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POINT-CONTACT I–V CHARACTERISTICS OF THE ELECTROLUMINESCENT ZnS:Mn,Cu THIN FILMS STUDIED BY STM*

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STM images of ZnS:Mn,Cu thin films and spatially resolved current–voltage characteristics are shown. The results make possible to estimate the morphology and conductivity distribution with nanometer resolution.

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I. Introduction

Recently discovered Scanning Tunneling Microscope (STM) [1, 2] has been developed into an effective and very important tool for studying the properties of physical surfaces [3]. One of the most interesting subject to which the STM is being currently applied is space resolved Scanning Tunneling Spectroscopy (STS) the first time suggested by Selloni et al. [4] and realized by Hamers et al. [5].

The STS gives information on surface properties through I–V or $(\mathrm{d}I/\mathrm{d}V)$–$V$ characteristics measured with STM at different spots with a resolution of few angstroms [6].

The conductivity of thin ZnS:Mn,Cu films was studied previously by the authors in connection with the dc-electroluminescence [7, 8].

In this work we have used the STM to obtain images of ZnS:Mn,Cu thin film surfaces and also to obtain spatially resolved I–V characteristics using STM in point-contact mode. To the best of our knowledge, so far there have been no reports on searching these films by STM.

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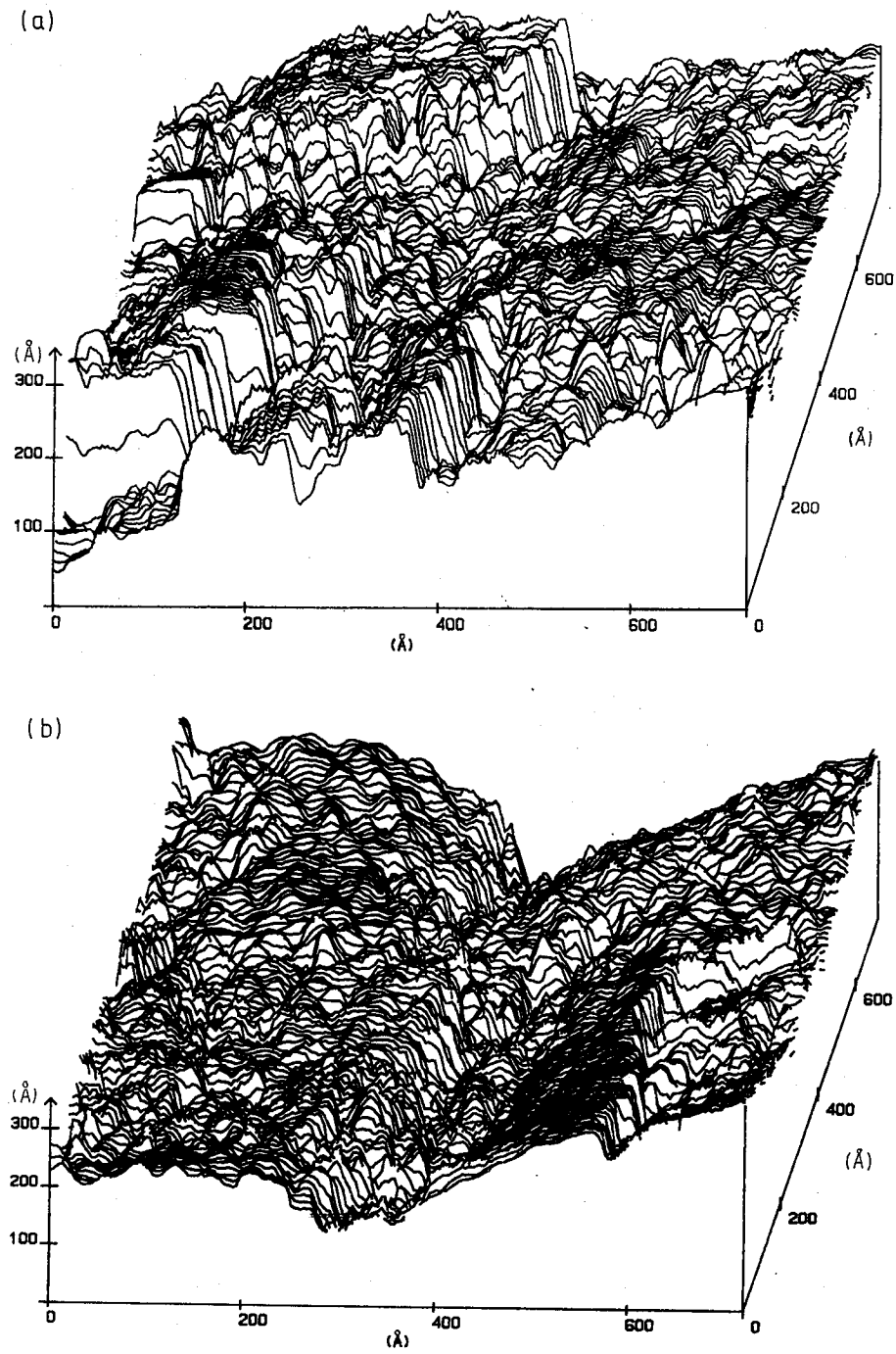

