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B-7-1 X-Ray Topographic Study of Lattice Defects Related with Degradation of GaAs-$Ga_{1-x}Al_xAs$ Double Heterostructure Lasers

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Since the degradation of GaAs-$Ga_{1-x}Al_xAs$ double heterostructure (DH) lasers has been correlated with dark-line-defects (DLD) by DeLoach et al.[1], lattice defects in the DH wafers have attracted special interest. Petroff and Hartman observed the generation of dislocation networks in the DLD position by electron microscopy[2]. In order to prevent the DH laser from rapid degradation, DLD sources must be eliminated. Ito et al.[3] identified the DLD sources by photoluminescence topography[4] as; (i) dark-spot-defects (DSD) observed in the photoluminescence pattern, (ii) DH wafer surface damage, (iii) crystal edge, and (iv) stacking faults.

With these data as background, we attempted to clarify the DSD sources by micro-X-ray topography in which a small specimen of $0.01\sim1$ mm^2 size is observable. In this paper, it is shown that almost all DSDs originate from dislocations in the GaAs substrate. In addition, depending on characteristics of the dislocations, some dislocations in the substrate are shown not to be DSD sources.

The specimens examined were chips (about 1 mm^2 x $30\sim400$ μm) cleaved from a DH wafer composed of three alternating layers of GaAs and $Ga_{1-x}Al_xAs$ grown by liquid phase epitaxy[5] on a $\{100\}$ GaAs substrate. This small sized specimen is convenient for taking an X-ray topograph of a curved specimen.

Before taking the X-ray topograph, the DSD distribution was investigated by means of photoluminescence topography[4] as shown in Fig. 1. In this figure the alphabetical characters A, B, and L and a, b, c, and d show the specific positions of the specimen and the DSDs, respectively.

After the large sized DSDs were correlated with lattice defects by an anomalous X-ray transmission topography using a 400 μm thick specimen including both a GaAs substrate and three alternating layers of GaAs and $Ga_{1-x}Al_xAs$, a normal X-ray transmission topograph of the substrate was taken in order to identify the DSD sources. This was done after the substrate was thinned from the back surface to about 30 μm in thickness and all epitaxial layers removed. This is because it was suggested that DSDs originated from dislocations inherited from the GaAs substrate[3].

As seen from the topograph of the substrate shown in Fig. 2, the dislocation pattern of type **a'** is the same as the one constructed by small sized DSDs (

type **a**) seen in the photoluminescence topograph shown in Fig. 1. The Burgers vectors of these dislocations were determined to be ½ **a** <110> parallel to the growth surface because these dislocation images vanished in topographs of g_{220} and $g_{\bar{1}\bar{1}1}$. Rozgonyi et al.[6] proposed a dislocation elimination technique in the DH wafer by adding phosphorous to the $Ga_{1-x}Al_xAs$ layers. Their technique is only effective in eliminating dislocations whose Burgers vector is ½ **a** <110> inclined at 45° to the interface plane because the misfit dislocation induced in the interface has the same Burgers vector. It should be noted that the Burgers vector of the type **a'** dislocation is different from that of the misfit dislocation. Therefore, their technique is not effective in the elimination of dislocation threading to the DH layer identified in our experiment.

Present results show that almost all DSD sources are substrate dislocations which terminate in the growth surface of the substrate. However, some dislocations whose axes are nearly parallel to the growth surface had no correlation with any DSDs. An etching study using AB etchant supported the above result , namely, about half of the DSDs were correlated with dislocation pits appearing on the surface of the wafer. This is because the pits are produced only at β-dislocations, if no impurity segregation occurs.

Present results show that the use of dislocation-free GaAs substrates is effective in eliminating DSDs. In fact, it is observed that the radid degradation scarcely occured in a DH laser fabricated from a DH wafer grown on a dislocation-free substrate.

References : 1) B. C. DeLoach et al., Proc. IEEE 61, 1042('73). 2) P. Petroff and R. L. Hartman , Appl. Phys. Lett. 23, 469('73). 3) R. Ito et al., J. Quantum Electron. July ('75 to be published). 4) R. Ito et al., Japan. J. appl. Phys. 12, 1272('73). 5) I. Hayashi et al., J. Appl. Phys. 42, 1929('71). 6) G. A. Rozgonyi et al., Appl. Phys. Lett. 24, 251('73).

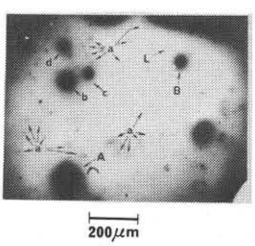

Fig. 1. DSDs (a, b, c, and d) observed by photoluminescence topography.

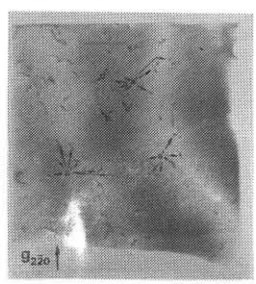

Fig. 2. An X-ray topograph of the GaAs substrate using $(2\bar{2}0)MoK_{\alpha 1}$.