Dynamical instabilities and mass transport in solids surfaces under external stress

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It is well known that in solids under external stress the mass transport rate is several orders of magnitude bigger than in the relaxed state. It is usually accepted that this phenomena is due to a high local stresses, which decrease the activation energy barrier for diffusion. However, the matter transport anomalies are also observed in the surface layer of solids under low applied stresses $\sigma/E \approx 10\text{-}4\text{-}10\text{-}3$ (E is the Young's modulus). In particular, at the Ge (111) surface the pattern with two wavelengths and with two different amplitudes of these waves is formed [1]. This structure is formed at the stage of inelastic deformation under applied stress $\sigma/E \approx 10\text{-}4$. The difference between the patterns formed under low and high stress is related to the lifetime of these structures. In the case of a low stress, the lifetime is finite (from few to tens minutes). If diffusion mechanism of mass transport is assumed, then a diffusion coefficient will be depended on the local curvature of the surface. Therefore the mass transport occurs faster in the zone with larger curvature [2-4]. However, using this model the formation of inhomogeneous structures with the large amplitudes at a short time scale is difficult to explain.

In considered paper a new insight on this problem is proposed. It was shown that taking into account the electron degrees of freedom in the general Hamiltonian allows to explain the high frequency oscillated heterogeneities appearing on the solid surfaces under external stress. It was demonstrated that electron-electron interaction leads to additional dynamic displacements of atoms and, consequently, to an additional mass transport. As example, a semi-infinite homogeneous isotropic one-component solid under uniaxial stress has been considered. In this approach two order parameters have been introduced: first, related to the perturbations of the electronic subsystem and the second described the dynamic atomic displacements. The coupled system of differential equations describing the evolution of the system has been obtained. The detail analysis of the solutions of these equations has been done. It was shown that the resulting short-lived waves can be associated to the damped auto-solitons i.e. localized non-equilibrium states of a system of nonlinear equations. The peculiarities of soliton excitation and the role of the thermal excitations on the matter transport processes at surface layer in solids under stress have been discussed.

References

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