Redeposited thin film's islands structures formation induced by multiple pulse impacts.

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Abstract

Plasma-surface interaction is investigated by means of computer simulation kinetic codes on the base of Ito-Stratonovich stochastic differential equations solution. Model of the heterogeneous condensation of metal vapour on the surface at fluctuation stage takes into account the both: adatoms clustering (or islands formation) and its Brownian motion due to a long-distance indirect islands interaction potentials. The structure of a thin film's islands deposition depends on surface irregularities: valleys and ridges due to blistering are able to be torn loose from surface, a fragments have to emit adatoms as well to acquire a charges.

The impact of powerful pulse fluxes of nano- and micro-second duration of ionizing radiation (IR) initiate a processes of surface damaging, formation and evolution of defects (lattice's pores under sample, islands of deposited materials on surface). The alteration of structural and phase state is calculated for the both: kinetic model of blistering and deposited liquid metal islands. The self-organization phenomena are similar to the layers of pores as well the chains of islands metal and alloys of chromium-manganese austenite steels. A correlation has been established between surface density of "macroscopic" structural defects on the irradiated plane of material - blisters and craters - and the density of high-energy helium (or hydrogen) atoms implanted into the sample during one pulse of the impact. In both cases the density mentioned had the value order of 10^5 cm^{-2}. In this paper we examine irradiation of steel by impulse of He ions with energy ~ 10 keV and dose ~ 10^{18} ions/cm^2. The examined steel must contains more refractory and less scattered component and less refractory but more scattered component, for example W and Ni. The impulse of IR cleans of the surface from fatty and others pollution on the one hand and on the other hand it results in surface scattering and change of the surface relief. We consider that the fluctuating stage of high-temperature blistering takes place during IR impulse and deposition of less refractory constituent of steel after IR impulse. New computer simulation methods [1,2] are concerned with modeling of nonequilibrium phase transition in "open" physical system and anomalous Brownian diffusion of defects in crystal lattice (or on the surface), which leads to synergetic self-organization phenomena (appearance of layers of porosity, wiskar's grows, structures of thin film cover's islands and others). Stochastic simulation method which is based on quasilinear equation of Fokker-Plank-Kolmogorov kind, statistically equivalents to the system of stochastic differential Ito-Stratonovich equations and on effective scheme of its solution which have been presented by modified computer simulation method of SDE solution (Artem'ev method [3]) which gives us information about kinetic distribution functions of defects (or thin film islands) from its sizes and depth in sample or from island's sizes and surface coordinates. Computer simulation results of redeposited thin film cover islands distribution are discussed with point of view of synergetic's surface structures formation.

Stochastic differential equations have common form for all examined processes: blistering, thin film formation and liquid metal cluster formation. The equation of cluster size has following form

$$\frac{dg}{dt} = -\frac{1}{kT} D_g(g,t) \frac{\partial \Delta\Phi(g,t)}{\partial g} - \frac{1}{2} \frac{\partial D_g(g,t)}{\partial g} + \sqrt{2D_g(g,t)}\xi(t),$$

$$t_0 \le t \le T_k, \quad g(t_0) = g_0 \in [g_{\min}, \ g_{\max}], \quad g(t) > 2,$$

g is cluster size, D_g is diffusion coefficient in size space, $\Delta\Phi$ is Gibbs potential, T_k is duration of fluctuating stage, ξ is stochastic function corresponding with increment of Wiener process, g_0 is initial cluster size (cluster size at moment of start calculation), g_{min} and g_{max} size boundaries of fluctuation.

The equation for one of space coordinate (x) has following form:

$$x(t) = x(t_0) + \int_{t_0}^{t} H_x(\tau, x(\tau), y(\tau), z(\tau))d\tau + \int_{t_0}^{t} \sigma(\tau, x(\tau), y(\tau), z(\tau))dW(\tau)$$

$$H_x = -\frac{1}{\gamma M_g} \frac{\partial U(x,y,z)}{\partial x} - \frac{1}{2} \frac{\partial D_x}{\partial x}; \qquad \sigma = \sqrt{2D_x}$$

U is potential of interaction between clusters, cluster and surface (for blistering) and cluster and surface defect (for thin film formation). Interaction between clusters is indirect, through lattice acoustic phonons and Friedel oscillation of electron density [1,2,4]. D_x is diffusion coefficient along x-axis, W is Wiener process.

