Texturing of Near-Surface Layers of Metals at High Power Ion Beam Treatment

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Abstract – A possibilities of the formation texture in metallic target irradiated by high power ion beam was investigated by method of X-ray diffraction. The formation of axial texture with axis of projection [001] is observed at aluminium and nickel samples. The formation of texture depend on the ion current density and thermophysical properties of target material. The direction of heat rejection at textured samples was determined from analysis of the inverse pole figures. This direction correspond to normal to the atomic plane (111).

1. Introduction

High power ion beam (HPIB) treatment is a unique method for a change of structured-phase conditions of surface layer of materials. The fast heating and cooling of surface layer result in the modification of materials properties [1]. The high speed crystallization and recrystallization can give rise to the formation of the texture which results in anisotropy of properties of polycrystal sample. The study of the texture produced by HPIB treatment has both the practical interest and the fundamental interest. It is allows the better to understand the mechanism of plastic deformation, recrystallization and the other processes running under HPIB treatment of metals and alloys.

2. Experiment

The processes of the formation the texture at aluminum and nickel irradiated by HPIB was studied at present work. For removing of the hardening after grinding and polishing of aluminum and nickel samples were annealled in the vacuum furnace for during 2 hours at the temperature 200 and 600 °C, accordingly.

High power ion beam was generated by the "Temp" accelerators. The compositions of beam were 70 % C^+ and 30 % H^+. The ion accelerating voltage was 300 kV, averaged ion current densities were 40–150 A/cm^2 and pulse duration was 50 ns.

The analysis of the preferential crystalline orientation was conducted by building of the direct pole figure (DPF) and the inverse pole figure (IPF) at the calculation difractograms, which was got on diffractometr "Dron-3M" [2].

At choice of the reflection for analysis of the texture was taken into account following factors. a) the factor of repeatability for investigated reflection must not was be big; b)the used diffraction maximums have small degradation because of small sizes of the coherence dissipation area and low microstresses (the pole figure was built on the measurement of peak intensity). The peak (111) was satisfied this equirements for all investigated materials. The intensity was counted out from level of the background. The difractogram of the notextured samples was registered for the calculation of the corrective factor K(α).

The building DPF was conducted with using of the net Boldyrev. The orientations of the texture were found on standard nets of the gnomostereographic projections.

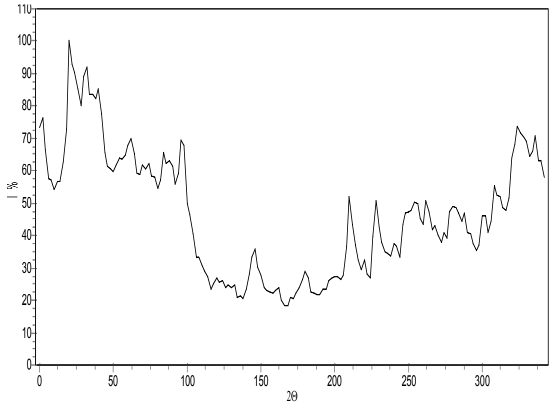
3. Results and discussion

The irradiation of target by HPIB is characterized by fast inputting of the energy in surface layer, heating of this layer to the high temperature (up to the melting temperature and boiling temperature) and following fast hardening. The high temperature gradients and the high cooling rates (~10^6–10^8 K/s) arise under such influence. In our experiments the formation of the axial texture with axis of the projection [001] was found on aluminum and nickel samples. The formation of texture is depended both from the ion current density and thermophysical properties of target materials. Fig. 1 shows fragments of the difractogram corresponding to the presence or the absence of the texture for the aluminum sample.

