

A. WRÓBEL*, E. KULEJ*, B. KUCHARSKA*

THE EFFECT OF CORROSION WEAR ON THE RECORDED TEXTURE OF A CLAD Al-Si COATING

WPLYW ZUŻYCIA KOROZYJNEGO NA REJESTROWANĄ TEKSTURĘ PLATEROWANEJ POWŁOKI Al-Si

An AlSi7,5 clad coating applied one-sided on metal sheet of AlMn1Cu alloy was tested. The coating was made in hot clad rolling process.

The coating was subjected to X-ray diffraction measurements paying attention to texturing. Pole figures were recorded for reflections (111), (220), (311) and (331) from the α_{Al} solid solution. The texture measurements were taken before and after the corrosion test. The coatings were subjected to salt spray corrosion tests (according to the PN-EN-ISO-9227:2007 standard) in three cycles of 6hrs, 12hrs and 18hrs, respectively. Comparison of the state of the surface and the sub-surface structure was also made in macro- and microscopic examinations. It was demonstrated that the corrosion attack had the character of pits and covered only half of the coating. The preferential places of pit initiation were matrix-silicon crystal interfaces. The first corrosion changes occurred after 1 hr of test. After 18 hrs of test, the corrosion attack had encompassed considerable surface areas of the clad coatings. The mass loss of coatings after 18 hrs of test amounted to 0.2%.

It was concluded that corrosion has little influence on changing the texture of coatings. Additionally, GIXRD measurements showed change of structure at the layer depth.

Keywords:

Przedmiotem badań przedstawionych w pracy są powłoki AlSi7,5 jednostronnie platerowane na taśmach AlMn1Cu. Powłoki powstały w procesie walcowania na gorąco.

Powłokę poddano rentgenowskim badaniom dyfrakcyjnym pod kątem stekstrowania, rejestrując figury biegunowe dla refleksów pochodzących od płaszczyzn (111), (220), (311) i (331) pochodzące od roztworu stałego α_{Al} . Pomiary tekstury wykonano przed i po teście korozyjnym. Powłoki poddano testom korozyjnym w mgie solnej (zgodnie z normą PN-EN-ISO-9227:2007) w trzech cyklach 6h, 12h oraz 18h. Dokonano porównania zużycia korozyjnego, stanu powierzchni oraz struktury przypowierzchniowej po teście korozyjnym w badaniach makro i mikroskopowych. Atak korozyjny miał charakter wżerów i obejmował tylko osnowę powłoki. Preferencyjnymi miejscami inicjacji wżerów były granice międzyfazowe osnowa-kryształy krzemu. Zmiany korozyjne wystąpiły po 1 h testu. Po 18 h testu atak korozyjny objął znaczne obszary powierzchni powłok platerowanych. Ubytek masy powłok po 18h testu wyniósł 0,2%.

Stwierdzono niewielki wpływ zużycia powierzchni na teksturę powłok, jednocześnie w pomiarach GIXRD wykazano, różnicowanie struktury na głębokości powłoki.

1. Introduction

Obtaining the combination of desired properties, primarily corrosion resistance, appropriate tribological properties or specific electrical and thermal properties, as well as aesthetic effects at lower costs compared to solid material, is possible e.g. through the application of cladding. Due to the large range of variations and possibilities of improving the properties of materials, more and more clad materials are produced around the world. The amount of clad plates alone produced in 2005 was more than one million tons (in 2001 this figure was about

60 thousand tons). Clad plates can provide an excellent alternative to e.g. high corrosion-resisting plates owing to their additional protective layer and, in the case of light-alloy substrates, a reduction of their weight, which is of key importance in many branches of industry, such as the automotive industry.

Metallic coatings that are being commonly applied nowadays, e.g. on the elements of car exhaust systems, are aluminium coatings. An alternative to the presently used hot-dip applied Al-Si coatings are clad Al-Si coatings, thanks to their lower specific weight and good plastic properties. Due to the minimizing of the vehicle

* CZĘSTOCHOWA UNIVERSITY OF TECHNOLOGY, INSTITUTE OF MATERIALS ENGINEERING, FACULTY OF MATERIALS PROCESSING TECHNOLOGY AND APPLIED PHYSICS, 42-200 CZĘSTOCHOWA, 19 ARMII KRAJOWEJ STR., POLAND

mass, it is increasingly common to propose the use of aluminium plates that are additionally clad with aluminium alloys which, in addition to their low weight, are also very ductile. Clad coatings are presently used e.g. for the manufacture of heat exchangers.

