Scanning electron acoustic microscopy of indium-doped semi-insulating GaAs

1993 Semicond. Sci. Technol. 8 320

(http://iopscience.iop.org/0268-1242/8/3/002)

Semicond. Sci. Technol. 8 (1993) 320–321. Printed in the UK

Scanning electron acoustic microscopy of indium-doped semi-insulating GaAs

B Méndez and J Piqueras

Departamento de Física de Materiales, Facultad de Físicas, Universidad Complutense, 28040 Madrid, Spain

Received 28 October 1992, in final form 17 December 1992, accepted for publication 5 January 1993

Abstract. Dislocation lines in {110} sections of In-doped GaAs are imaged by scanning electron acoustic microscopy (SEAM). Cathodoluminescence measurements show the presence of a high indium concentration at dislocations. It is proposed that the semi-insulating property of the sample and dislocation decoration contribute to the SEAM contrast.

1. Introduction

Doping LEC-GaAs with a few per cent of indium can reduce the dislocation density by several orders of magnitude [1]. Semi-insulating indium-doped GaAs is therefore of interest as a homogeneous substrate suitable for device fabrication. Several methods have been used in recent years to observe and characterize the defects present in In-doped LEC GaAs. In (110) specimens, straight ⟨100⟩ dislocations decorated by precipitates as well as doping striations have been observed by x-ray topography and infrared absorption [2, 3]. Scanning electron acoustic microscopy (SEAM) has been used in recent years to characterize compound semiconductors. In the case of GaAs, SEAM has been found [4] to be much more useful for characterizing semi-insulating material than n-type material. SEAM images of semi-insulating undoped and Cr-doped GaAs revealed [4, 5] the cellular structure in these materials while single dislocations were not imaged. Due to the low dislocation density and the semi-insulating properties of GaAs:In, this material appears to be suitable for further study of the SEAM capability in GaAs characterization and in particular for revealing single dislocations under specific experimental conditions. In the present work SEAM has been used to observe {110}-oriented GaAs:In. The observations were complemented by SEM cathodoluminescence (CL) methods.

2. Experimental methods

A {110} sample of indium-doped LEC semi-insulating GaAs was used. The sample had a thickness of 1 mm and polished faces. SEAM measurements were performed in a Cambridge S4–10 or a Hitachi 2500 scanning electron microscope. In order to get additional information on the defects, CL was measured in the same instruments. The CL experimental arrangement has been described previously [5, 6]. The SEAM system used in this work has also been described [7]. Basically it consists of a chopping system with a pair of condenser plates and beam blanking electronics to create a periodically modulated beam with frequencies in the range 40–240 kHz. The acoustic signal is detected by a piezoelectric ceramic transducer on which the sample is clamped.

3. Results and discussion

Dislocations with a certain structure along their lines are observed in the SEAM and CL images (figure 1). The structure, part of which is marked with arrows in figure 1, is probably related to the decoration of the dislocation by impurities and precipitates. The presence of precipitates spaced several microns along dislocation lines in GaAs:In has been described by several authors (for instance in [2, 8]) and seems to agree with the present SEAM observations. It appears then that SEAM allows the observation of dislocation lines in GaAs:In as well as decorating particles. This is a consequence of the particular experimental conditions of this work. The main generation mechanisms of the electron acoustic signal in semiconductors are piezoelectric and excess carrier coupling [9]. In [4] it has been reported that dislocations in n-type GaAs, readily observable by CL, are not visible in the SEAM image due to the high carrier concentration that screens the piezoelectric contribution to the acoustic signal. Only cellular structure and possibly dislocation emergency points are imaged by SEAM in semi-insulating material. It is suggested that the semi-insulating property of the samples used here together with the strong decoration of dislocations by

