434. The analysis of defects propagation in navigating electronic devices

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Abstract. Defects in the form of microcracks in Ti_8C_{12} contacts of passive electronic components of navigating devices operating at different temperatures and pressure were analyzed. Research results have demonstrated the possibility of early prevention of potential accidents. Microscopic studies are systematized depending on various physical and chemical influences on devices. The mathematical model for defects definition in local points of contacts with an error of about 5 – 7.5 % has been applied.

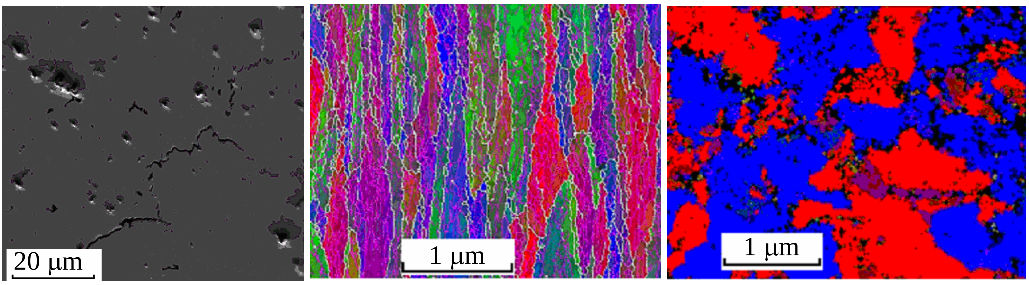
Keywords: defect propagation, cluster, microcrack, grain boundary, navigating electronic devices.

Introduction

Modern mechanical engineering, aircraft and rocket production are impossible without the application of elements of micro- and nano-electronics, multipurpose sensors and navigating devices. Passive electronic components like resistors, capacitors compose more than 80 % of components in these devices. Such components are produced using traditional rules, practically without the estimation of loadings and vibrations taking place in real operation conditions. Mechanical and thermal influences on separate elements of the navigating devices working in extreme conditions, which impossible to simulate by terrestrial conditions, are not considered also. Actually sign-variable values of temperatures and pressure can be created in terrestrial conditions, combined with vibrations, impacts and other influencing factors. At the same time such objects are affected by gravitational force, Coriolis force, complex bending, torsion, etc., which is difficult to predict and simulate during experiments. In such electronic components sufficiently complex task of local defects prevention is additionally encountered considering potential material changes on the atom-molecular level. Some examples of defects diagnostics in passive electronic components are presented in [1]. Usually at the height from two and more km above ground some contacts collapse, but on the ground after flights such defects cannot be diagnosed by traditional methods. Jumping changes in the quantum conductors caused by recrystallization in the material and the occurrence of microcracks were established during researches of electron transmission through a linear molecule and a role of delocalized and localized electronic states in current formation were investigated [2]. Profile of these defects has been systematized with the subsequent creation of mathematical model of local defect formation and growth. Such mathematical model allows predicting a place and coordinates of defects on an external conductor surface [3].

Experimental

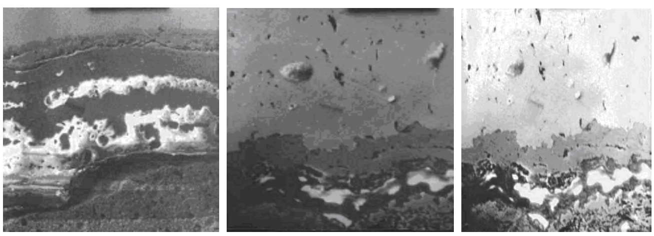
The purpose of present work is the study of destruction processes (occurrence and propagation of microcracks and other defects) in passive electronic components Ti_8C_{12} contacts due to external influences, which can be checked using devices with ferro-modulation sensing elements. Examples of hydrogen corrosion of passive electronic components contacts from Ti_8C_{120} and $VC_{0.875}$ are presented in Fig. 1.



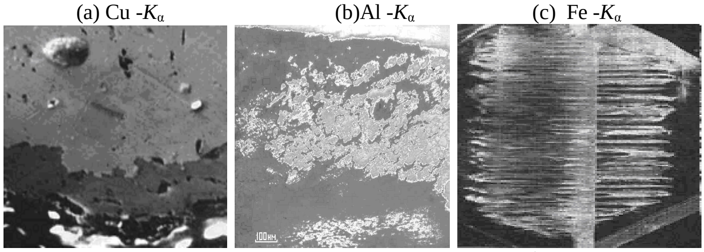
(a) (b) (c)