The properties of a cladding, e.g. its corrosion resistance and heat conduction, are assessed by the properties of the applied layer, and they are equal to those of the solid material. Metals that are most often clad include carbon steel, as well as aluminium, copper, nickel, and their alloys. Claddings are produced in the form of sheets, plates, strips, tubes, rods and wires, while they can either single- or double-sided, depending on the conditions that must be met by the clad element. The thickness of applied layers, depending on the type and intended application, can range from 1.5 to 15% of the substrate thickness, which in practice, with various application methods, means a thickness from several micrometres to several millimetres.

There are two methods of application of clad coatings:

- cold cladding: cold rolling, stamping, drawing, explosive cladding;
- hot cladding: hot rolling, drawing, pouring, centrifugal casting, flame-plating, surfacing, hot isostatic pressing, sintering [1-3].

The basic technique of examining textures is the X-ray diffraction technique followed by the analysis of recorded polar figures. Materials used for coatings exhibit different textures, depending on the technology of their manufacture. In sputtering technologies, textures oriented in the coating growth direction are predominant, whereas in cladding technologies the textures of coatings are consistent with the textures of plastic deformation (rolling) [4-5].

2. Material and methodology of researches

2.1. Material

The testing material was an Al-Si coating (EN AW-4343) applied onto AlMn1Cu aluminium plate by the hot cladding method (Tab. 1).

TABLE 1

Chemical composition (EDX), weight % (Jeol scanning microscope) – the averaged result of three measurements

Chemical composition (EDX), weight %			
Al	Si	Fe	O
8.96	8.32	0.42	1.57

The microstructure of the claddings has the form of a composite, in which silicon crystals of rounded, very often regular shapes are evenly distributed within the α_{Al} matrix (Fig. 1).

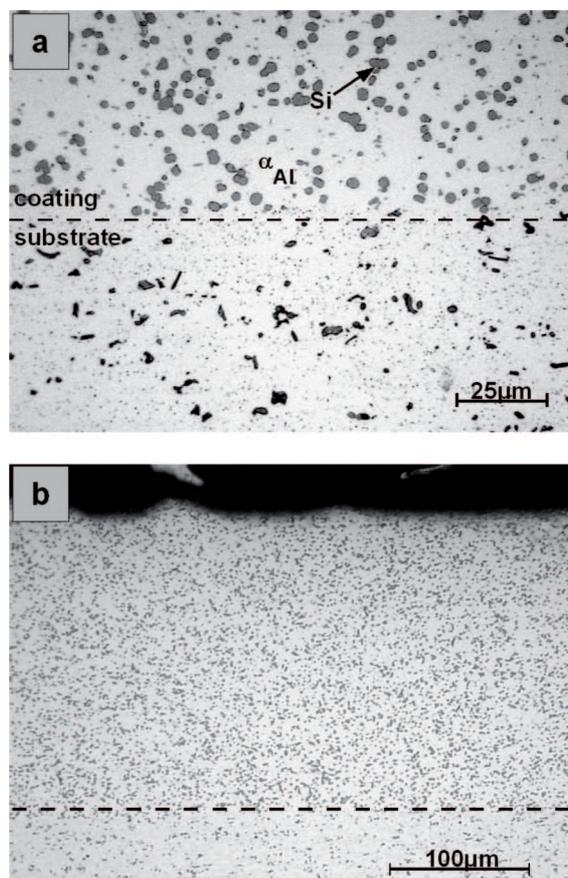


Fig. 1. Microstructure of the hot rolled coating: a) the coating/substrate boundary region b) on the cross section of the coat, etched by 1%HF

2.2. Methodology

The coating was subjected to corrosion tests (according to the PN-EN-ISO-9227:2007 standard) in a salt spray chamber, type BS1, of a capacity of 600dm³, supplied by Braive Instr. During the test, a solution of 5%NaCl in CH₃COOH with a pH of 3.1-3.3, and at a temperature of 35°C, was sprayed within the chamber. The test samples were positioned at an angle of approx. 35° relative to the horizontal plane. The test was carried out in three cycles (two samples for each cycle) of a duration of 6, 12 and 18hrs respectively. After each cycle a samples were washed in stream of distilled water. The coating surfaces were subjected to macro- and microscopic examinations (with a ZEISS Axiovert 25 optical microscope and a Jeol scanning microscope). In addition, the specimen mass before and after the corrosion test was estimated in order to determine the coating mass loss after the salt spray test. The measurements were

executed with using electronic weigher Radwag WPS 360/C device with an uncertainty of 0.001g (using the calibration weight). Results from the mass measurement are rounded to two decimal places.