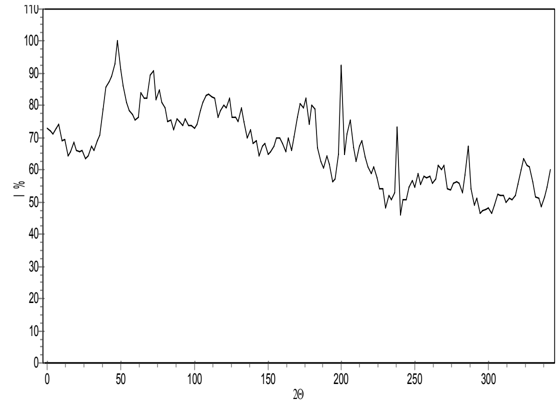
It was found that HPIB irradiation with the ion current density j=50 A/cm^2 of the aluminum samples does not result in the texture formation. Under HPIB irradiation of the aluminum samples with the ion current density j=100 A/cm^2 and j=150 A/cm^2 result in the texture formation what is confirmed by the appearance of additional textured maximums. The appearance of the preferential orientations for these ion current density is determined probably by the development of the recrystallization.

The formed texture is the growing texture. The processes of the preferential recrystallization and the growing grain occur at thermal influence HPIB.

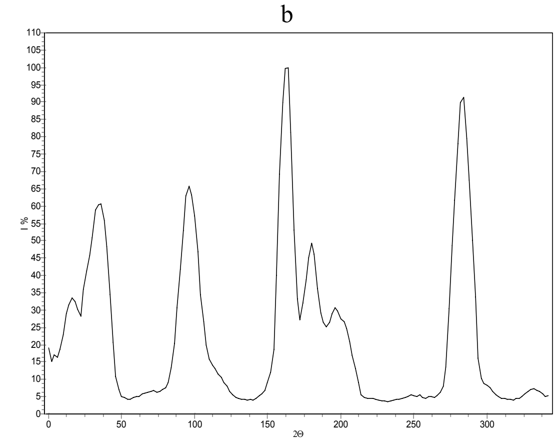
These processes lead to the formation of the annealing texture. The aluminum have the low temperature melting (660 °C), high heat conductivity (237 W/(m·K) at 300 K) and the small shear modulus (29,5 GPa) and therefore the recrystallization processes not evolve at the ion current density 50 A/cm². An increasing of the ion current density results in a development of these processes. Data of the metallographic analysis shown on Fig. 2 justify the development of the recrystallization and growing of the recrystallized grain with the increasing of the ion current density.



a

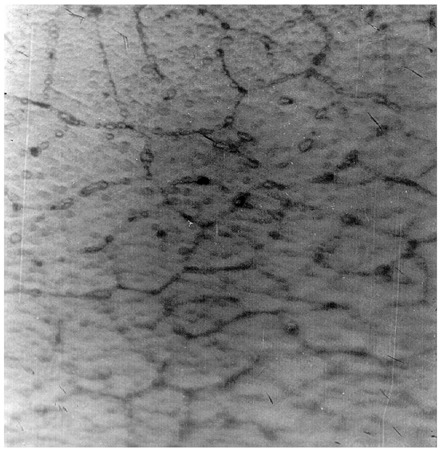


b

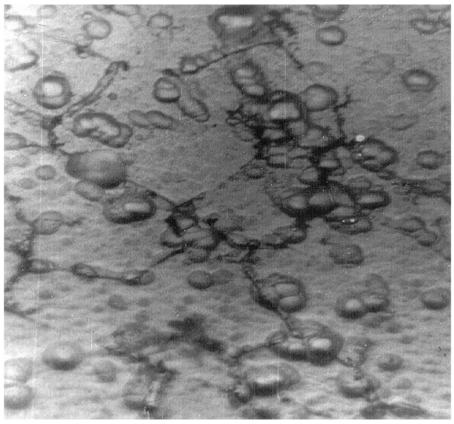


c

Fig. 1. Fragments of the difractogram of Al: a – unirradiated samples; b – sample irradiated by HPIB with *j*=50 A/cм², c – sample irradiated by HPIB with *j*=150 A/cм²



a



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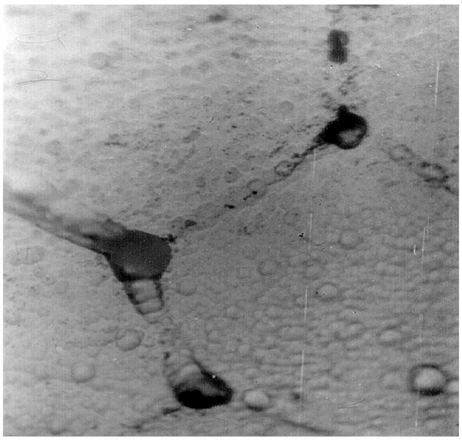

c

Fig. 2. Microstructures of the aluminum before and after HPIB irradiation (x460): a) initial; b) *j*=50 A/cm² c) *j*=150 A/cm²

