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Ljubiša Balanović
Dejan Tanikić

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Hasan Ali Taner, Ali Aras, Muhammad Hashim Rasa *(TURKEY)*
Investigation of the effect of depressant and collector conditioning times on cobalt recovery by flotation *464-467*

Aleksandar Cvetković, Žaklina Tasić, Marija Petrović Mihajlović, Maja Nujkić, Milan Radovanović, Ana Simonović *(SERBIA)*
Microplastics *468-471*

Sanja Petrović, Srđana Magdalinović, Ljubiša Obradović, Sandra Milutinović, Bojan Drobnjaković, Slađana Krstić *(SERBIA)*
Tailing management: tailings filtering equipment *472-475*

Jelena Stefanović, Jelena Đorđević, Sandra Guševac *(SERBIA)*
XRD analysis of corrosion product formed in industrial aggressive environment *476-480*

Muhamad Ghulam Isaq Khan, Filip Rajković, Miljana Popović, Dejan Prelević, Aleksandar Ćitić, Tamara Radetić *(SERBIA)*
Initiation of abnormal grain growth in cold-rolled sheet of AA5182 Al-Mg alloy: role of texture *481-484*

Danijela Voza, Hesam Dehghani, Milica Veličković *(SERBIA)*
The dissolved oxygen prediction based on the machine learning techniques *485-488*

Hasan Açan, Hasan Ergin *(TURKEY)*
A novel model for minimizing mine closure costs and the optimum final quarry boundry *489-492*

Ivana Jovanović, Dragan Milanović, Oliver Dimitrijević, Vesna Conić, Igor Svrkota *(SERBIA)*
Role of wing tank in DMS process. Suspension velocity through the seal leg orifice – case study *493-496*

Dejan Petrović, Jelena Ivaz, Saša Stojadinović, Predrag Stolić, Dragan Zlatanović *(SERBIA)*
Risk management and mining machines maintenance – a brief review *497-500*

Stefan Đorđievski, Dragana Adamović *(SERBIA)*
History of surface water pollution by mining and metallurgical activities in Bor, Serbia *501-504*

Olivera Dragutinović, Vaso Manojlović, Đorđe Veljović, Stefan Dikić, Marko Simić *(SERBIA)*
Investigation of the properties of Co-Cr-W and Co-Cr-Mo alloys coated with hydroxyapatite for use in dental implants *505-509*

Zoran Karastojković, Dragoslav Gusković, Ognjen Ristić, Zorica Kovačević *(SERBIA)*
About the "relative plasticity" between steel matrix and non-metallic inclusions *510-513*

Aleksandar Jovanović, Mladen Bugarčić, Milena Milošević, Marija Vuksanović, Muna Abdualatif Abduarahman, Miroslav Sokić, Aleksandar Marinković *(SERBIA, LIBYA)*
Modified hybrid cellulose membrane for Nickel(II) ions removal from industrial wastewater *514-517*

Elena Todorova, Nadezhda Kazakova, Georgi Chernev *(BULGARIA)*
Structural investigation via SEM analysis of silica hybrid materials *518-521*

INITIATION OF ABNORMAL GRAIN GROWTH IN COLD-ROLLED SHEET OF AA5182 Al-Mg ALLOY: ROLE OF TEXTURE

Muhamad Ghulam Isaq Khan[1], Filip Rajković[2], Miljana Popović[1], Dejan Prelević[2], Aleksandar Ćitić[3], Tamara Radetić[1]

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Abstract

In this work, we investigate the role of crystallographic texture on the onset of abnormal grain growth (AGG) in AA5182 alloy. TMP included 65% cold-rolling reduction and isothermal annealing at 480°C at various times. The microstructure characterization by optical microscopy in polarized light revealed that AGG starts after holding for 5 min at 480°C. Further investigation of the sample with incipient abnormal grains was conducted by an SEM equipped with an EBSD detector. The incipient abnormal grains appear to have an orientation of minor texture components, i.e. different cube variants, most likely due to the enhanced grain boundary mobility. However, texture fails to explain the difference in the propensity toward AGG in the region close to the sheet surface and its center, which is likely caused by the non-uniform distribution of the intermetallic particles.

