DEPOSITION OF NANODROP PHASE FROM EMITTER TIP ON NEARBY MOBILE SURFACE

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The formation processes of low-sized structures by the means of fine-dispersed phase of liquid metal ion source (LMIS) are considered. The emitting tip is located in close distance from moved surface with the aim of deposition of narrow stripes. At distance tip – surface near 80 µm on the axis of thin and wide traces of (İn$^+$, Sn$^+$) ions the massive continuous paths by width of several microns are obtained. The structure of deposited stripes by the length more than 10 mm is the grain structure. At further approach of tip to surface the path melts because of high density of ion current and heterogeneous profile of its cross-section becomes smooth. For deposition of narrower structures, it is necessary the effective cooling of conducting mobile substrate.

Keywords: liquid metal ion source, field emission, nanoparticle.
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INTRODUCTION

The nanodrop deposition on conducting surface is very perspective method for the creation of different surface structures. For this purpose, the liquid metal ion sources are used. The generation of charged drops on certain conditions takes place in liquid metal ion sources along with ion field emission [1]. If divergence angle of ion beam achieves 90^0 then the divergence of drop flux is 3- 4^0 [2]. The size of ion emission zone is near 5 nm that confirms the high original density of ion current and small sizes of generated drops. The sizes of the least charged drops are obtained from the condition of Relay stability [3]:

$$\frac{E^2}{8\pi} \rangle \frac{2\sigma}{R},$$

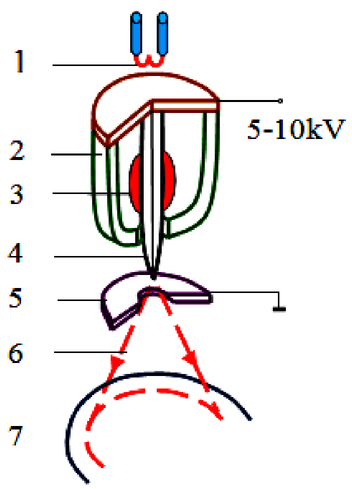
where E is field strength on surface of a drop of radius R, σ is liquid surface tension coefficient.

The histogram of deposited particle sizes presents itself the sharply decreasing exponential function in range 2- 40nm [2]. The number of small particles on 3 order exceeds the number of the biggest ones. The separate drops with sizes near100nm are observed. Note that the generation of nanoparticles takes place by threshold way and it is accompanied by ion current oscillation with frequency of tens of megahertz (MHz). The excitation of capillary instability on surface of liquid emitter [4] is the reason of the oscillation.

The registered particle sizes define the formation possibility of low-sized structures on the surface by the means of source dispersed phase that is the subject of present investigation.

EXPERIMENT

The LMIS of container type, by the means of which the beams of ions In, Sn, Au, Ni, Ge, B (fig. 1, a) are obtained, is used.



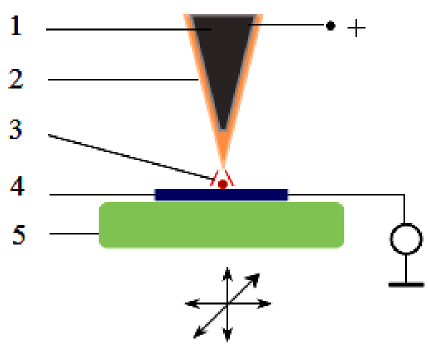


Fig. 1. a) LMIS scheme: 1 is cathode, 2 is container, 3 is working substance, 4 is tip, 5 is extractor, 6 is ion beam, 7 is collector; b) scheme of substrate three-dimensional shift relative to emitter tip: 1 is tip, 2 is working substance, 3 is ion beam, 4 is substrate, 5 is piezo-table.

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The material of refractory tip is chosen for each working substance with the aim of reliable wetting of its surface. The graphite container with the tip and working substance is heated from backside by electron bombarding up to melting point of working substance. The strength of several kilovolt for the achievement of ion emission, is given on extractor situated in the distance up to 1mm from the tip. At ion current near 40 μA (In, Sn) its oscillations with frequency of tens of megahertz appear, simultaneously, the charged particles are generated. At necessity the beam composition is defined by the means of mass-analyzer with crossed electromagnetic fields of Vin velocity filter type [5]. Taking under consideration the small divergence of nanoparticle beam it is possible the obtaining the narrow paths at horizontal shift of substrate situated in close distance from the tip. In the given case, the complex ion optics isn't used. The polished plates from cuprum, tungsten, molybdenum and silicon are used in the capacity of conducting substrate. The piezo-table by mark PZU 2300 which allows the vertical shift up to 300µm with accuracy to 1nm and horizontal shift up to 100 mm (fig. 1, b), controlled by the computer, is used for precision shift of the substrate in three coordinates. The velocity of horizontal shift varies in interval 0,5–2 mm/sec. The piezo-table is put in vacuum camera. It demonstrated the reliable work at residual pressure $p \lesssim 10^{-5}$ mm of mercury. The system is mounted on the base of vacuum installation A-700 Q Leybold-Heraeus with turbo-molecular evacuation. The deposited stripes are analyzed by the means of optical, raster electron and atomic force microscopes.

