Epitaxial CdSe thin films grown by a modified Closed Space Isothermal Vapor Phase Technique using two elemental sources.

O. de Melo, H. Rodríguez
Physics Faculty, University of Havana, San Lázaro y L, Vedado, 10400 Havana, Cuba.

Abstract: Using a closed space isothermal vapor phase technique we have grown CdSe thin films on GaAs (100) substrates. A boron nitride crucible previously used for the growth of HgCdTe was modified to allow the presence of two elemental sources. The grown is performed by exposing the substrate to these Cd and Se elemental sources successively. Moreover, the theoretical possibility of this kind of growth process is discussed in the work. X-ray diffraction patterns confirm the epitaxial growth of CdSe films on the GaAs substrates.

I. Introduction

In the last years, the growth of low dimensional systems based on II-VI semiconductor compounds such as quantum wells, multiquantum wells and superlattices has received a particular attention due to their potential applications in optoelectronic devices.[1] In particular highly strained systems like CdSe or CdZnSe on ZnSe offer the possibility of obtaining self- assembled quantum dots[2] as a result of the Stranski- Krastanow growth mode. One of the methods to grow these heterostructures is atomic-layer epitaxy (ALE) in an ultra-high-vacuum environment which allows a good thickness control of one monolayer per cycle.[2] In this work we describe an attempt to build a novel and relatively low cost technique, that allows a good control of the film thickness, and a low growth temperature for depositing very thin films of II-VI compounds.

II. Theory

Our analysis is centered in the CdSe system, but the ideas can be extended to other binary compounds. The growth process proposed here consists of exposing the substrate of GaAs (100) to Cd and Se elemental sources alternatively. The whole system is at constant temperature (isothermal condition), for that reason the unique driving force for growing is the compositional difference between the elemental source and the substrate or the previously grown film surface. This difference of chemical potential exists because the vapor pressure of the pure element is higher than that of the compound. At the initial stage of the exposure, the elemental source "sees" a compound (GaAs or CdSe) at the surface of the film. Once the surface covered with the atoms of this elemental source, the difference in vapor pressure (chemical potential) is eliminated, the equilibrium is reached and the growth stops. Next the substrate is shifted to the other source concluding a cycle. From this point of view, the growth is self-controlled and independent of the temperature. This procedure is reminiscent of ALE with the difference that this is a quasi-equilibrium technique (self-controlled by equality of the vapor pressures) while ALE is fully out of equilibrium (self-controlled by means of the sticking coefficient). Although the sticking coefficient definition is not valid for a quasi- equilibrium system like that described here, we can follow the analogy with ALE. A rough approximation would be consider that the sticking coefficient is unity while the surface of the growing films is not completely covered for any of the elements (growing surface vapor pressure lower than source element vapor pressure). After that, the sticking coefficient will be zero up to the next source is placed under the substrate. The time needed for covering the growing surface will be different for Cd or Se (mainly due to the difference in vapor pressures between these two elements), but after this interval the growth will stop. So, if the exposure time is set higher than this minimum time; the film thickness will be determined by the number of cycles rather that by the total time of exposure.

III. Experimental

The deposition system is shown in Fig. 1. A quartz reactor containing a boron nitride (BN) crucible is placed in a flat temperature profile. The crucible has two parts: the upper is mobile and holds the substrate, the lower has two containers for the elemental sources and an aperture that communicates the upper part with the environment, allowing the purging of residual gas that remains in the substrate compartment when it is changed from one source to another. The process occurs in Pd purified H_2 flux.
The CdSe films were grown at 320 °C. The time of exposure to each source was 2 seconds; the growth duration was 100 cycles.

IV. Results and conclusions

The X-ray diffraction patterns were collected by using a D5000 Siemens powder diffractometer with zero point deviation of 0.0012 Å, using Cu-Kα radiation. The diffractogram of a CdSe film is shown in Fig. 2.

