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# Microstructure refinement of selected copper alloys strips processed by SPD method

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**ABSTRACT**

**Purpose:** A growing trend to use the new copper-based functional materials is observed recently world-wide. Ultrafine grained copper, solid solution hardened and age-hardened copper alloys are applied where combination of high electrical conductivity with high strength is required.

**Design/methodology/approach:** This study was aimed to investigate microstructure in strips of copper alloys with different stacking fault energy value. The investigated materials have been processed by one of the severe plastic deformation method, using different variants of continuous repetitive corrugation and straightening (CRCS). Deformation was executed by parallel and perpendicular corrugation and straightening of strip sample.

**Findings:** Continuous repetitive corrugation and straightening is a promising method for refining of microstructure of metallic strips.

**Practical implications:** A growing trend to use new copper-based functional materials is observed recently world-wide. Within this group of materials particular attention is drawn to those with ultra fine or nanometric grain size.

**Originality/value:** The paper contributes to the microstructure evolution of solid solution hardened and age-hardened copper alloys strips produced by original RCS method.

**Keywords:** Copper alloys; Severe Plastic Deformation; Refined microstructure; Electron microscopy

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MATERIALS MANUFACTURING AND PROCESSING

## 1. Introduction

Our former studies were focused on producing the more advantageous set of functional properties in copper alloys to reach the required range of mechanical properties and respectively high electrical conductivity. The second aspect of the study was related to the problem how to maintain the set of properties stable in operating conditions, both with respect to variable dynamic, thermal and current loads. With that objective in mind investigations into development of a technology for production of precipitation and dispersion hardened copper alloys were conducted, including the alloys of ultrafine or even nanocrystalline matrix [1-6]. The former studies into production of ultrafine crystalline microstructure were conducted by RCS method with application of an original, designed by the authors, tool coupled with the testing machine Instron [7-10]. Based on the produced results, two types of profiled rolls were constructed which made possible to roll strips with parallel and perpendicular corrugation, and with straightening [11]. That prototype was used for examination of the efficiency of microstructure refining on the samples of strips made of chromium copper and brass (CuZn30).

## 2. Material and methodology

In the studies a laboratory stand for repetitive corrugation and straightening of strips was used (Fig. 1). The deformation was performed on strip samples of 0.9x20mm cross-section made of chromium copper (CuCr0,6) after partial quenching from temperature of 950°C and 1x20mm cross-section made of (CuZn30) brass after annealing in the temperature of 550°C for 1 hour. The CuCr0,6 strip was subjected to 74 full cycles (corrugation + straightening) of deformation with toothed rolls (Fig. 2), while the CuZn30 strip was deformed in 8 full cycles (corrugation + straightening) with grooved rolls (Fig. 3). To guarantee uniformity of deformation in both cases the strip before each cycle of corrugation was turned 180 degrees. The study was conducted to assess the efficiency of microstructure refining in the applied method of cyclic corrugation and straightening. The microstructure was examined by optical and electron scanning microscopy with EBSD analysis.

## 3. Results and discussion

The results of examination of microstructure of CuCr0,6 alloy in the initial state are presented in Figs. 4, 8 and 9.

The material was partially supersaturated, as confirmed by presence of precipitates of chromium. Average grain diameter was 3,2 µm, with the largest surface fraction represented by the grains in the range 6-8 µm. Also smaller individual grains of the size 21-23 µm were observed. The fraction of twin grains was at the level of 25%. Low-angle boundaries (below 15°) represented 26% and high-angle boundaries (over 15°) 74% of the total number of grain boundaries. Clusters of low-angle boundaries were located in the area of larger grains.