RESULTS AND DISCUSSION

At usual ion release by the means of extractor (distance tip-extractor 0,5–1mm) the emission threshold voltage is 5÷6 kV. At the replacement of extractor by the plane substrate and approach of tip to it, the emission voltage essentially decreases. The stripe containing ions and indium nano-particles deposited on the tungsten plate is presented in fig. 2.

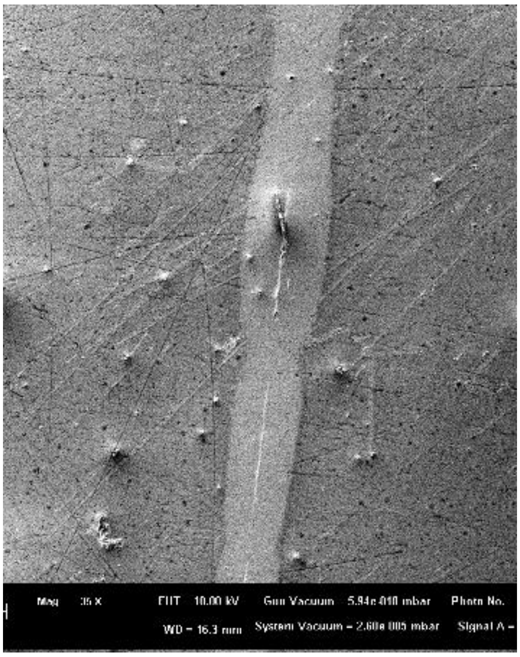
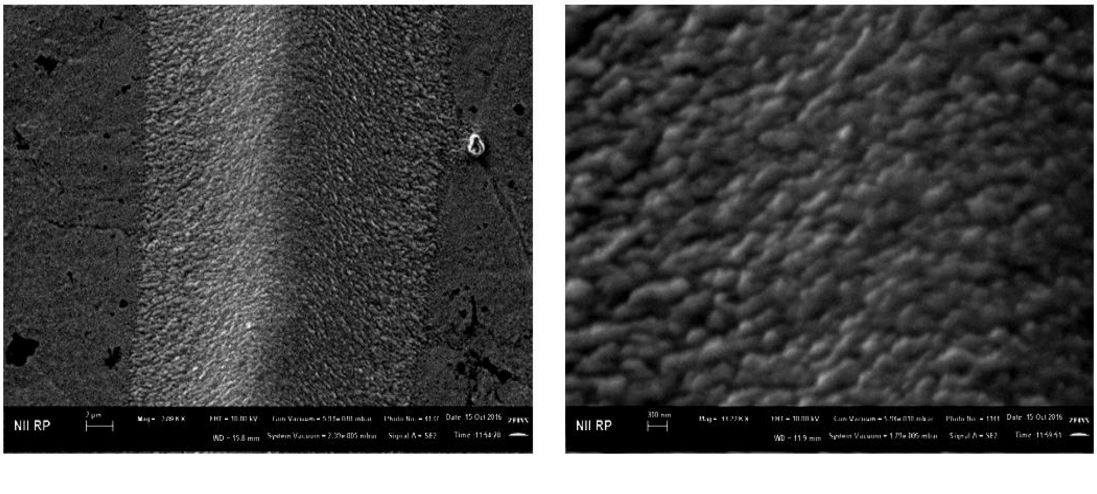


Fig. 2. FEM is the image of indium stripe on the surface of tungsten plate.

The extraction voltage is 4,5 kV, the distance tip-plate is 200µm. The stripe has the width near 200µm and it is defined by diameter of ion beam. The narrow path caused by nanodrop deposition is clearly seen in the middle of the stripe. This path width is 20µm (fig. 3, a) and its central region is essentially increased in comparison with neighbor regions, it has coarse-grain structure (fig. 3, b). The character diameter of extended grains is 50-60 nm and the length is 100-200 nm. These sizes exceed the generated nanodrop sizes [6, 8]. Probably, the substrate significantly heats, the deposited particles aren't condensed that leads to their coagulation and formation of big grains because of high density of ion current. The calculation shows that the ion current density is approximately 10A/cm^2 on the distance 10 cm from tip and beam power is $3 \cdot 10^4$ Vt/cm^2. The effective energy dissipation from the substrate is necessary in order to the nanodrops condensed not attach to each other.



a) b)

Fig. 3. a) FEM-image of the trace of deposited nanoparticles; b) trace structure.