On samples irradiated by HPIB with the ion current density 100 and 150 A/cm² was observed the growing recrystallized grain. On nickel samples the textured maximums were found for all the ion current density of HPIB irradiation. The nickel have the high melting temperature (1455 °C), the low heat conductivity (91 W/(m K) under 300 K) and comparatively high shear modulus (76,98 GPa). Therefore formed textures are probably not the growing textu-

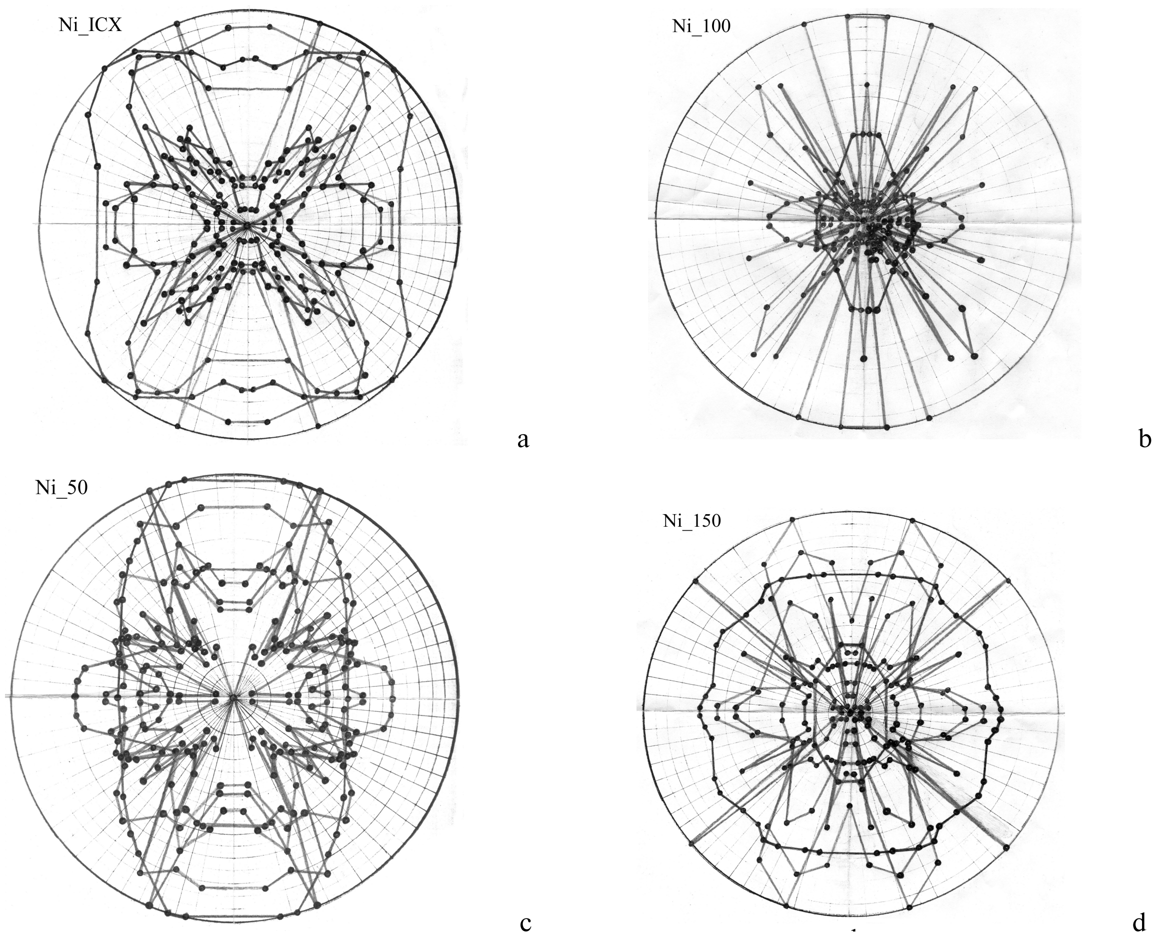

Fig. 3. The direct pole figures built by means of nets Boldyreva for samples of the nickel: a – unirradiated; b, c, d – HPIB irradiated with the ion current density 50, 100 150 A/cm^2, respectively