Fig. 1. Stand for repetitive corrugation and straightening of strips

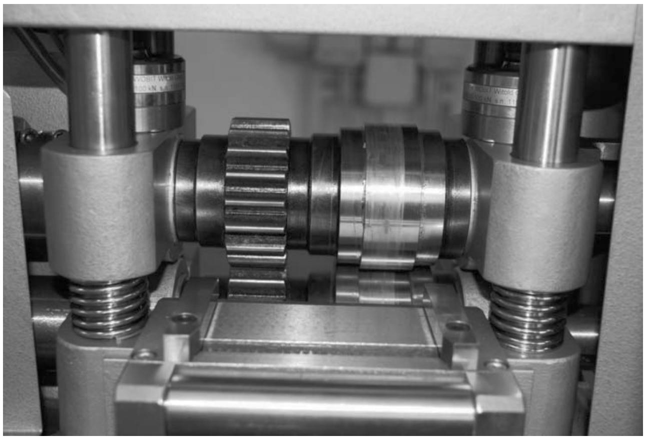

Fig. 2. Toothed and flat rolls for RCS process

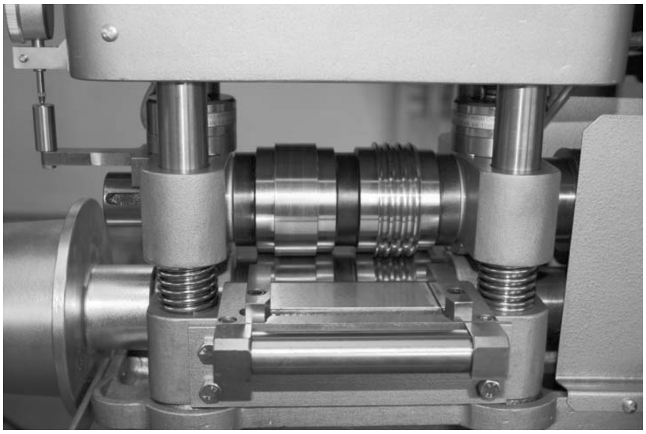

Fig. 3. Groove and flat rolls for RCS process

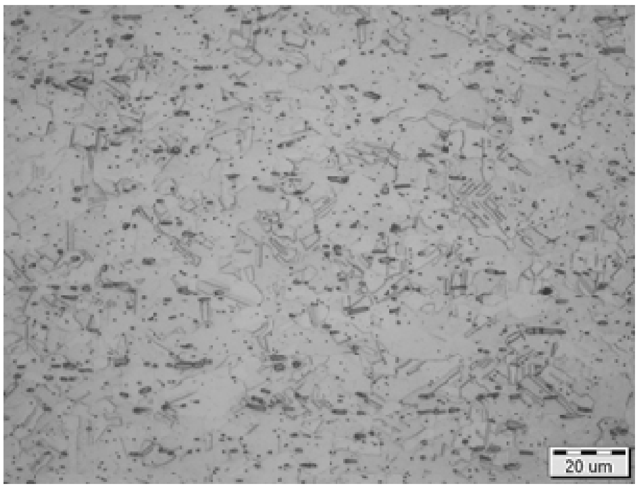


Fig. 4. Microstructure of CuCr0,6 alloy, initial state after partial supersaturation