X-ray measurements of the coating were taken using a Seifert 3003TT X-ray diffractometer and radiation generated by a copper anode tube ($\lambda_{Cu}=0.154\text{nm}$). The examinations included measurements in the symmetric Bragg-Brentano geometry (XRD) in diffraction angle range of $2\Theta = 20 \div 115$ with an angular step of 0.2° and a counting time of 2s, grazing-incidence X-ray diffraction (GXRD) in diffraction angle range of $2\Theta = 35.5 \div 40$ with an angular step of 0.03° and a counting time of 2s with the radiation incidence angle, $\alpha=9^\circ$, as well as measurements of textures for the planes (111), (220), (311), (331). For the X-ray measurements of texture, $25\text{mm}\times 25\text{mm}$ specimens were taken from the claddings.

3. Result of researches and discussion

3.1. Corrosion test

The microscopic image of the surface of coatings after the corrosion test shows corrosion centres being located preferentially in rolling scratches and hollows on the coating surfaces. These locations are particularly exposed to corrosion attack due to the smaller cladding thickness and the accumulation of the corrosion medium in them (Fig. 2). As the test duration extended, the surface areas affected by corrosion attack grew.

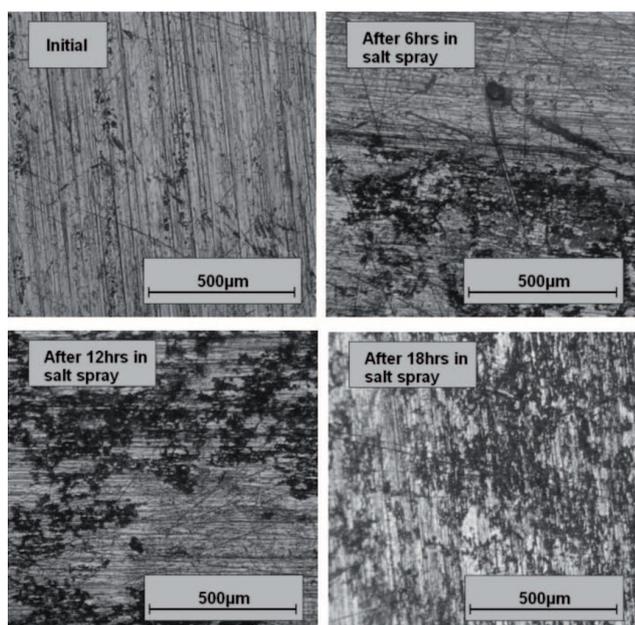


Fig. 2. The surface of coating Al-Si before and after the corrosion test

The corrosion wear of coatings within the test durations used was confirmed by a specimen mass measurement (Fig. 3). The coating mass loss after 18 hrs of test amounted to 0.2%.

