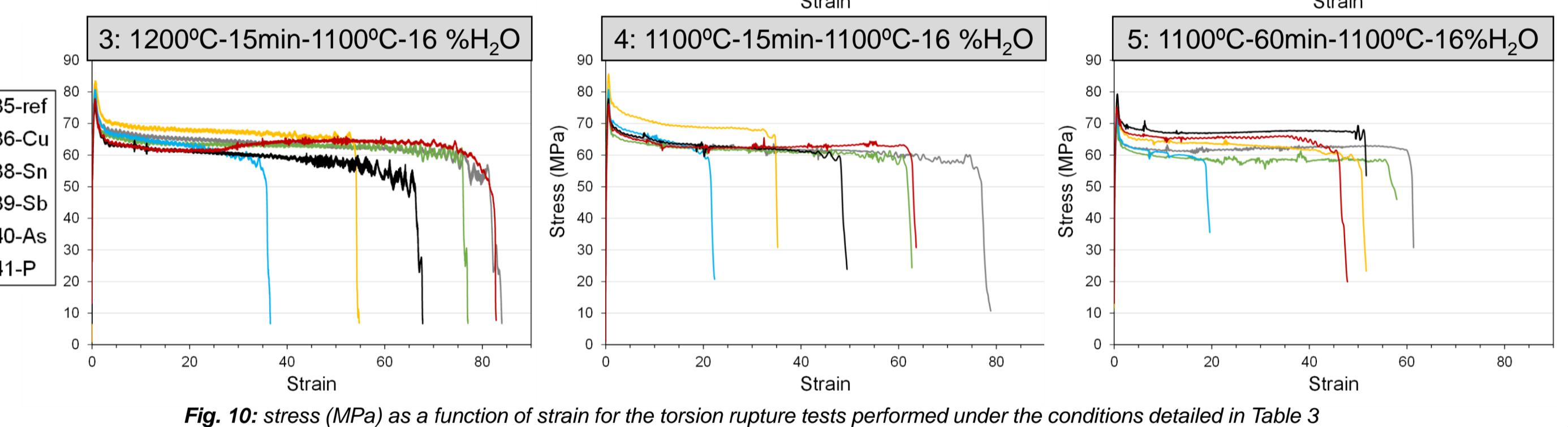


Table 3: equivalent circular diameter (μm) grain size after the solubilization step

Cycle	T preh. (°C)	t preh. (min)	T def. (°C)	Atm.
1	1200	15	1200	Ar
2	1200	15	1100	Ar
3	1200	15	1100	16% H ₂ O
4	1100	15	1100	16% H ₂ O
5	1100	60	1100	16% H ₂ O

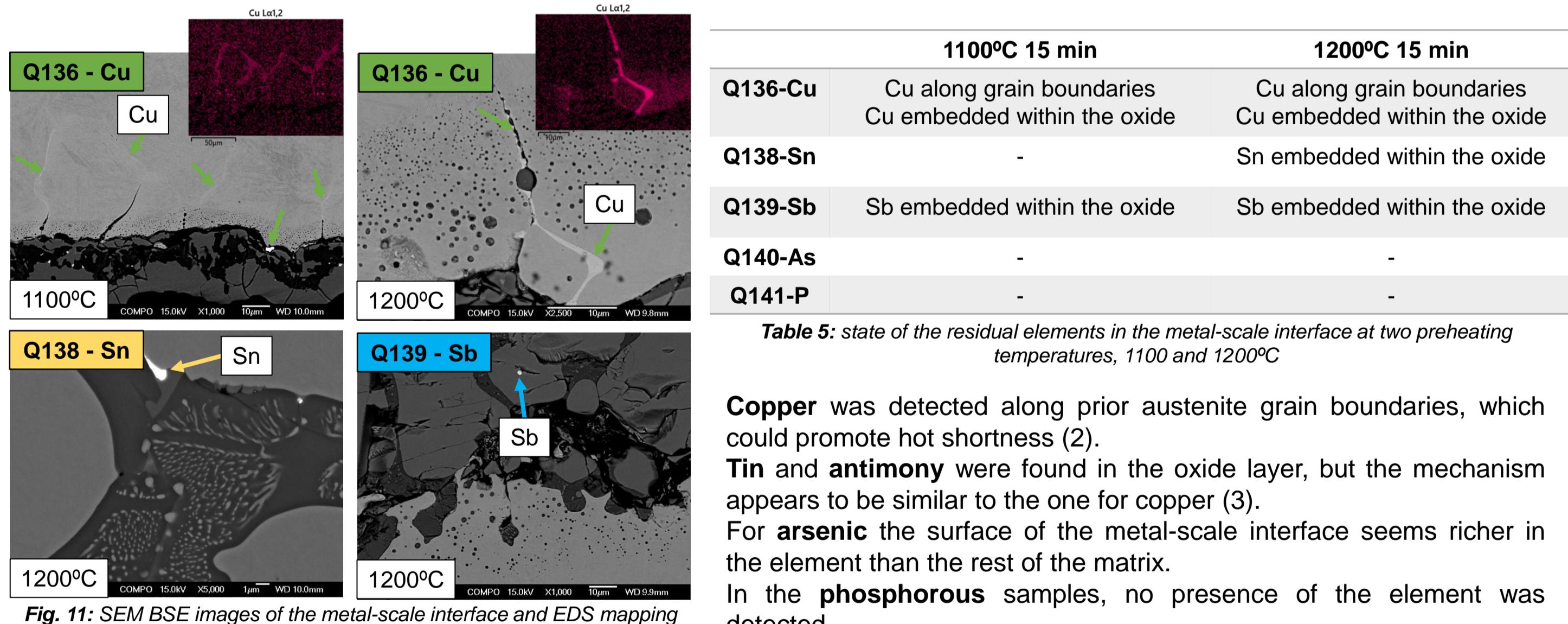
Table 4: conditions of preheating (temperature and time), deformation and test atmosphere of the different cycles performed