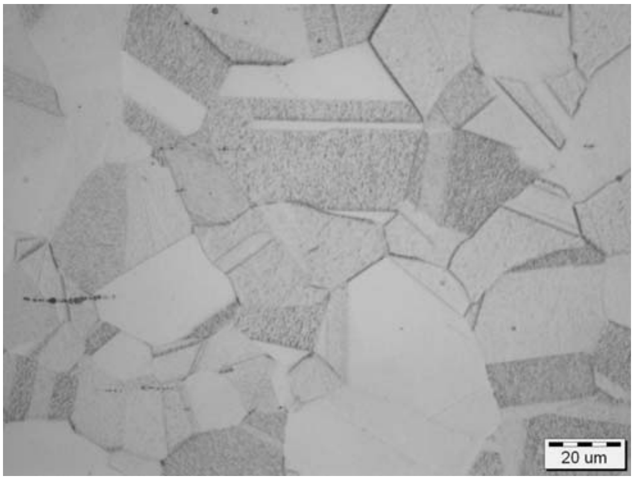


Fig. 5. Microstructure of CuZn30 brass, initial state

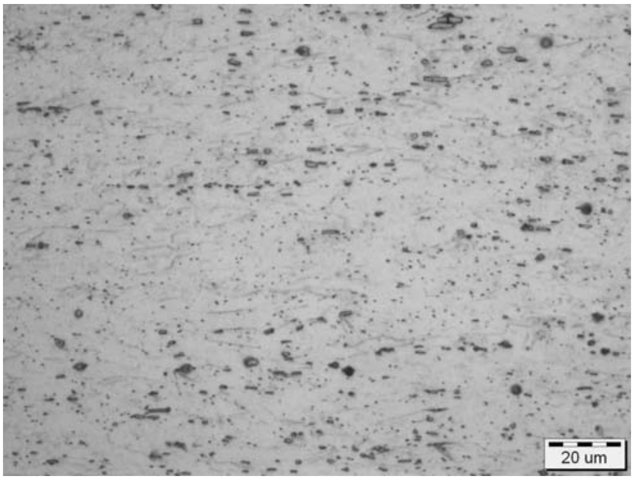


Fig. 6. Microstructure of CuCr0,6 alloy after 74 RCS cycles

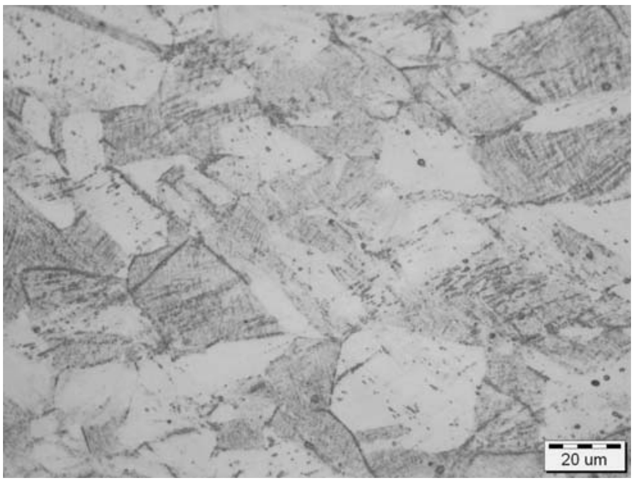


Fig.7. Microstructure of CuZn30 brass after 8 RCS cycles

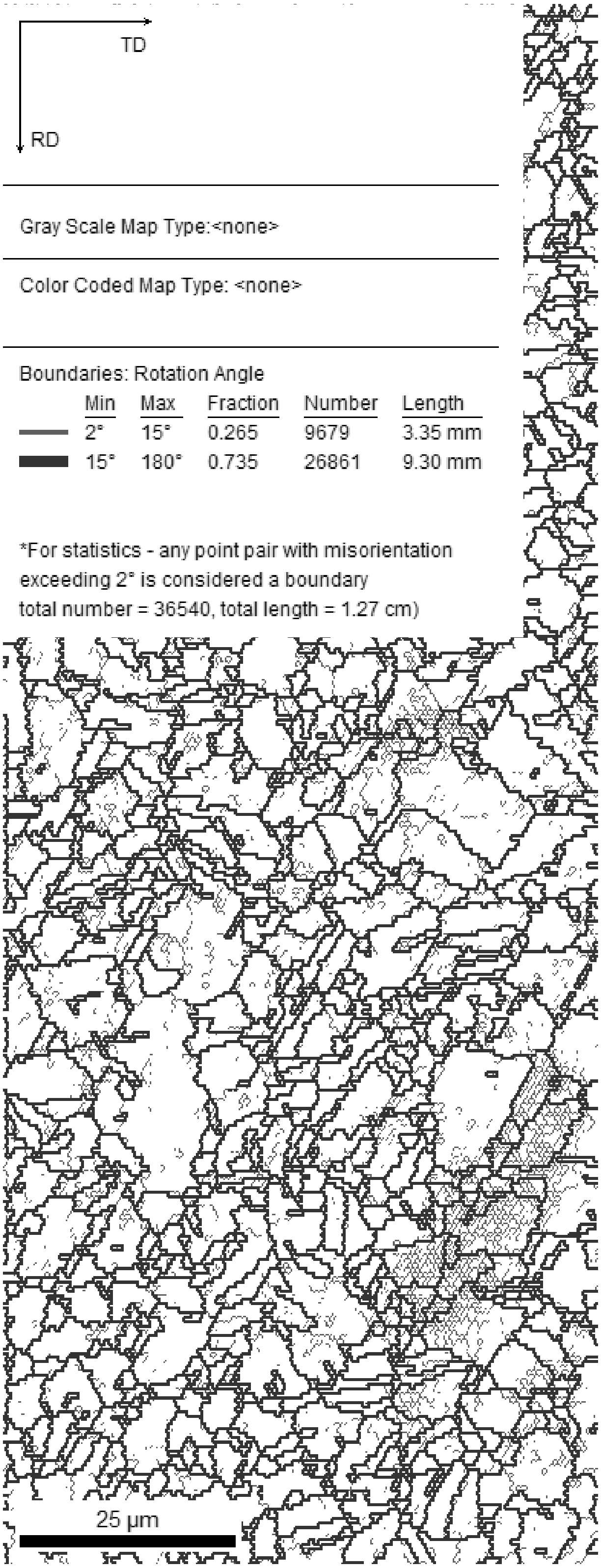


Fig. 8. Map of grains and subgrains in CuCr0,6 alloy in initial state

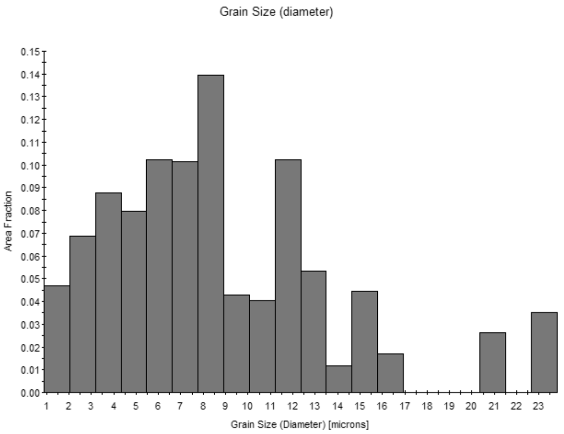


Fig. 9. Grain size distribution of CuCr0,6 alloy in initial state

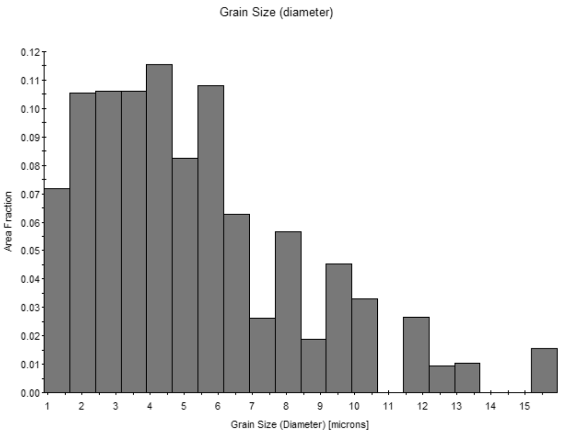


Fig. 10. Grain size distribution of CuCr0,6 alloy after 74 RCS cycles

After deformation of CuCr0,6 alloy by RCS method microstructure refining was observed, Figs. 6, 10 and 11. Average grain diameter was 6,2 µm and the maximum grain diameter did not exceed 29 µm. No twin grains were observed. The grains were partly elongated along the direction of rolling. A significant number of subgrains was observed in the grains. Low-angle boundaries (below 15$^{o}$) represented 57% and high-angle boundaries (over 15$^{o}$) 43% of the total number of grain boundaries.

Microstructure of CuZn30 alloy in the initial state is presented in Figs. 5, 12 and 13. The material was in the annealed state

Average grain diameter was 20 µm, with the largest surface fraction represented by the grains in the range 25-45 µm. Some individual grains of the size 140 µm were also observed. The fraction of twin grains was at the level of 35%. Low-angle boundaries (below 15$^{o}$) represented 21% and high-angle boundaries (over 15$^{o}$) 79% of the total number of grain boundaries.