0268-1242/93/030320+02$07.50

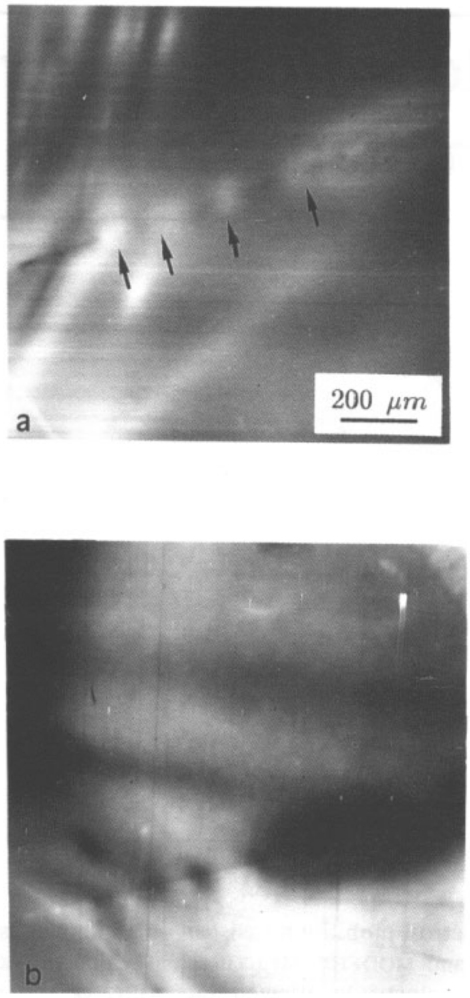

Figure 1. (a) SEAM and (b) CL images of the same dislocation line of a GaAs:In sample. The SEAM image was recorded at room temperature, with a beam energy of 30 keV and a chopping frequency of 100 kHz. Arrows show decoration features along the dislocation line.

indium impurities allow dislocations to be imaged by SEAM. In [4] it has been suggested that the reason for strong SEAM defect contrast of semi-insulating GaAs is related to a piezoelectric signal generation mechanism. In this mechanism the electron beam injection creates a varying electric field in the piezoelectric material, and consequently elastic waves are generated.

A possible contribution to the observed SEAM contrast, besides the piezoelectric contribution, is the effect of a high indium concentration at the dislocation. Bresse and Papadopoulo [10, 11] have shown that the electron acoustic signal varies with the doping level in GaAs and observed doping striations in heavily (10^{20} atoms cm^{-3}) Be-doped GaAs. This effect was attributed to the impurity-induced variation of the thermal conductivity of the semiconductor. This suggests that the dislocation contrast could be enhanced by a high indium decoration. In order to investigate this possibility CL spectra have been recorded at different points of the sample. Figure 2 shows the CL spectra at the dislocation line, in its proximity and in a dislocation-free region. The different points were determined from the CL image. The peaks of the spectra appear with a relative shift which is attributed to the different local indium concentration. Kirillov *et al* [12] have reported that the indium content determines the position of the luminescence band maxima. Taking into account this observation, the spectra of figure 2 reveal a higher (about a factor 2) indium concentration at the dislocation than in a region that is distant from dislocation lines. This result supports the possibility that indium decoration contributes to the dislocation SEAM contrast.

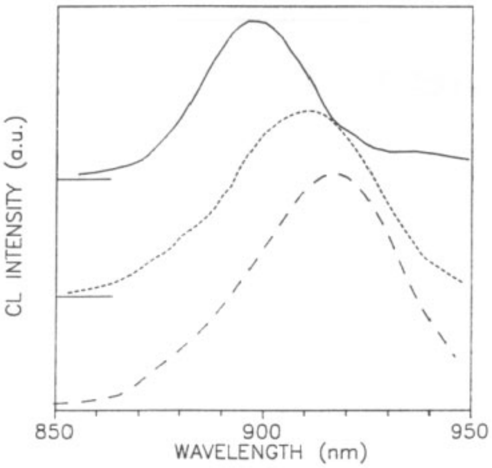

Figure 2. CL spectra from different positions in the sample. The full curve corresponds to a spectrum from a dislocation-free region; the long and short broken curves are spectra recorded at the dislocation line and in its proximity respectively.

Acknowledgments

This work was supported by the Volkswagen Foundation and by DGICYT (Project PB 90–1017).

References

[1] Jacob G, Farges J P, Schemali C, Duseaux M, Hallais J, Bartels W J and Roksnoer P J 1982 *J. Crystal Growth* **57** 245
[2] Stirland D J, Hart D G, Grant I, Brozel M R and Clark S 1987 *Microscopy of Semiconducting Materials 1987 (Inst. Phys. Conf. Ser. 87)* p 269
[3] Kidd P, Booker G R and Stirland D J 1987 *Microscopy of Semiconducting Materials 1987 (Inst. Phys. Conf. Ser. 87)* p 275
[4] Méndez B and Piqueras J 1992 *Appl. Phys. Lett.* **60** 1357
[5] Méndez B and Piqueras J 1989 *Microscopy of Semiconducting Materials 1989 (Inst. Phys. Conf. Ser. 100)* p 789
[6] Méndez B and Piqueras J 1992 *J. Appl. Phys.* **69** 2776
[7] Urchulutegui M, Piqueras J and Llopis J 1989 *J. Appl. Phys.* **65** 2667
[8] Yonenaga I and Sumino K 1987 *J. Appl. Phys.* **62** 1212
[9] Kultscher N and Balk L J 1986 *Scanning Electron Microscopy I* p 33
[10] Bresse J F and Papadopoulo A C 1988 *J. Appl. Phys.* **64** 98
[11] Bresse J F and Papadopoulo A C 1987 *Appl. Phys. Lett.* **51** 183
[12] Kirillov D, Vichr M and Powell R A 1987 *Appl. Phys. Lett.* **50** 262