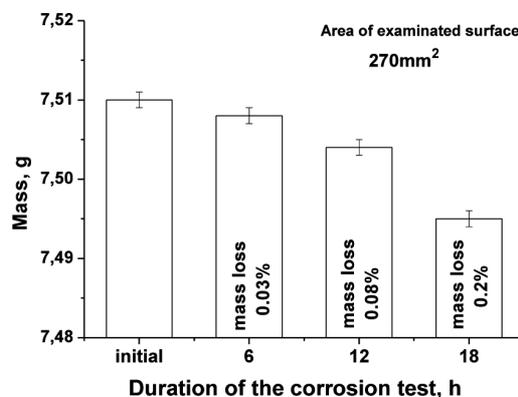


Fig. 3. The specimens mass before and after the corrosion test

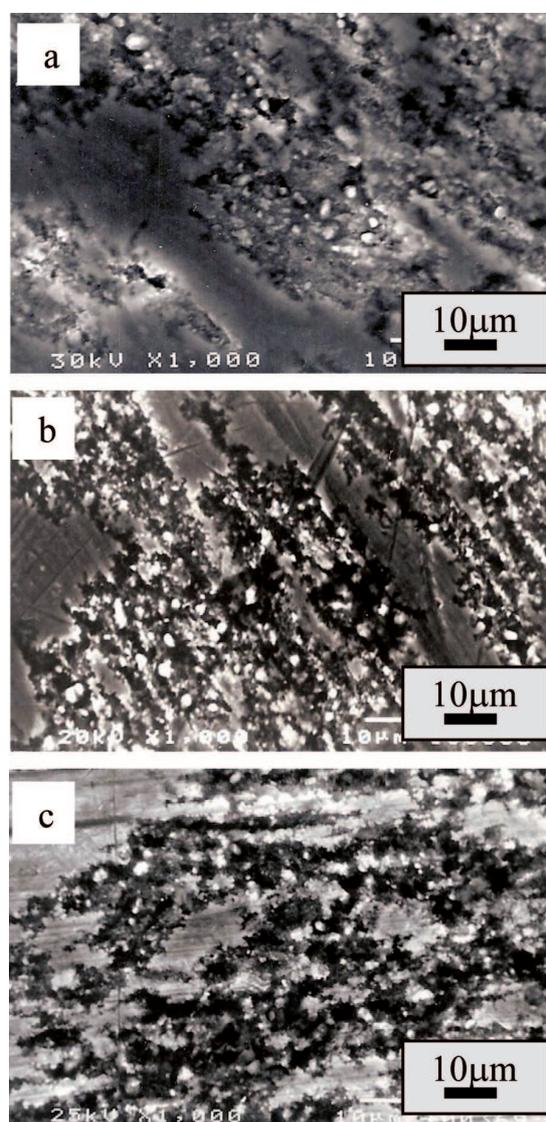


Fig. 4. SEM microscopic image of coating after a) 6h, b) 12h, c) 18h cycles in the salt spray test

The examination of the coating surface using an electron scanning microscope showed that only the α_{Al} solid solution dissolved under the influence of salt mist, whereas the Si crystals remained undissolved and lay within shallow pits (Fig. 4). The salt mist action on the cladding surfaces resulted in the removal of the passive film, as a consequence of which the very reactive nature of aluminium was exposed, whereas silicon, as a chemically passive element, did not undergo corrosion [6].

3.2. X-ray examinations

The analysis of the diffraction patterns obtained from the XRD measurements of the coating before and

after the corrosion test indicated that the coating was built from phases corresponding to the Al-Si equilibrium system [7]. Reflections originating from the α_{Al} solid solution and silicon crystals were obtained (Fig. 5). The analysis of the phase composition of coatings was made using the diffractometric database PDF4+ (01-077-6849, 00-005-0565).

After the salt spray test, the overall intensity of reflections coming from the α_{Al} planes changed, as shown in Figure 6. After the corrosion process, a change in reflection intensity relationship was found – for the main reflection from the solid solution $\alpha_{Al}(111)$ the increase was 46%, while for the weakest reflection coming from solid solution $\alpha_{Al}(331)$, 12%.

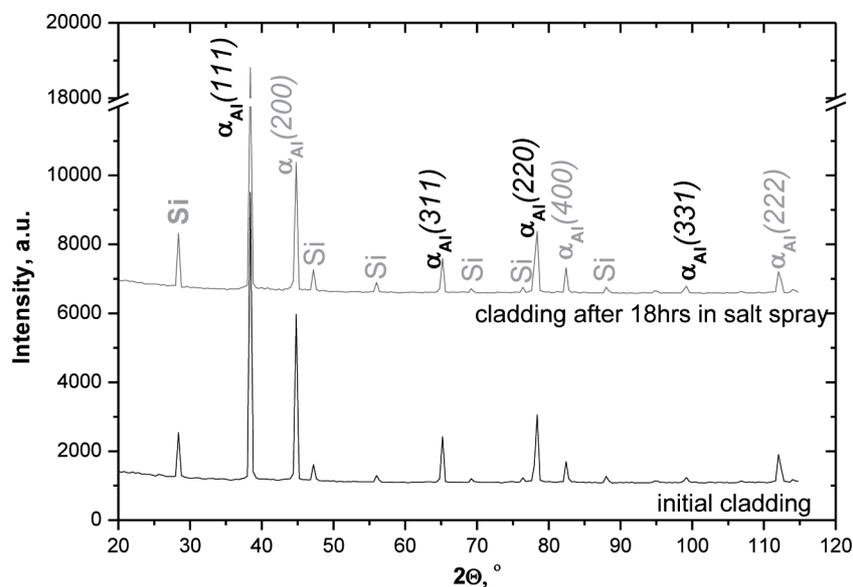


Fig. 5. Diffraction patterns from the Al-Si coat before and after the corrosion test