***Keywords**: Abnormal grain growth, Microtexture, AA5182 alloy*

1. INTRODUCTION

Recrystallization and grain growth have been subjected to extensive research for over a half of century due to the enormous influence of grain microstructure on the properties of metal materials [1]. However, some fundamental aspects of grain growth, like conditions for the appearance of abnormal grain growth (AGG), are not well understood. Except for a few cases, AGG is undesirable as severely deteriorates mechanical properties of the alloy [1].

The studies of AGG in particle-containing Al-Mg-Mn alloys show that its occurrence depends on the annealing temperature and crystallographic texture of the alloy [2,3]. A high volume fraction of dispersoids can suppress AGG. Hence, the AGG frequently occurs at annealing temperatures close to the solvus when the grain boundary pinning dispersoids coarsen and dissolve [2,3]. However, there are reports of AGG taking place in heavily deformed alloys at annealing temperatures well below solvus [4]. The texture has a major role in low-alloyed Al-alloys with insignificant dispersoid fraction [5,6]. The initiation of AGG is attributed to the size advantage of grains of certain texture components.

In previous work, we reported on observations of AGG in the range of Al-Mg alloys [4,7]. Annealing of the cold-rolled sheets at temperatures >400°C led to AGG and the formation of a microstructure consisting of two bands of abnormal grains enclosing fine-grained material in the center of the cold-rolled sheet. An increase in the content of particle-forming elements, such as Mn and Fe, in the alloy drives the onset of AGG toward higher temperatures [7]. On the other hand, an increase in the cold work lowers the onset temperature [4]. This study aims to examine the role of crystallographic texture in the initiation of abnormal grain growth in AA5182 aluminum alloy.

2. EXPERIMENTAL

The material under study was industrially processed - DC cast and hot rolled AA5182 alloy provided by Impol Seval Aluminium Rolling Mill company. The as-received hot band underwent further processing in the laboratory that included cold-rolling with 64% reduction followed by annealing at 480°C for various times (τ = 0-180 min). The chemical composition of the alloy is given in Table 1.

Table 1 – Chemical composition of the studied alloy (wt%)

Mg	Mn	Si	Fe	Ti	Cu	Zn	Cr	Zn	Other
4.04	0.371	0.0732	0.186	0.0019	0.011	0.0397	0.011	0.0223	0.0082

The microstructure of the alloy, in cold-rolled state and after annealing, was studied by optical microscopy. Longitudinal sections of the cold-rolled sheet, i.e. RD-ND orientation, were mechanically polished and electrolytically etched in Barker's reagent to reveal grain microstructure. The crystallographic texture was characterized in SEM JEOL JSM-6610LV coupled to an EBSD detector Symmetry S3 at the U. of Belgrade, Faculty of Mining and Geology, Depart. for Mineralogy, Crystallography, Petrology and Geochemistry. EBSD data were processed with AZtecCrystal 2.2. From the EBSD data samples orientation distribution functions (ODF) were computed assuming orthotropic symmetry of the cold-rolled sheet, i.e., plane strain. Mechanical polishing was followed by electro-polishing of the specimens for EBSD characterization. Areas, ≈750x500 μm^2, were scanned with step size 1.5-2 μm.

3. RESULTS AND DISCUSSION

The grain microstructure of the cold-rolled sheet is characterized by elongated, strip-like grains whose thickness and length vary across the cross-section (Figure 1a). Close to the surface, thin grains form within a 600-800 μm thick band. Further toward the center, there is a gradual increase in the grain's thickness and length. Such grain microstructure could be traced to the grain microstructure and size distribution within the hot-band.