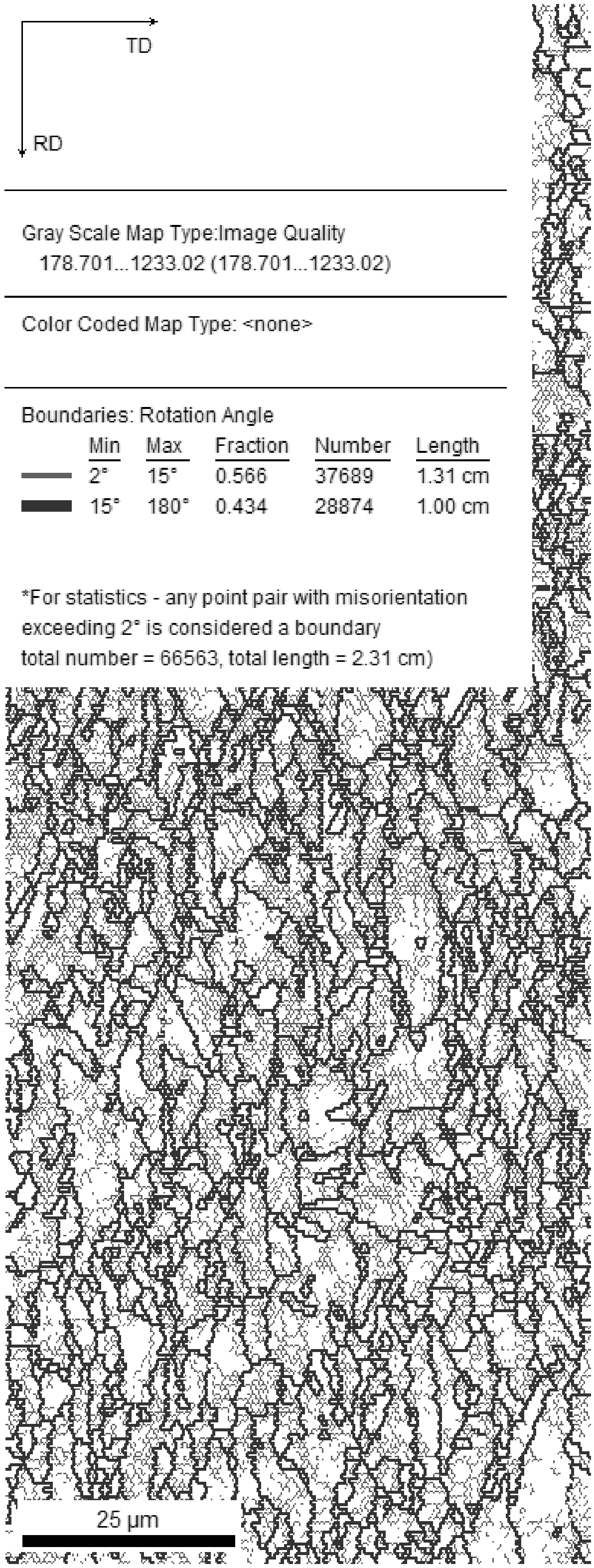


Fig. 11. Map of grains and subgrains in CuCr0,6 alloy after 74 RCS cycles

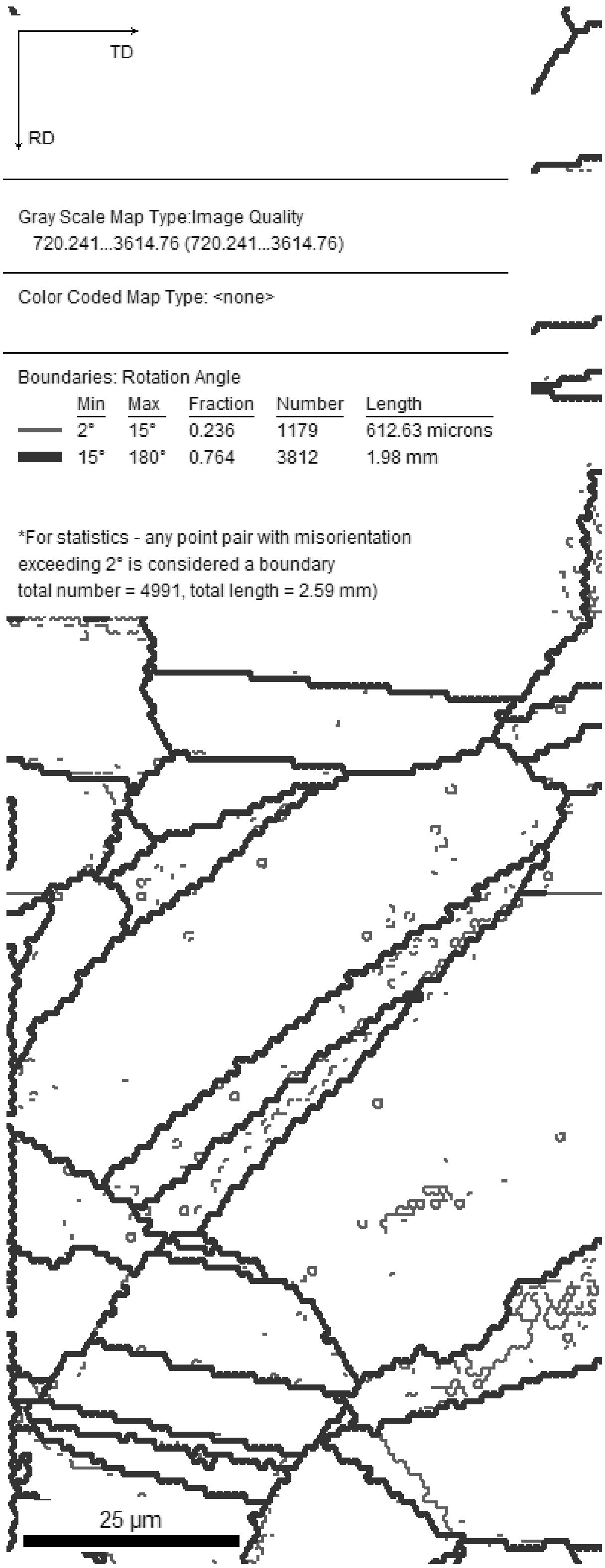


Fig. 12. Map of grains and subgrains of CuZn30 brass in initial state

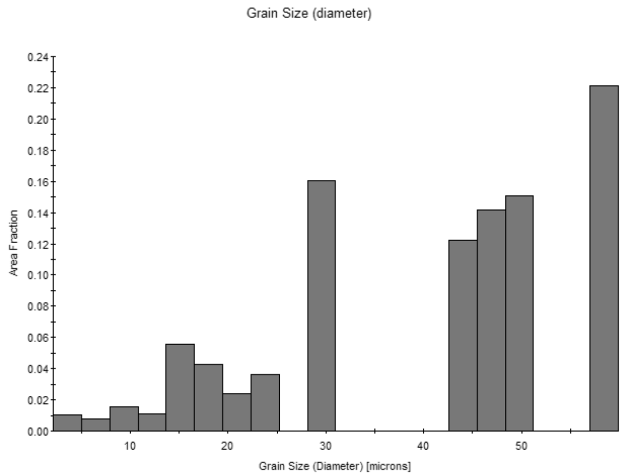


Fig. 13. Grain size distribution of CuZn30 brass in initial state

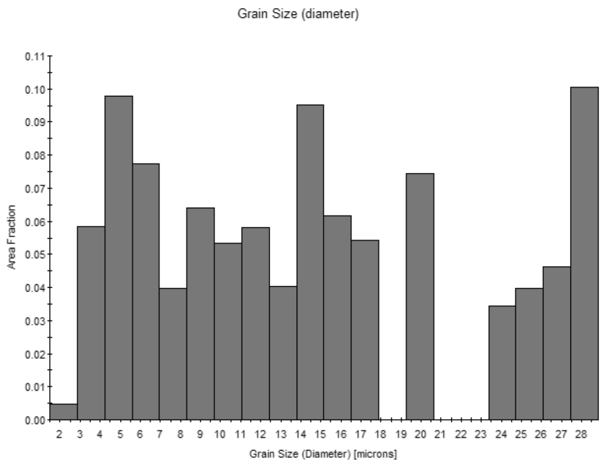


Fig. 14. Grain size distribution of CuZn30 brass after 8 RCS cycles

After deformation of CuZn30 alloy by RCS method microstructure refining was observed, Figs. 7, 14 and 15. Average grain diameter was 2.3 μm with the largest surface fraction represented by the grains in the range 2-5 μm. No twin grains were observed. Individual grains were partly elongated along the direction of rolling. In the result of the deformation new high-angle grains and subgrains were formed. Low-angle boundaries (below 15$^{o}$) represented 81% and high-angle boundaries (over 15$^{o}$) 19% of the total number of grain boundaries.