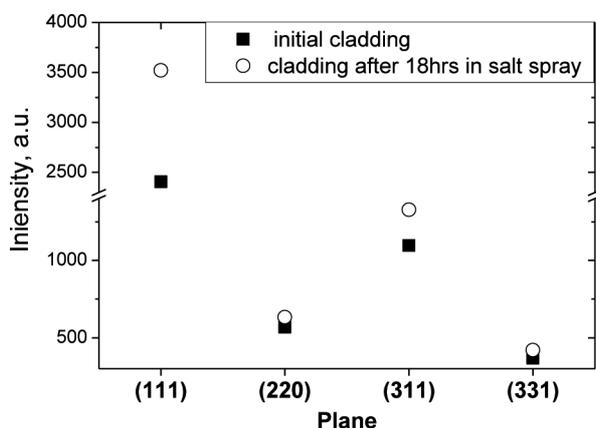


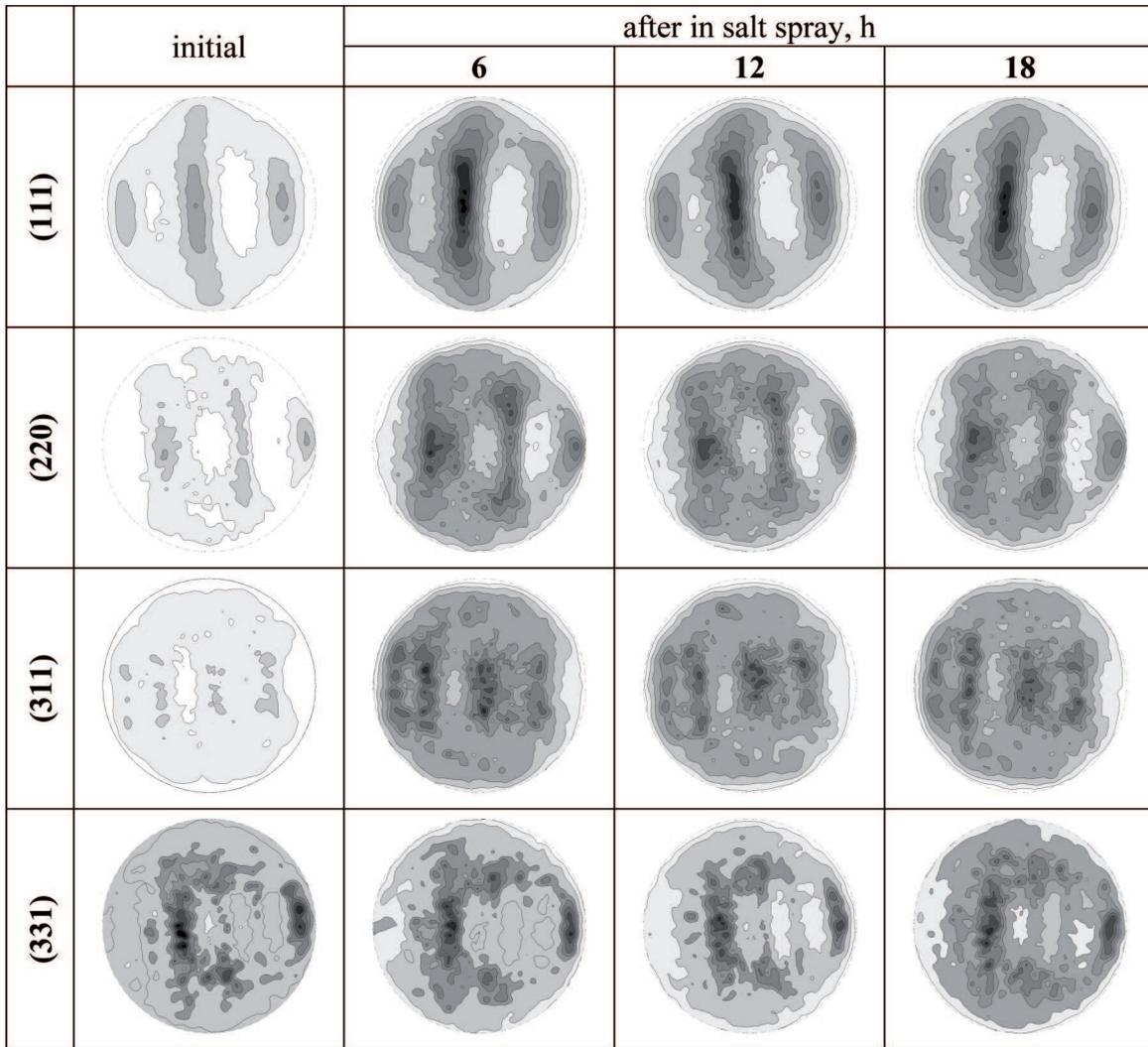
Fig. 6. Comparison of the overall intensity of reflections coming from the α_{Al} solid solution before and after the salt spray test

