

EFFECT OF LASER INFLUENCE ON MARTENSITE TRANSFORMATION INTO NEAR-SURFACE LAYERS OF Fe-AL-C ALLOYS

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The solid solution of Fe-Al-C alloys in wide concentration and temperature intervals consists of austenite phase with f.c.c. crystal lattice (γ -phase), ordered carbide $\text{Fe}_{4-x}\text{Al}_x\text{C}_y$ (K-phase) with f.c.c. lattice, tetragonal α -martensite and aluminium ferrite with b.c.c. lattice (α_k) [1, 2, 3]. In the quenching process of alloys from high temperatures (1000-1250 °C) into the water, owing to propensity of aluminium and carbon atoms to ordering, in f.c.c.-lattice of γ -phase along crystal directions [100] submicrovolumes (0.2 - 1.5 nm) with higher contents of alloyed elements and higher degree of the nuclear order are forming [2]. The f.c.c.-lattice of these submicrovolumes has greater parameter of an elementary cell (0.372 - 0.378 nm), than elementary cell of f.c.c. matrix lattice of γ -phase (0.366 - 0.367 nm). Both f.c.c. - lattices are equally oriented and coherent among themselves. After cooling to the liquid nitrogen temperature austenite transform to α -martensite, particles of K-phase don't transform to martensite to the liquid helium temperature. Coherency and the mutual orientation of f.c.c.-lattices γ - and K-phases equally with introduced into γ -lattice carbon atoms determine not only parameters, but α -martensite with b.c.c.-lattice formed from austenite also:

1) α -martensite, formed from austenite with f.c.c. lattice which is not coherent with K-phase lattice, has tetragonality degree proportional to the quantity of carbon dissolved in austenite and 24 Kurdyumov-Zachs orientation rates;

2) α -martensite, formed from austenite with f.c.c. lattice being coherent with K-phase f.c.c. lattice, has an anomalous high value of c/a of b.c.c. lattice elementary cell and 48 twinned Greninger-Troyano orientation rates. Degree of c/a -martensite anomaly and quantity of its orientations, except other factors, depend on a value of coherent stresses, arranged between f.c.c. and b.c.c. lattices accordingly γ - and α -phases during the $\gamma \rightarrow \alpha_m$ -transformation process.

It was chosen the single crystalline Fe-4%wt. Al-2%wt.C sample (after quenching the alloy from 1150°C into the water) the axis of which was coincided with the axis [100] of austenite f.c.c. lattice. This specimen was exposed to fivefold (8 msec) laser impulse action (10J) in the end of it, i.e. along the axis [001] _{γ} . Essential changes of austenite structure were not found. Then the sample was cooled into the liquid nitrogen (-196 °C). The series of X-ray surveys was performed in the X-ray chambers of rotation RKV-86 with 0.2 mm collimator aperture

$\gamma \rightarrow \alpha_m$ transformation takes place in the sample. Peculiarities of α -martensite structure on different distances from treated surface allow to determine the character of martensite transformation in different near-surface layers of single crystal sample after laser exposure (Table.1).

A) Surface layer (up to 0.2 mm) consists only of γ -phase which does not undergo $\gamma \rightarrow \alpha$ martensite transformation up the liquid nitrogen temperature. Obviously, it is connected that the layer, during laser influence this nearest to the fusion top surface, is enriched, by ascending diffusion, by alloyed elements, mainly by carbon, which reduce a point of $\gamma \rightarrow \alpha_m$ transition below -196 °C.

B) In near-surface layers 0.25 ÷ 0.75 mm and deeper than 4.5 mm from the surface presence of α -martensite with anomalous high degree of tetragonality testifies that there are additional coherent stresses between the α -martensite b.c.c. lattice and f.c.c. lattice of K-phase submicrovolumes. In this layer after laser influence the coherency between f.c.c. lattices γ - and K-phases is saved and this coherency is not disturbed during the transformation of a f.c.c. lattice of austenite in b.c.c. lattice α -martensite with anomalous high tetragonality. On the stereographic projections is fixed an asymmetrical arrangement of poles α -martensite among themselves and in relation to poles of austenite, that it is possible to explain by presence of residual thermal distortions of an austenite crystal lattice and significant disorientation of coherent scattering blocks, which bring an asymmetry to the lattices orientation of austenite and martensite during $\gamma \rightarrow \alpha_m$ transformation. The quantity of martensite poles testifies about the complete twinning of it in process of martensite transformation (Fig.1,c). It is extremely inconvenient to determine precisely a plane of twinning in this case. In high carbon aluminium alloys the presence of twinning orientations testifies about going of martensitic transformation by the athermal kinetics [4].

C) Formation of α -martensite with $c/a = 1.091$ at a depth of 0.75 ÷ 1.0 mm and 4.0 ÷ 4.5 mm witnesses to the absence of additional coherent stresses between b.c.c and f.c.c lattices of α - and K-phases and corresponds to availability in crystal lattice 2% implanted carbon atoms. In this case the half-width of diffraction reflections (002) α -martensite on X-ray rocking films have decreased twice, i.e. the intense condition in martensite has become significant less, than in previous case. These data, obviously, are connected that in these layers of austenite single crystal during impuls laser treatment the coherence of f.c.c. lattices γ - and K-phases is disturbed, and consequently after $\gamma \rightarrow \alpha_m$ transformation the additional coherent stresses between b.c.c. martensite lattice and f.c.c. K-phase lattice, not connected with introduced carbon atoms, are absent. Reduced quantity of martensite (10.0) poles around of austenite (110) pole on stereographic projection permits to make an assumption that the martensite transformation realizes not on all planes of twinning, i.e. some part of martensite forms on isothermal kinetics [4].