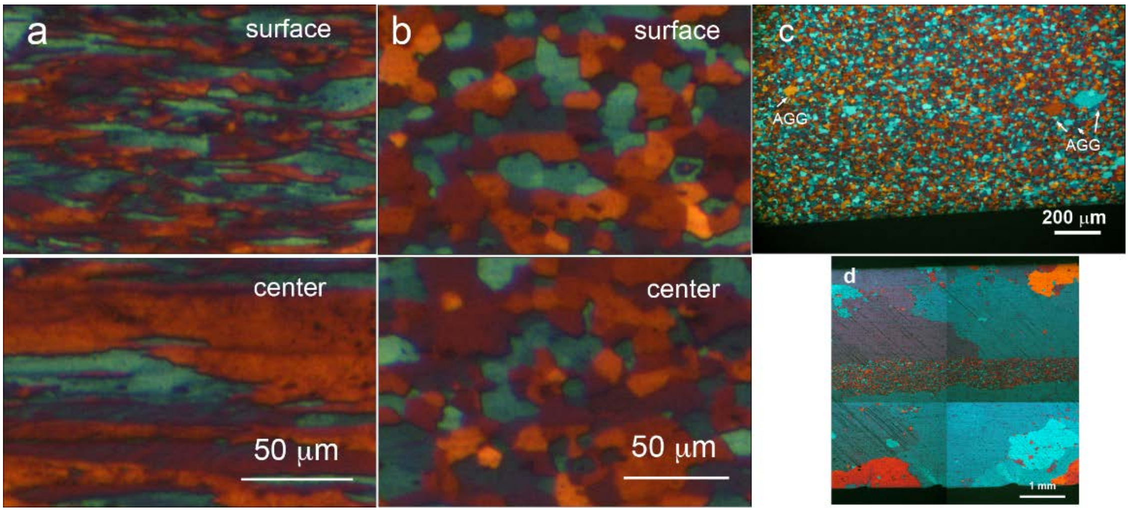

Figure 1 - The grain microstructure of the alloy: (a) cold-rolled state; (b) upon reaching 480°C; (c) annealing for 5 min at 480°C; (d) annealing for 180 min at 480°C.

Recrystallization throughout the cold-rolled sheet occurred during heating up to the annealing temperature (Figure 1b). While there is a gradient in grain size across the sheet thickness, there is no evidence of the presence of enlarged grains that would indicate the onset of the abnormal grain growth. Annealing for 5 min did not significantly change a mean grain size of ≈ 9.9 μm in the band-region close to the sheet surface. However, enlarged grains (Figure 1c) appeared in the region up to 700 μm from the sheet surface. Longer anneal led to the formation of the bands of abnormal grains. The thickness of the abnormal grains band increased with annealing time, but the strip of fine-grained material in the sheet center was preserved even after annealing for 180 min (Figure 1d). In contrast to excessive grain growth in the outer parts of the sheet, the mean grain size in the plate center increased more slowly from 14.5 to 17.7 μm. Annealing at higher temperatures resulted in AGG throughout the plate, with abnormal grains originating also in the center part of the sheet [4].

To evaluate the effect of crystallographic texture and preferential orientation of the grains on AGG, microtexture analysis was conducted in the regions close to the surface and the center of the sheet. The characteristic ODFs of the grains with normal size distribution are shown in Figures 2a and b. The texture is weak, with maximums of 3.99× and 3.18× random in the region close to the surface and center, respectively. Although the microstructure shows the morphology of recrystallized grains, the fraction of the cube texture component, which is typical for the recrystallization texture of Al-Mg alloys [1], is at or below the random level. ODF-s show the presence of the β-fiber indicating retained rolling texture. The β-fiber is displaced from the ideal position, and ODF of the central region (Figure 2b) characterizes a larger deviation of Cu and R/S components and weak brass component. While the recrystallization mechanism is unknown, it is likely to adopt a similar path to one proposed for the transformation of S grains into R component [8].