re, but the deformation texture. These data are confirmed by the results of the metallographic radiographic analysis which indicate sharp refinement of the grain in the nickel sample under all the ion current density of HPIB irradiation and increasing 1,2 and 3 types of the stress. The analysis of the DPF was shown that the formed texture in aluminum and nickel samples is the axial texture with axis of the projections [001]. On Fig. 3 are presented DPF for the nickel.

In this the case the basic orientations of texture are planes (111) and directions [001]. The analysis DPF for samples of the nickel irradiated by HPIB with j=150 A/cm^2 has shown that lines to equal intensity degenerates in the like lines for untextured sample. This can be connected with the strong refinement of the grain for such mode of the irradiation and impossibility defining of the some directivities.

The calculation of the inverse pole figures (IPF) was conducted by two normalization methods on Vilison and Morris [3, 4]. It is established that under the normalization on Vilison the preferable orientation is a normal to atomic plane (111). For the case of normalization on Morris: the preferable orientation is normal to planes – (111), (100), (110). The normalization on Morris gives more detailed and more exact information about location of the normal to atomic planes relative to the working surface of the sample.

The average pole density [5] was calculated. Results of the calculation are presented in Table 1. It is seen that the pole density in the textured sample depends on mode of HPIB irradiation. For aluminum the maximal average pole density correspond the ion current density 150 A/cm^2, for nickel 50 A/cm^2. The maximal pole density for nickel considerably exceeds the maximal pole density for aluminum.

This data indicate that external direction of nickel sample irradiated by HPIB at j=50 A/cm^2 with comparatively greater probability is the parallel normal to planes (111). This direction coincides with the direction of the heat rejection in depth of the sample.

Table 1.

Material	j, A/cm^2	P_{middle}, ad. unit
Al	100	30,9
Al	150	46,9
Ni	50	87,1
Ni	100	18,1
Ni	150	45,2

4. Conclusion

Texturing of the near-surface layers of metals at HPIB treatment was investigated. It was found that:

1. HPIB irradiation of the aluminum and nickel samples gives rise to forming the axial texture with axis of the projection [001]. In addition in aluminum it is the texture of recrystallization, but in nickel it is the texture of deformation. The absence of the texture in the aluminum samples irradiated by HPIB with j=50A/cm^2 can be connected with insufficient for recrystallization the temperature of near-surface layer.

In the nickel samples irradiated by HPIB with j=150 A/cm^2 one cannot determinate the direction of the texture. The probably it is connected with strong refinement of grain under such the ion current density. The small grain size has not allowed to reveal the directivity of grain.

2. Planes and axis of the texture was determinated. In aluminum and nickel it is the plane (111) and the direction [001]. The direction of the heat rejection was determined for textured samples. This direction corresponds to the direction of normal to atomic plane (111).

References

[1] V.A. Gribkov, V.I. Grigorev, B.A. Kalin and V.L. Yakuschin, *Perspective radiation-beam technologies of the processing material*, Moscow, Round year, 2001, pp. 309–328.

[2] M.M. Borodkina, E.N. Spektor, *Rentgenographical analysis of the texture of metals and alloys*, Moscow, Metallurgy, 1981, pp. 43–46.

[3] I.P. Kudryavcev, *The texture in metals and alloys*, Moscow, Metallurgy, 1965, pp. 87–106.

[4] G. Vasserman, I.Grevem, *The texture of metal materials*, Moscow, Metallurgy, 1969, pp. 501–527.

[5] I.V. Gervas'eva, Fizika of metal and materials science, 98, 80 (2004).