## 4. Summary

The paper presents promising preliminary results of the studies into a method for production of ultra-fine grained microstructure by repetitive corrugation (parallel and perpendi-

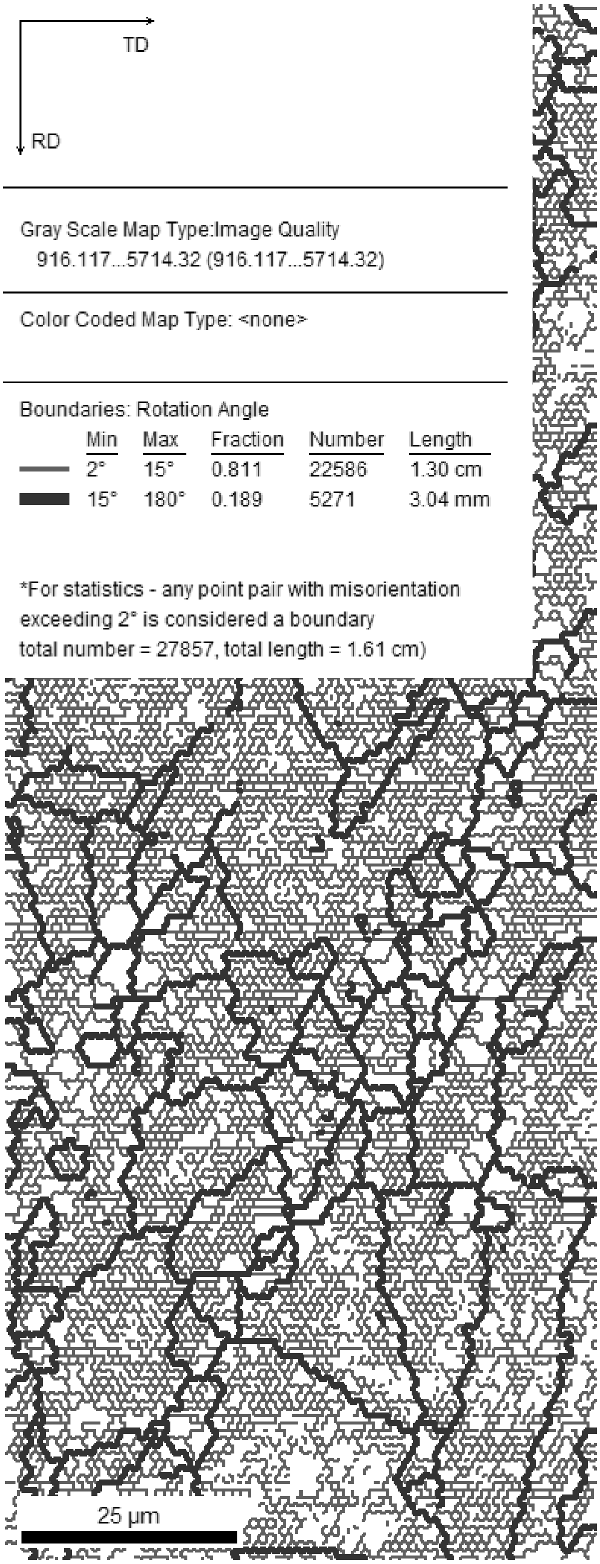


Fig. 15. Map of grains and subgrains of CuZn30 brass after 8 RCS cycles

cular) and straightening (RCS). The study was conducted on specifically constructed machine (rolling mill) according to the authors' idea.

The conducted studies show that both parallel and perpendicular corrugation results in significant changes in number of grains, and especially in subgrains, which leads to microstructure refining. The examined two materials are characterised by different microstructure response to the intensive deformation in the designed machine. A characteristic feature of CuZn30 brass was noticed, as it turned out no twin grains were observed after deformation process.

Further research is directed towards in-depth examination of the mechanisms which are responsible for the change of microstructure, also with application of transmission electron microscopy.

## Acknowledgements

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