Fig. 1. Examples of Ti_8C_{12} and $VC_{0.875}$ contacts hydrogen corrosion in the passive electronic components of navigating devices: a) a crack in titanium carbide at changes of air temperature from +20 till 40 ^oC; b) stratification of agglomerates (grains from 5 up to 50 µm) of pressed vanadium carbide due to pulse irradiation and η =22 kHz, I = 20 W/sm^2, τ = 48 hour. The color scale corresponds to transformations of the sample from loadings; c) hydrogen corrosion of pressed vanadium carbide grains from 5 up to 50 microns due to steady and pulse irradiation η =22 kHz, I = 20 W/sm^2, τ = 720 hour (red – the rests of grains, blue – oxides cavities)

In case of vibrations and sign-variable change of temperature and pressure a sample breaks along on grains boundaries between disordered and ordered phases. Disorder – order of VC0,875 → V8C7 nano-crystallites was found by jumping increase of the period of face-centered cubic lattice on 0.0004 nanometers [1, 2]. Results of transmission electron microscopy with microprobe analyzer of secondary electron emission at various Kα radiation can be interpreted on a miscellaneous (Fig. 2, a-e).



(a) Cu -K_α (b)Al -K_α (c) Fe -K_α



(d) Ti -K_α (e) Co-K_α (f) $CaCO_3$-A

Fig. 2. The section of end face of a conductor. Diffraction of reflected electrons at K_α – radiation. JSM-U3 scanning tunneling microscope, × 8000 (a-e) and × 1400 (f)

Thus section of aragonite demonstrates multiple occurrences of parallel microcracks (Fig. 2, f). The morphological research of grains boundaries (Fig. 3, a-c) of heterostructures surface (Fig. 3, d-e) and inside of monocrystal, where from external influences, appear parallel (Fig. 3, f) and transverse (Fig. 3, g) nanocraks and fractures, explain the kinetics of microcracks formation.

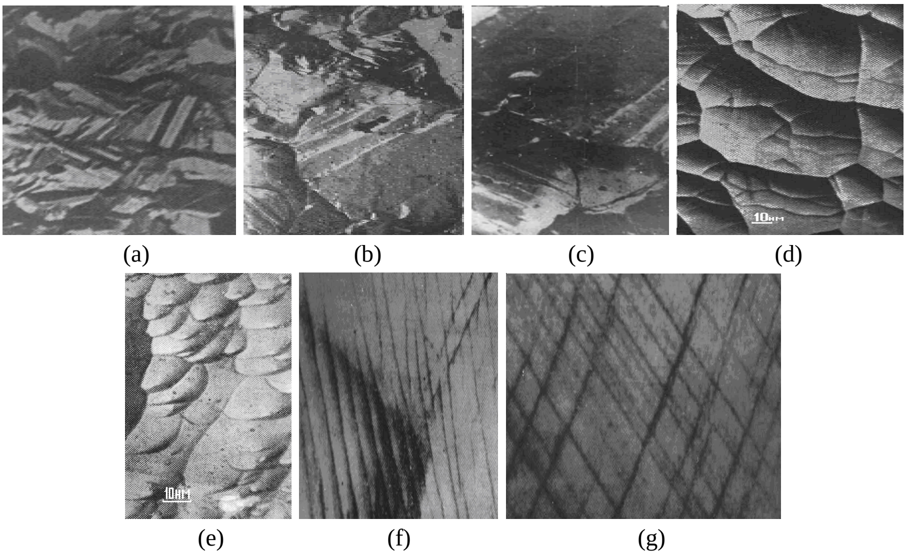


Fig. 3. Photos of structures. Scanning tunneling microscope JSM-U3, × 840000 (a-e), × 1000000 (f-g)

Investigations have revealed the jumping movement of dislocations. Their generation mechanism was described in [4] and further studied from the point of view of particles dispersion and distribution taking into account borders migration [5]. Considering the cluster dispersion with different potential and energy barriers that decrease at elastic pulse action [5], velocity of dislocations movement and migrations of grains boundaries through chaotic grid obstacles was studied too. The phenomenon as the occurrence in a crystal of some effective stresses braking dislocations movement was conditionally considered. But actually any real physical stresses in a crystal did not exist. The analysis of 1860 samples has revealed that during growth grains are joined basically by faces {100} and {110} on polycrystals boundaries. Thus, as a rule, three grains form one general point *A* (Fig. 4), which under the influence of external physical actions and clusters migrates, i.e. a local grain-boundary migration exists.

