change with temperature and strain rate, are shown to be critical to determine the twinning to slip transition. It is foreseen that the same concept can be applied to Mg alloys and, for that matter, to hcp metals. The apparently contradicting reported evidences of the dependence of the occurrence of twinning with grain size [7,17–24] might be reconciled when the corresponding GB network topologies and spatial distribution of orientations are taken into account. Finally, our study suggests that models relating the average grain size with bulk mechanical properties, such as the HP law, should be taken with caution, as they ignore both the intrinsic nature of individual GBs, as well as their spatial distribution. The large scatter in the HP parameters found for Mg and its alloys [6–15] could, perhaps, be a blatant call for more sophisticated models that take into account structure-dependent GB properties.

4. Conclusions

In this work the origin of the transition in the dominant deformation mechanism from twinning to slip in pure Mg with grain refinement, with decreasing strain rate and with increasing temperature is investigated. With that aim, compression tests at a wide range of strain rates and temperatures were performed in two rolled and annealed polycrystals with grain sizes of 19 and 5 μm. The twin and slip activities were estimated by an exhaustive EBSD-assisted slip trace analysis study. The following conclusions can be drawn from the present study:

(1) A transition from twinning to basal slip dominated flow takes place at 50 °C and $10^{-3}\,s^{-1}$ when the grain size is reduced from 19 to 5 μm. In the fine grained polycrystal strain is accommodated predominantly by basal slip taking place along well defined deformation bands. The origin of the transition lays on the differences in the GB networks of the two polycrystals emerging from the processing and, more precisely, in the higher connectivity between grains that are favorably oriented for basal slip present in the fine grained polycrystal.

(2) A similar transition from twinning to basal slip dominated flow takes place at 50 °C when the strain rate is decreased from 10^{-3} to $10^{-5}\,s^{-1}$ and at $10^{-3}\,s^{-1}$ when the temperature is increased from 50 to 150 °C. It is shown how this transition is due to the relaxation of constraints at GBs with decreasing strain rate and increasing temperature, leading to better connectivity between grains that are favorably oriented for basal slip.

(3) At $10^{-3}\,s^{-1}$ and 250 °C basal slip is still the dominant deformation mechanism but the contribution to strain of non-basal slip increases noticeably due to the well-known decrease of the CRSS of prismatic and pyramidal systems with temperature as well as to enhanced cross-slip from basal to non-basal planes.

(4) The current study suggests that the topology of the GB network, and the nature of individual GBs, together with the spatial distribution of orientations, play a decisive role in the selection of the dominant deformation mechanisms in pure Mg polycrystals, hinting that care must be taken when relating bulk mechanical properties with average grain size values.

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