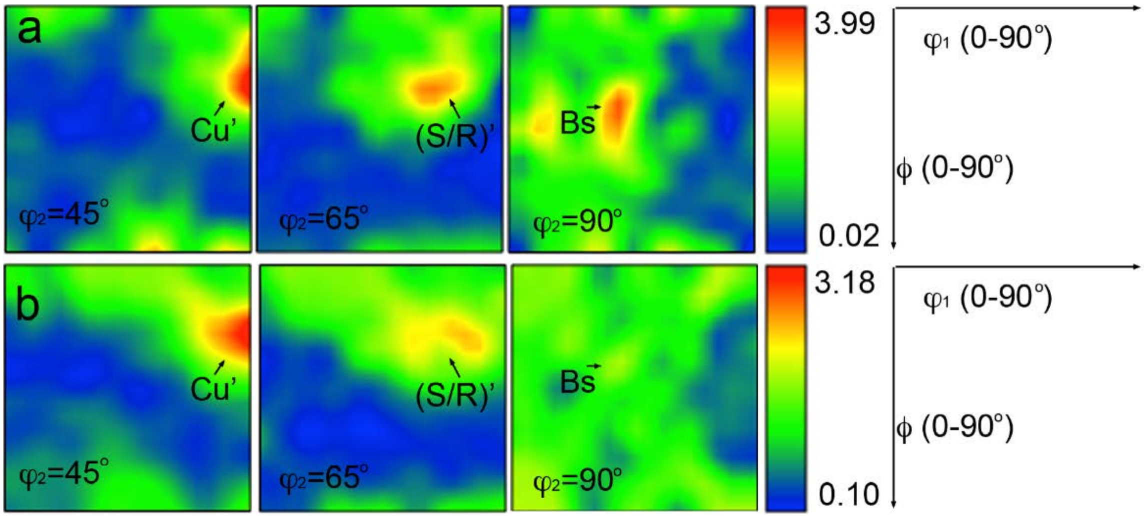

Figure 2 - ODF of the grains having normal size distribution: (a) region close to the sheet surface; (b) region corresponding to the sheet center. Sample was hold for 5 min at 480°C.

A few grains exhibit propensity toward AGG; out of over 5000 grains analyzed, only seven had a size more than 3× mean grain size. Among them, one had a Brass orientation, while others adopted some cube variants: cube (1), cube ND (1), cube RD (1), and rotation cube (3). Analysis of the grain size distribution did not show any size advantage of these components; actually, their mean grain size was slightly below average. Regardless of the difference in formation mechanism among cube texture variants, the first three being recrystallization and rotation cube shear component, their common feature is low volume fraction. Low volume fraction results in lower interconnectivity of grains with the same texture component. While ≈50% of grains in the dominant texture component, R/S orientation, form clusters of 3 or more grains, less than 15% of grains in one of the cube orientations form groups of 3, if any (Figure 3). Due to the similar orientation of clustered grains, their grain boundaries tend to have limited mobility. Inversely, the grains surrounded by different texture components might have enhanced mobility [9].

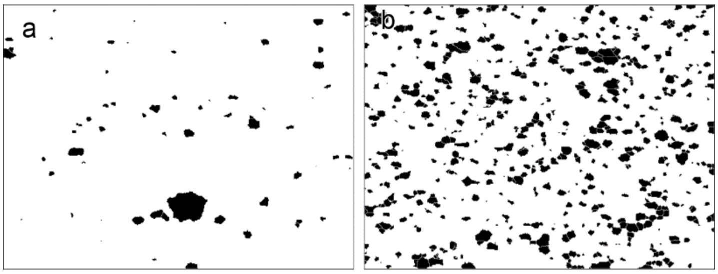

Figure 3 - Distribution of grains of specific texture components: (a) cube; (b) (R/S)'.

However, texture cannot be the sole factor in the AGG initiation. The fact that the surface and central region of the cold-rolled sheet have different propensity toward AGG but are similar in ODF-s points out the other factors. The most likely factor is non-uniform particle distribution, but somewhat larger grain size and broader grain size distribution should not be ruled out.

4. CONCLUSION

The grain morphology of the studied AA5182 alloy indicates the recrystallized microstructure at the onset of abnormal grain growth. However, microtexture analysis shows the absence of the recrystallization texture components and the presence of retained rolling texture; the β-fiber components are displaced from the ideal position. Incipient abnormal grains have an orientation of the different cube variants that are minor texture components and are likely to have higher grain boundary mobility. Due to similarity of ODF from different regions, the crystallographic texture fails to explain the higher propensity toward AGG in the region close to the surface.

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