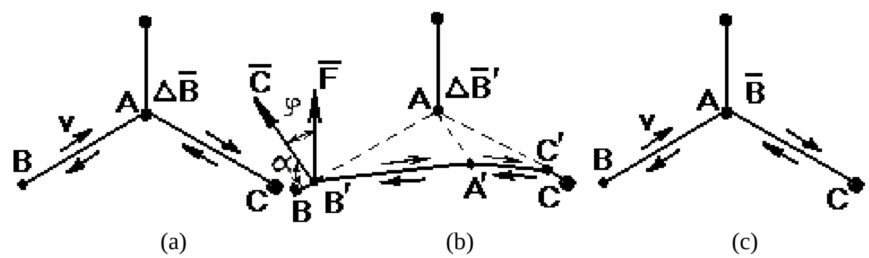


Fig. 4. The scheme of grain-boundary migration: (a) - at the initial moment, (b) - during cluster pressure in a point *A* in direction *AA′*; (c) - returning of boundary in initial position

Local migration and boundaries reorganization in superplastic materials at experiment conditions requires the clarification of cluster role on the change of boundaries migration velocity and their influence on defects growth rate. Analyzing Fig. 4 it was assumed that dislocations with Burgers vector $\Delta\overline{b}$ (Fig. 4, a) are formed during boundary migration through grains junction in places where clusters were accumulated. Such phenomenon prevents the subsequent polycrystals growth [5]. Local reorientation of boundaries near grains junction influences the value, direction and energy per Burgers vector $\Delta\overline{b}$, creating an opportunity for the accumulation of quantum energy in such area to critical value of attack angle. In such conditions cluster dislocations move from junction place to grain volume with further micro-process finish. Thus local move of boundaries near grains junction softens strain fields and conditions grain boundary sliding on sides *BA* and *AC* and with local migration of boundaries to position *B'A'* and *A'C'* (Fig. 4, b). Such migration of boundary leads to quasi-reduction of elastic energy for clusters continuously to the distributed dislocations with Burgers vector density (1):

$$\overline{p} = \Delta\overline{b} / AA' = \omega v_b/v_m \qquad (1)$$

where $v_b = v'_b d$ – rate of grain boundary sliding; v'_b – rate of boundary deformation of border; *d* – the average size of grains (*d* = 1 – 10 nm); *ω* – geometrical factor, which creates the field of instability of internal stresses σ_j near the junction (according [4] a $\sigma_j = A_o Gp/2\pi$,; where A_o – the multiplier of geometry, which depends on a direction of local migration); v_m – average effective speed of grain-boundary migration; *G* – size of a massive, which is affected by local internal stresses σ_j [4]; *p* – dislocations density.

Thus, two-axis dislocation dipole with bend *AA'* is formed on segment *AA'*. Then "total Burgers vector of dislocation dipole" *AA'* achieves the value (*AA'*) and level || lattice dislocation moves from the cluster to grain volume. Therefore with clusters enlarging and grain boundaries the equilibrium position will take place (Fig. 4, c). The Motive force of junction local migration, which foregone dislocation is the pressure force $\overline{F}$ of disposition on the cluster (Fig. 4), equal (2):

$$\overline{F} = 2\overline{C}\sin(\alpha/2), \qquad (2)$$

where $\overline{C} = (G\,|\overline{b}\,|^2)/2$ is tangential tension force acting on dislocation lines.

Thus the attack angle can be defined by the equation:

$$\alpha = 2\arcsin(\overline{F} / 2\overline{C}) = \pi - \varphi, \qquad (3)$$

where φ is a angle between vector $\overline{C}$ and tangential in point *B'* during shift moment.

If $\overline{F} \geq \overline{F}_k$ then $\alpha \geq \alpha_k$ and a dislocation overcomes cluster, grabbing it to grain volume that builds a following layer of polycrystal edge, simultaneously localizing the microcrack without external influence. In case of external influence (sign-variable values of temperature, pressure, vibration, etc.) the dislocation plays a role of a wedge, destroying a material. Hence, the local intense point has been found (point *A*, Fig. 4). The solution of such model is presented in work [6].

Conclusions

Microphotos of radial sections in parallel planes of level-by-level growth of separate polycrystal differ one from another depending on concentration of impurity clusters. However all the subsequent configurations basically differ from the previous by attack angles and in the lengths of dislocations segments containing spherolitic polycrystals. More dense congestion of clusters and crystals boundaries strengthens a material and the number of segments increases more intensively. However, in case of external influence, the stresses on crystal edges increase and this can affect the occurrence of microcracks. According to research results it is possible to affirm that for the control of damage level of such electronic devices magnetostatic methods are applicable using matrixes with ferro-modulation sensing elements. Particularly such diagnostic technique is in development for space engineering applications. Diagnostics of micro objects destruction can be performed using a mathematical model with the subsequent solution of corresponding problems and the transition from the known differential equations of an electromagnetic field to the integral type, based on Green's identities, can be accomplished. Such model allows not only prediction of microcrack generation but also estimation of direction of their propagation during operation of devices. The calculation of physical fields in the general statement of a problem is more applicable to objects with the metal weight not less than 1 g and thickness of substrates more than 500 nm. Therefore for detection of defects on micro objects with area about 1-2 mm^2 and layer thickness 0.2-10 nm another concept of modeling for predicting processes of micro objects destruction should be developed.

Acknowledgements

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