Fig. 1. Two typical 72 × 72 nm^2 STM images of ZnS:Mn,Cu thin film surface. The tunnel current – 4 nA, the bias voltage – 0.5 V (a), 0.05 V (b). Room temperature.

II. Experimental

The local tunneling I–V characteristics were performed using home-built cryogenic scanning tunneling microscope with VERNITRON piezotube similar to that described by Fein et al. [9].

The control of x, y motion of the tip and collecting the data were provided by an interactive program written for an IBM compatible PC/AT computer. Point-contact characteristics were made with the feedback of the STM turned off. Tungsten and gold probe tips obtained by chemical etching were applied. The samples were prepared in the following way. Thin ZnS:Mn films were deposited on a glass substrate, previously provided with indium-tin-oxide, by thermal evaporation in vacuum of about 10^{-4} Pa. Copper was introduced into the film through immersing it in aqueous solution of $CuCl_2$ and then annealing at 673 K in vacuum to force an uniform dopant distribution and a structure improvement. More details on the preparation of the samples can be found elsewhere [7].

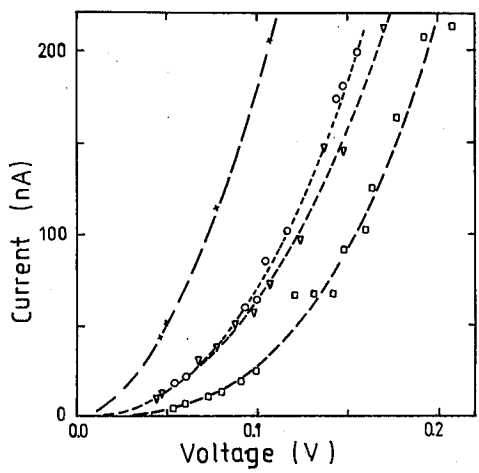

Fig. 2. Point-contact current–voltage characteristics measured at different spots of ZnS:Mn,Cu thin film, at 77 K. Lines represent the best fit to power function ($I \propto V^n$) with n varying from 1.9 to 3.0.

III. Results and discussion

This work has been aimed at getting an information about the usefulness of STM in studying thin electroluminescent films of ZnS:Mn,Cu. Two kinds of experiments have been carried out.

In the first experiment STM images were obtained by scanning the film surface area of about 70×70 nm^2. Although the film layout is rather irregular, some characteristic features can be noticed as well in Fig. 1 as in other pictures taken for

different samples and in different spots. Some parts of the film are distinguishable elevated, their surface being flat. The steep walls of the elevation are about 10 nm in height. The features suggest assuming these regions to be microcrystallites of size ranging from 10 to 20 nm. The second characteristic feature in STM images is existence of "ditches" (see Fig. 1b) that separate two different regions.

In the second experiment with STM point contact current–voltage characteristics with the tip-sample distance reduced to zero were measured. To date, we have not been able to fix the measuring tip at the intentionally selected spot, so the characteristics have been taken in random spots of the sample. The set of I–V characteristics spatially resolved, measured at 77 K, is shown in Fig. 2. The points are experimental data and the curves has been fitted to power functions which appeared to be the best fit.

Although the characteristics differ significantly, they all follow the power function $I \propto V^n$, where n varies from 1.9 to 3.0 suggesting the conduction mechanism to be the space-charge-limited-current, as previously has been assumed in [8]. The variations of I–V plots are coherent with the film morphology mentioned above.

These tentative results show that the application of STM for studying the electroluminescent ZnS:Mn,Cu films should be a fruitfull method giving detailed information about morphology and the distribution of local conductivity in the subnanometer scale, not available by other methods.

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