PHOTOLUMINESCENCE IN POLYCRYSTALLINE GaAs AT 5K

P. B. Perry and A. E. Blakeslee
IBM Research Center
Yorktown Heights, New York 10598

(Received September 20, 1978; revised April 17, 1979)

Photoluminescence at 5K is used to measure the radiative recombination in a potential solar cell material -- polycrystalline GaAs. In some samples the electron-hole pair recombination is extremely efficient, yielding luminescence intensities up to 40% of that of monocrystalline GaAs. These samples are characterized by a peak at approximately 1.49eV, which is similar to that observed in the monocrystalline GaAs. However in other samples a broad, less intense band at approximately 1.47eV is seen.

Key words: GaAs, solar cells, photoluminescence.

Polycrystalline GaAs deposited on an inexpensive foreign substrate has been proposed as the active material for low cost solar cells. The major problem to be anticipated with photovoltaic devices made from such layers is grain boundary recombination. Since the loss of photogenerated minority carriers by recombination at grain boundaries would seem to be related to the reduction in luminescence efficiency by defects, a process that has been extensively studied, examination of polycrystalline GaAs films by low temperature photoluminescence (PL) might provide an indication of whether a given layer will yield an efficient solar cell. Use of this technique has not been reported for polycrystalline GaAs, but T. Yao et al. have used it in the study of defects in molecular beam epitaxially-grown ZnTe polycrystalline thin films. Related work on amorphous silicon was done by Engemann et al., who, with the aid of luminescence
data, were able to obtain some insight as to the nature of defects in non-crystalline silicon.

The GaAs films that we have chosen to study with this technique were grown by the metal-organic mode of chemical vapor deposition, wherein gaseous Ga(CH$_3$)$_3$ and AsH$_3$ react to form GaAs on RF-heated substrates. Substrates used for this work were W, Ta, fused quartz and graphite. They were cleaned in typical fashion with solvents and acids, rinsed with deionized water, and subjected to an in situ bakeout at 1000°C. All but one of these films were grown at 700°C, using a partial pressure of 0.3 Torr Ga(CH$_3$)$_3$. The partial pressure of AsH$_3$ was either 1.5 or 6 Torr. These conditions produced films with average grain size $\sim$ 0.5 $\mu$m on all substrates. The other film, sample BV-40, which showed the most interesting behavior, was made with a two-step growth procedure. This consisted of nucleating the grains for 30 seconds at 600°C and 0.3 Torr Ga(CH$_3$)$_3$ plus 1.5 Torr AsH$_3$, then continuing the growth at 850°C with the Ga(CH$_3$)$_3$ pressure reduced to 0.1 Torr. This process resulted in a film with considerably larger grains on the average of about 2 $\mu$m in diameter. It was difficult to say with any certainty what the doping levels were although it was known that sample BV-40 was definitely n-type.

For excitation, the 1 watt 5145Å (2.41eV) line of an Ar$^+$ laser was used. The incident power density was approximately 50 watts/cm$^2$. The samples were cooled in a Janis dewar and held at the desired temperature of 5K. The radiative recombination emission was chopped at 100 Hz and analysed with a single pass Spex spectrometer. The slit resolution of the spectrometer for all the runs reported here was 3Å. The detector used was a cooled S1 photomultiplier in tandem with a lock-in amplifier.

In figure 1 we show the luminescence spectra of five samples taken at 5K. Sample D112 is monocrystalline GaAs and is included here as a reference. Its spectrum was obtained using the same geometry and conditions as in all the samples shown. Samples BV16-2 and BV3 were grown on W substrates. The BV16-2 sample had a 'high' As/Ga ratio of nominally 20:1, compared with the As/Ga ratio of 5:1 for the other samples. Samples BL33 and BV21-2 were grown on SiO$_2$ and tantalum substrates respectively, using the preparation technique described above.

The data shown in figure 1 suggest two distinct classes of results. The class I spectra reproduce quite closely the luminescence spectrum characteristic of monocrystalline GaAs, although with a somewhat attenuated peak intensity and a small frequency shift. In addition these peaks are accompanied by two sideband excitations at $\sim$1.45eV and $\sim$1.515eV. The class II spectra are quite different and consist of a single rather broad