Whisker junctions between growth structures on CdS layers

E. NIKOLOVA, S. SIMOV, N. PASHOV, E. KANTARDJIEVA
Institute of Physics, Bulgarian Academy of Sciences, Sofia, Bulgaria

A phenomenon is described when two growth structures in evaporated CdS layers could be linked by a whisker at a certain height above the layer surface as a result of which a bridge-like system is created. The experimental techniques of obtaining CdS layers are described. The peculiarities of these bridge-like systems were studied by electron microscopy (TEM). Simple bridge-like systems are reported, consisting of a single whisker connecting two growth structures and some more complicated cases where this link is realized by whisker-platelet-whisker.

The phenomenon described is discussed in terms of the diffusion-dislocation mechanism of whisker growth. Assumptions have been put forward concerning the impact of such formations on the local parameters of the layer.

1. Introduction

Several papers [1-4] have been published on the growth of whiskers in obtaining CdS monocrystals from a gas phase. Sears [1] reported CdS whisker growth at condensation of a saturated gas phase. Ibuki [2] observed, under specific conditions (sublimation and recrystallization in a nitrogen flow), the growth of CdS monocrystals and long whiskers with a diameter of several microns. Reynolds and Green [3] produced whiskers several microns thick and up to 3 cm long together with CdS crystals grown from gas phase in an atmosphere of H_2S. Certain problems of the dislocation growth mechanism of whiskers from CdS have been discussed by Chikawa and Nakayama [4].

We are aware of only two papers concerned with observations on whiskers grown on evaporated thin layers of CdS [5, 6]. Tooper *et al* [5] found that whiskers grow on CdS layers deposited through evaporation on mica monocrystals. Kaganovich *et al* [6] observed with the aid of a metallographic microscope radially divergent sheafs of whiskers ending with spheres, on monocrystal CdS layers evaporated on mica substrates.

In our previous publications [7, 8] were announced electron-microscopic observations on whiskers grown on the surfaces of thin CdS layers deposited on cleaved mica substrates through evaporation *in vacuo*. These whiskers had the form of needles with a diameter of ~ 0.1 μm, length up to 4 μm and mean density of distribution on the substrate 2 to 5×10^6 cm^{-2}. Whiskers ending with a polyhedral formation were most frequently found. They were named "pin-like" whiskers. Their morphology is described in [7], while in [8] are discussed certain aspects of the growth of monocrystal heads characteristic of pin-like whiskers.

In the present paper a phenomenon in the growth of CdS whiskers is described which has not so far been encountered in the literature. It has been found that two growth structures could be linked by a whisker at a certain height above the layer surface. In this way a bridge-like system is created.

2. Experimental techniques

The layers on which were found these whisker junctions were obtained by evaporation of CdS *in vacuo* of the order of 10^{-6} Torr from a closed quartz crucible, the temperature of the CdS source being $650 \pm 50°C$ (CdS of spectral purity was used). Fresh air-cleaved mica sheets heated to $300 \pm 30°C$ were employed as substrates. It has been experimentally established that out of this temperature range, well-formed whiskers do not grow. The deposition rate was about 3Å sec^{-1}.

The thickness of the layers determined with the aid of an interference microscope varied between 1 and 2 μm.

The surface structure of the layers was studied by electron microscopy (TEM), using C/Pt replicas obtained by the conventional method of Bradley by the simultaneous evaporation of carbon and platinum. To separate the replica from the layer, CdS was completely dissolved with nitric acid.

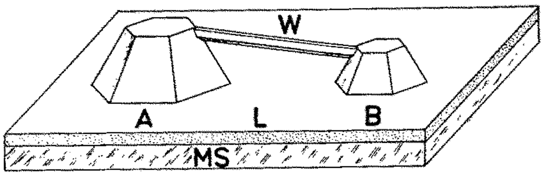

Figure 1 Diagram of a bridge-like system: A = growth structure, B = growth structure, W = whisker, L = CdS layer, MS = mica substrate.

3. Results and discussion

Fig. 1 shows schematically what we mean by a bridge-like system. This system consists of A-W-B, where A and B are growth structures and W is the whisker (bridge) that connects them. In a previous publication [7] we pointed out that CdS whiskers growing from definite growth structures, are always oriented nearly parallel to the basal plane. Such a bridge system observed on a CdS layer grown in this way is shown in Fig. 2. A continuous transition was established in many such simple and more complicated systems. Examples of such complicated transitions between growth structures based on the system whisker-platelet-whisker are shown in Figs. 3 and 4.