HOT SHORTNESS

Since no evidence of hot shortness was found in the mechanical curves, further analysis was conducted.

The state of the different residual elements after the preheating stage in an oxidizing atmosphere (16% H₂O) was studied.



	1100°C 15 min	1200°C 15 min
Q136-Cu	Cu along grain boundaries	Cu embedded within the oxide
Q138-Sn	-	Sn embedded within the oxide
Q139-Sb	Sb embedded within the oxide	Sb embedded within the oxide
Q140-As	-	-
Q141-P	-	-

Table 5: state of the residual elements in the metal-scale interface at two preheating temperatures, 1100 and 1200°C

Copper was detected along prior austenite grain boundaries, which could promote hot shortness (2). Tin and antimony were found in the oxide layer, but the mechanism appears to be similar to the one for copper (3). For arsenic the surface of the metal-scale interface seems richer in the element than the rest of the matrix. In the phosphorous samples, no presence of the element was detected.

CONCLUSIONS

HOT DUCTILITY RELATED CONCLUSIONS

- Existence for all the materials of a low temperature high ductility region, a high temperature high ductility region and a ductility trough between these ranges in which low ductility intergranular failure often occurs.
- Sb appears to improve ductility, as its trough is narrower, and As and P to worsen it, since their ductility drops at a higher temperature than the rest of materials. The reference steel, Cu and Sn samples show a very similar behavior.
- For all materials, the start of the ductility trough is related to the austenite to ferrite phase transformation.
- The intergranular failure in the ductility trough occurs by a microvoid coalescence mechanism caused by the presence of a thin film of ferrite around the prior austenite grains.
- A study of the inclusions present in the materials was carried out since the formation of intragranular ferrite seems to be related to inclusions. The presence of MnS, Al₂O₃ and BN predicted by the Thermocalc software was confirmed by EDS analysis.

TORSION RELATED CONCLUSIONS

Some general trends in the stress-strain curves obtained from torsion rupture testing are observed:

- Sb, Sn and As tend to reduce the ductility to some extent, although no signs of hot shortness or drastic ductility loss were detected under the tested conditions.
- The most critical conditions are at 1100°C and 15 min preheating stage and a deformation temperature of 1100°C under a 16% H₂O oxidizing atmosphere.

Further analysis was conducted under oxidizing conditions in order to observe the state of the different residual elements after the preheating stage:

- Cu was detected along prior austenite grain boundaries, which could promote hot shortness.
- The mechanism behavior of Sn and Sb appears to be similar to the Cu mechanism: the elements are liquid at that temperature and thus are able to diffuse into grain boundaries.
- Flexion studies will be carried out in the future in order to analyse more deeply the hot shortness behaviour.

REFERENCES AND ACKNOWLEDGEMENTS

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NANO-S-MART

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