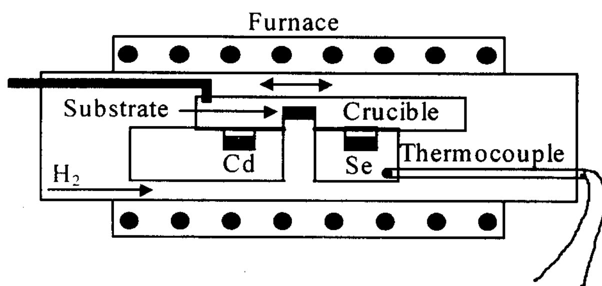

Fig. 1. Sketch of the growing system

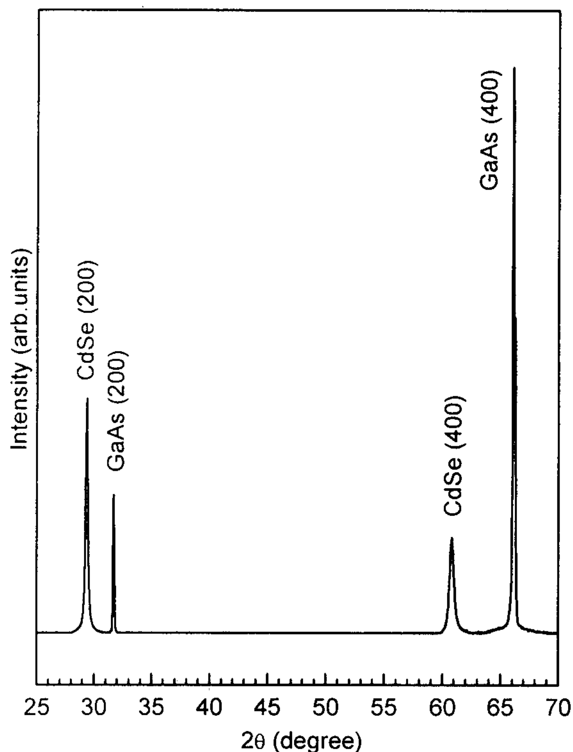

Fig. 2. X-ray diffraction pattern of a CdSe film grown on a GaAs substrate.

Besides the two peaks corresponding to (200) and (400) diffractions of the GaAs substrate, only two peaks due to the (200) and (400) diffractions in the CdSe cubic zincblende structure were observed (the doublet observed in the (400) peak of GaAs is due to the characteristic emission spectrum of the x- rays Cu target). This is an indication that the growth was epitaxial. The fact that the (200) peak of CdSe is more intense than the (400) one can not be explained in terms of structure factor of these planes. In fact, for the zincblend structure, one expects that (200) intensity will be lower than (400) intensity. However, a similar intensity relation for a 1μm thick CdSe film grown on GaAs by Metalorganic Molecular Beam Epitaxy (MOMBE) have been observed.[4] The reason of this behavior is not clear but it could be related with deformation of the strained lattice or tilts.

.A thickness of approximately 700 Å was measured with a talystep profilometer. If the thickness is divided by the total number of cycles (100 cycles), we obtain that the growth rate was 7 Å/cycle, which is 1.15 times the reticular parameter. It seems that approximately two monolayer per cycle were deposited in each exposure.

There are two possible explanations for this behavior: i) The equilibrium pressure is attained when about two monolayers of the pure element are deposited; ii) The equilibrium pressure is attained when one monolayer is deposited, but the time of purging was not enough and the atoms of the residual gas (i.e. Se) react with the atoms of the next source (i.e. Cd) leading to the deposition of more than one monolayer on the substrate. This residual gas transported from a source to the other could deposit not only at the growing film but also at the source. In fact we have seen a change in the color of the surface of the Cd source. This indication of cross contamination supports the second explanation.

Acknowledgments

The authors thank to Dr. L. Baños for X-ray measurements, Dr. I. Hernández-Calderón for useful discussions and Ms. S. de Roux for technical assistance.

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