The change in the intensity of the main reflections from the α_{Al} solid solution in the coating before and after each corrosion test cycle was reflected in the picture of the recorded polar figures (Table 2). The corrosion tests carried out did not cause any change in the distribution of poles; however, they had the effect of increasing their intensities. The greatest increase in the intensity of poles occurred on the polar figures recorded after the first corrosion test (6 hrs of salt spray test). After the subsequent test stages, the intensity increase was weaker.

The changes in texture intensities result from the dissolution of the sub-surface coating layer. Thus revealed structure of deeper layers was shown in the GIXRD examination [8-11].

TABLE 2

Polar figures (111), (200), (311) and (331) of the α_{Al} solid solution



After longer test durations, the reflection (111) from the coating underwent asymmetrization and was shifted toward larger angles, which confirms a stronger texture and the presence of tensile stresses (Fig. 7).

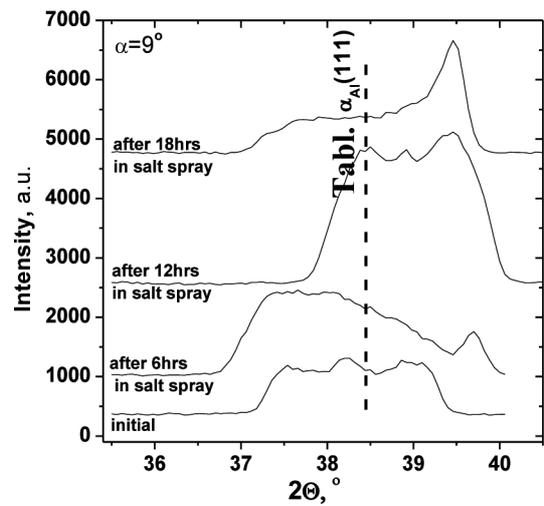


Fig. 7. GIXRD diffraction patterns from the Al-Si coating at a constant radiation incidence angle

4. Conclusions

Good corrosion properties are among the basic quality criteria of claddings. The salt spray corrosion tests of the hot rolled Al-Si cladding showed pitting corrosion initiated in rolling scratches and hollows. The claddings underwent corrosion in the α_{Al} solid solution region, whereas the Si crystals remained undissolved. Such a corrosion character is caused by the high chemical activity of aluminium, and very low of silicon. The effect of corrosion wear is a coating mass loss, and thus a change in texture intensity.

The deeper material layers exposed as a result of corrosion exhibited a stronger texture and a tensile stress region.

REFERENCES

- [1] A. Wróbel, B. Kucharska, Arch Metall Mater **55**, 1, 205-210, (2010).
- [2] F. Stalony-Dobrzański, K. Pieła, L. Błaż, P. Ostachowski, Rudy i Met. Nież., R. **55**, 2, 99-107, (2010).
- [3] A. Wróbel, B. Kucharska, Z. Nitkiewicz, Inż. Materiałowa **3**, (175), XXXI, 394-397, (2010).
- [4] J. Dutkiewicz, J. Bonarski, Mater Design **18**, Nos. 4r6, 247-252, (1997).
- [5] P. Colombi, P. Zanola, E. Bontempi, L. E. Depero, Spectrochim. Acta B **62**, 554-557, (2007).
- [6] W.S. Miller, L. Zhuang, J. Bottema, MAT SCI ENG. **A280**, 37-49, (2000).
- [7] B. Kucharska, A. Wróbel, E. Kulej, Z. Nitkiewicz, Sol St Phen **163**, 286-290 (2010) doi: 10.4028/www.scientific.net/SSP.163.286.
- [8] B. Kucharska, E. Kulej, Arch Metall Mater **55**, 1, 45-51, (2010).
- [9] B. Kucharska, E. Kulej, Z. Nitkiewicz, Inż. Materiałowa **3** (175), ROK XXXI, 439-441, (2010).
- [10] B. Kucharska, K. Domańska, 51 Konwersatorium Krystalograficzne, Wrocław 261, (2009) in polish.
- [11] K.N. Stoev, K. Sakurai, Spectrochim. Acta B **54**, 41-82, (1999).