D) Formation of α -martensite with $c/a = 1.009$ at a depth of $1.0 \div 3.0$ mm from the end witnesses about a deficit of alloying elements in near-surface layers on the one hand, and an absence of no matter additional coherent stresses on the other hand. During laser influence take place infringement of a coherence between crystal lattices of austenite and K-phase and ascending diffusion of introduced atoms. From the near-surface layers to surface some quantity of carbon is diffusing, and then, at subsequent cooling, the $\gamma \rightarrow \alpha_m$ transition occurs already in near-surface carbon depleted layer of a single crystal. On stereographic projection more than half of martensite poles are absent (Fig.1, d, e). It is possible to assume, that in this layer martensite transition occurs, basically, on isothermal kinetics by sliding, but not by twinning.

Onto the depth 5.0 mm α -martensite, oriented by 48 twinned Greninger-Trojano oriental rates, was fixed (Fig.1,b).

Thus, it has been established that in austenite single crystal samples Fe-4%wt.Al-2%wt.C subjected to fivefold impulse laser exposure (8 msec,10J) in the direction of crystal lattice [001], structure change of austenite reaches the depth of 4.5 mm from the surface. Analysis of martensite crystal lattice parameter and its orientation relations allowed to make a supposition that after laser exposure near-surface 4.5 mm layer consisted of six different in structure austenite interlayers. Martensite has different orientation in reference to residual austenite in these interlayers.

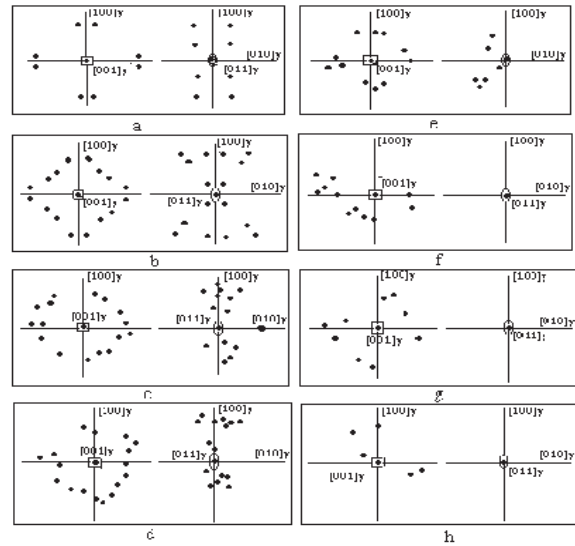


Fig.1. Fragments of stereographic projections α -martensite and austenite corresponding to the X-ray films taken from single crystal: a - carbon steel (24 Kurdjumov-Zachs oriental rates); b - high carbon Al-steel (48 Greninger-Trojano OR); after laser treatment of the single crystal Fe-2%wt.C-4%wt.Al specimen top; c - to 0.2 mm from the top; d - 0.25 - 0.5 mm; e - 0.75 mm; f - 1.0 mm; g - 2.0 mm; h - 3.0 mm.

References

1. Nishida Keiso, *Bull.Fac.Eng.* **24** (1968) 71.
2. Tyapkin Y.D., Gulyayev A.A., Georgiyeva I.G. *FMM (Fizika metallov i metalovedeniye)*. **43** (1977) number 6, 1297.
3. Gulyayev A.A., Tyapkin Y.D., *MeTTM.* **4** (1982) 9.
4. Lysak L.I., Drachinskaya A.G., Andryushchenko V.A., *FMM.* **62.** (1986) no. 1, 98.

	Distance from top surface, mm	Structure state of austenite after laser treatment	Phase structure after cooling to -196°C
1	0.2	f.c.c.-lattice of γ -phase, C & Al enriched	γ -phase
2	$0.25 \div 0.75$	f.c.c.-lattice of γ -phase and submicrovolumes of K-phase are coherent	$\gamma + \alpha_i$ with anomalously high tetragonality
3	$0.75 \div 1.0$	f.c.c.-lattice of γ -phase and submikrovolumes of K-phase are not coherent	$\gamma + \alpha_i$
4	$1.0 \div 3.0$	f.c.c.-lattice of γ -phase, ? C & Al depleted	$\gamma + \alpha_i$ carbon depleted
5	$3.0 \div 4.0$	f.c.c.-lattice of γ -phase	γ -phase
6	$4.0 \div 4.5$	f.c.c.-lattice of γ -phase and submikrovolumes of K-phase are not coherent	$\gamma + \alpha_i$
7	$4.5 \div 10.0$	f.c.c.-lattice of γ -phase and submikrovolumes of K-phase are coherent	$\gamma + \alpha_i$ with anomalously high tetragonality