Theoretical and experimental studies on the kinetics of the growth processes of whiskers carried out by a number of authors have

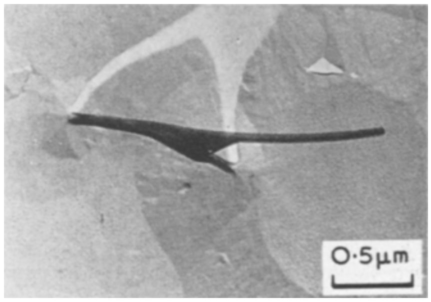

Figure 3 A complicated bridge-like system (whisker-platelet-whisker).

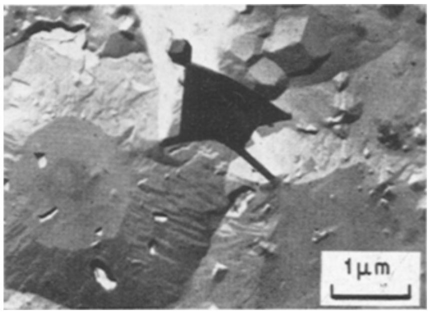

Figure 4 A complicated bridge-like system (whisker-triangular platelet-whisker).

confirmed in many cases the diffusion-dislocation mechanism of their formation from a gas phase.

The essence of this mechanism is presented in [10] and briefly it consists in the following: one-dimensional growth of a whisker is governed by an axial screw dislocation, creating a free step of growth on the top face of the whisker column. The growth is accomplished by the addition of substance to this step both from atom deposition (from the gas phase) directly on the growing face and from diffusion along the lateral column faces towards the top of the whisker. In addition to the

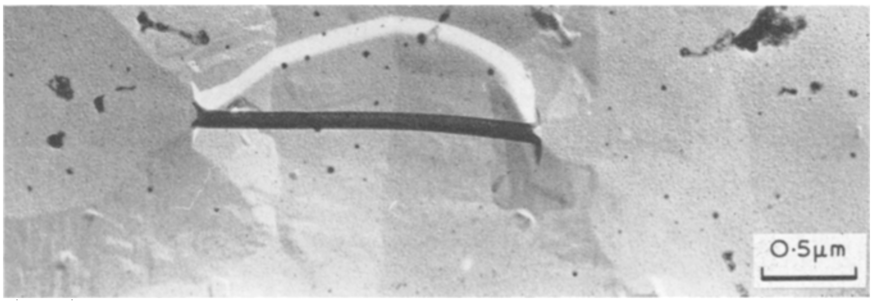

Figure 2 A simple bridge-like system.

axial growth of whiskers, after reaching a definite length, a radial growth also begins.

On the grounds of these concepts concerning the growth mechanism, it is possible to suggest a phenomenon occurring when a whisker starting from a given growth structure contacts the neighbouring one. It is obvious that the growth processes will not be discontinued at the moment of the whisker coming in contact with the adjacent growth structure owing to the continuing time of the transport of material along the whisker column in the direction towards the growing end. So an uninterrupted solid transition can be established between the whisker and the contacted growth structure.

With a system of the type whisker-platelet-whisker it could be assumed that the events proceed in the following sequence: from a growth structure grows a whisker, on which is formed a platelet which in its turn gives rise to a second whisker that is linked to another growth structure. In support of this assumption is the existence of complex whiskers, recently observed by us, which consist of several pin-like whiskers growing from each other and all lying in different planes. These last observations lead us to believe that the formation of a platelet in the case when two different whiskers meet, as was found by Pfefferkorn [9], is a considerably less probable phenomenon at the observed whisker densities in the CdS layers.

As is seen in the micrograph, Fig. 4, a typical platelet has a triangular form and could give rise to a new whisker or a polyhedral formation, or to both.

4. Conclusions

That certain physical properties (mechanical, electrical, optical, etc.) of whiskers strongly differ from those of monocrystals and layers of the same material is a well-known fact. In view of these considerations, the presence of such whisker "bridges" in CdS layers could markedly change some local physical parameters of the investigated layer. This could play an important role in the application of evaporated CdS layers in microelectronic components.

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