The substrate is fixed to massive cuprum radiator for increase of thermal tap from the substrate. The approach of the tip to the surface allows us to deposit the narrower stripes with axial path width in several microns (fig. 4).

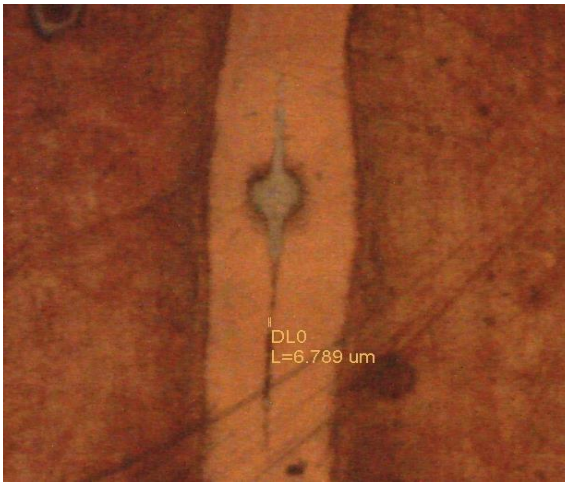
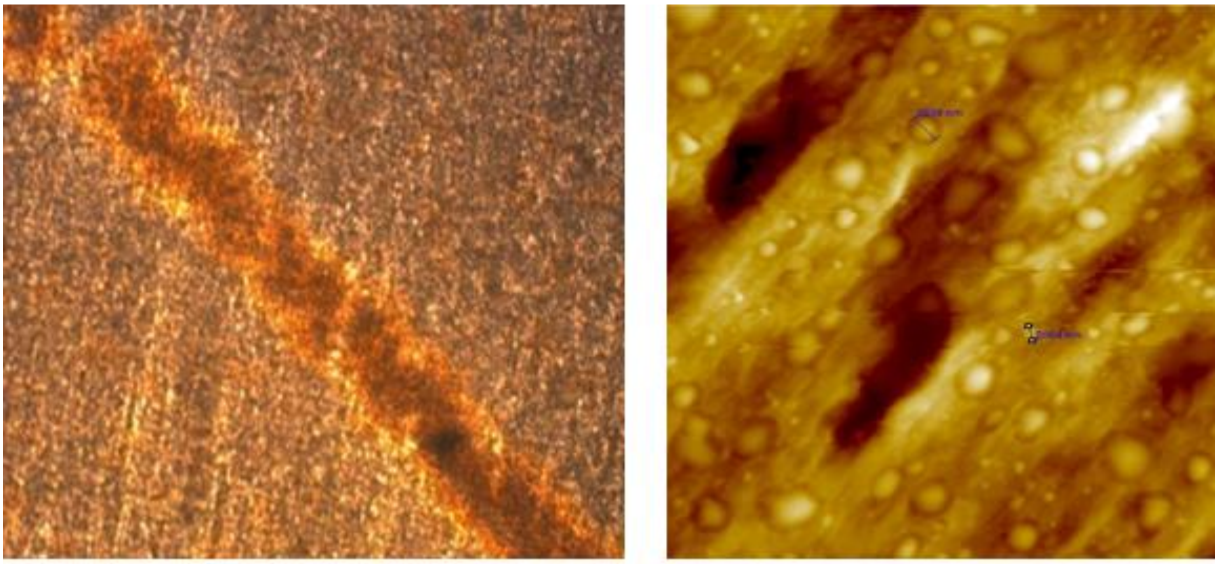


Fig. 4. The optical image of indium stripe on the surface of cuprum plate. The distance tip-plate is 80 μm, U= 3 kV.

The further approach of the tip to the surface leads to smoothing of transversal profile of the deposited stripe: it becomes more heterogeneous one (fig. 5, a). Probably, now the deposited substance is heated almost up to the melting point and axial massive path isn't condensed. The stripe structure isn't already grain one but in it the dispersion phase distributes evenly (fig. 5, b). The big particles with sizes in several microns are easily distinguished, but probably, the number of small particles is essentially exceeding the number of big ones.



a)   b)

Fig. 5. a) AFM-image of indium stripe on the surface of molybdenum plate. The distance tip-plate 50 μm, U =3,5 kV, b) Dispersed stripe structure.

CONCLUSION

The long stripes In and Sn of width in several microns are formed by deposition of fine-dispersed phase of liquid metal ion source on nearby uncooled surface. The stripe structure is caused by particles of submicron sizes. There are not complex elements of ion - optical devices in system. The formation of narrower surface structures presenting themselves the practical interest is possible by appropriate substrate cooling. If paths are deposited on cooled thin metal film, then it can be eliminated by etching. The given method can be applied in micro-electronics with the aim of carrying out of different technological operations.

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