The values of corresponding coefficient and model assumption for each examined case can be fond in previous paper of authors [1,2]. Let us begin consideration of corresponding part of examined problem.

Blistering is a process of formation of lattice defect's gas bubbles (blisters) in the subsurface layer of a solid body irradiated by flux of gas ions (with low solubility). Recently we put forward the model of heterogeneous condensation on bubble surface, non-equivalence of bubbles position (most likely that bubbles embedded in the lattice point), the breaking of connections of crystal lattice [1]. Bubbles can come on surface and destroy on it. If suppose that before start of IR impulse the surface of steel substrate was ideal what surface after finish of fluctuation stage looks like as fig.1.

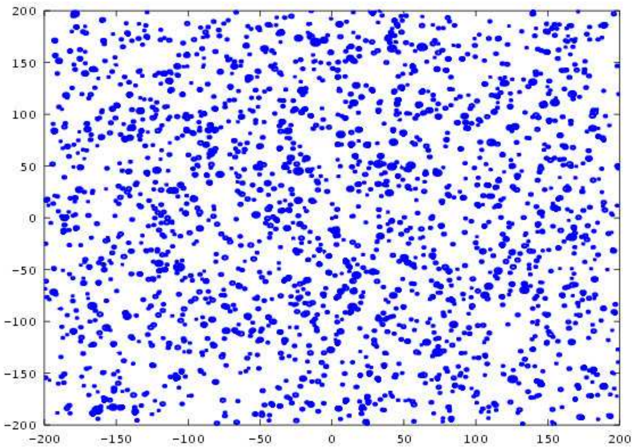

Fig.1 The steel surface after finish of fluctuation stage of blistering is shown. Colour indicates imperfections of surface: blisters covers and craters which were formed when bubbles destroyed on surface. Space coordinates *x* (abscissa axis) and *y* (ordinate axis) are measured in lattice parameters of steel.

Let us examine the formation of thin film of less refractory material on surface of more refractory materials with presence of imperfection on surface [2]. In case of linear dislocation on solid surface the solid surface will be look like fig.2 at finish fluctuation stage.

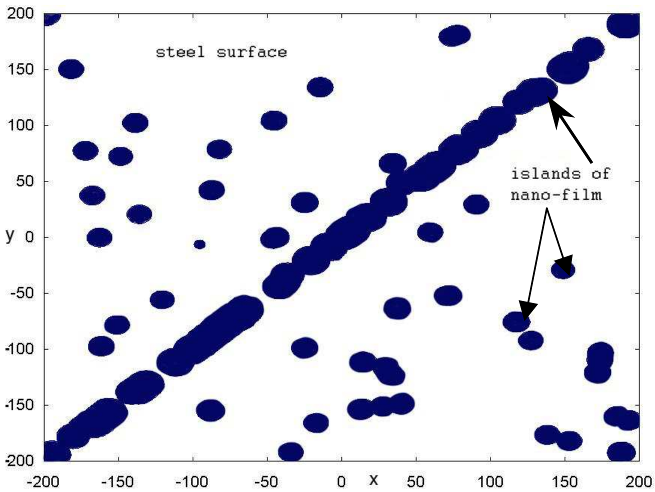

Fig.2 presents the surface of steel substrate with linear dislocation at time of fluctuation stage finish. The dislocation equation is $y=x$. Space coordinates *x* (abscissa axis) and *y* (ordinate axis) are measured in lattice parameters of steel.

Numerical experiments confirm that probability of islands positions near dislocation is several times more than far from it.

So, we can conclude that blistering during IR impulse makes non-ideal surface relief with knolls and craters which radiuses are from 2Å to 15 Å usually. These surface defects such as dislocation or grain boundary are centres of thin film formation after IR impulse. Surface imperfections quicken nano-film formation.

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