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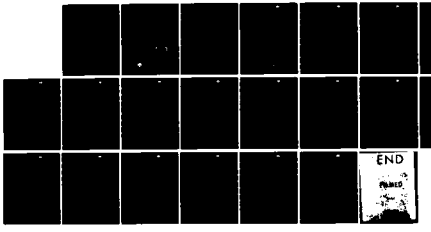

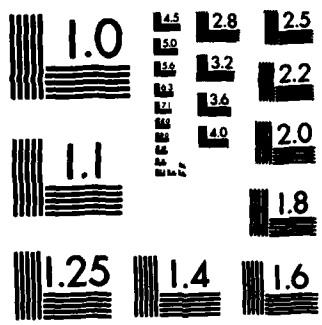

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GROWTH OF CdTe/HgTe SUPERLATTICE WITH THE LADA TECHNIQUES

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Principal Investigator

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Growth of HgTe/CdTe has been demonstrated by the laser assisted deposition technique (LADA). HgTe and CdTe compounds were used as sources. Multi-layered structureswere deposited by scanning a pulsed laser beam alternately over these sources. Superlattice parameters such as composition and period thickness were controlled by the scanning mode of a focused laser beam. The superlattices were characterized optically and electrically. Effect of band narrowing due to superlattice formation was observed.

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1.0 INTRODUCTION

Superlattice (SL) is a modulated structure made of alternating layers of two or more materials. The band edge offset between the constituents form periodical energy barriers which confine the carriers and create new energy levels known as the sub-bands.[1] These quantum mechanical features result in many unique electro-optical properties not found in corresponding alloy systems. The properties are determined by two parameters: composition and period thickness.

Constituents forming a superlattice must have the same crystalline structure and closely matched lattice constants. Many materials satisfy this requirement. However, the success in achieving desired properties critically depend on precise control down to a few atomic layers, i.e., thickness, uniformity, interface abruptness, etc. Among the existing growth techniques, molecular beam epitaxy (MBE) offers the most accurate control over these parameters, and to a lesser extent, similar controls are also offered by metallo-organic chemical vapor deposition (MOCVD). Most MBE and MOCVD work have been concentrated on III-V compounds, therefore, it is not a surprise to see that the majority of the known superlattice systems belong to the III-V family,[1] with few exceptions such as GaAs/Ge[2] and $Pb_{1-x}Sn_xTe/PbTe$[3] systems.

With recent surge of interest in epitaxial growth of HgCdTe for IR imaging applications, a new superlattice of HgTe/CdTe[4] has been proposed. Constituents of this system are very dissimilar. CdTe is a semiconductor with an energy gap of 1.6 eV. HgTe is a symmetry induced zero-gap semi-metal. The Γ_6 state that typically forms the conduction band of a zincblende structure lies 0.3 eV below the Γ_8 state of the conduction band. In the theoretical investigation by Schulman and McGill,[4] a zero band offset was assumed on the basis of common anion arguments and the similarity of the host lattice constants. Same assumption was also adapted in other calculations using different formalisms.[5,6] The conduction band discontinuity provides barriers for the motion of electrons which give rise to two-dimensionally confined electron

states in HgTe layers. When the layers become very thin, box quantization effect will remove the Γ_6/Γ_8 degeneracy and form subbands. Figure 1 shows the variation of HgTe/CdTe superlattice bandgap with period thickness (i.e., HgTe layer thickness) for several compositions, as calculated by Schulman and McGill.[4] The gap starts from values close to that of the corresponding alloy. It decreases gradually and approaches zero asymptotically. Calculations by Smith[5] and by Bastard[6] show similar trends except a more gradual approach to zero gap. The ability to tune the energy gap throughout a wide range of IR spectrum by changing the period thickness suggests the potential application of HgTe/CdTe superlattice as an IR detection material. It will be most advantageous to be used for detecting far IR radiation. In that region, the SL bandgap dependence on HgTe layer thickness is weak, thus reducing the fabrication problem regarding response uniformity. On the contrary, the bandgap of an alloy is a very sensitive function on composition in this region and uniformity control will be difficult. The confined carrier motion behavior also gives rise to other device possibilities. Calculation by Smith indicates the reduction of tunneling length due to the barriers of the CdTe layers. The tunneling length of a superlattice along the superlattice axis is much shorter than the tunneling length of an alloy with the same energy gap. Therefore, he suggests the use of superlattice to fabricate photodiode with low tunneling for far infrared detection. These speculations justify the merit for detailed study of this system.

Despite the attractive potential, fabrications of this superlattice have only been realized recently by MBE[7] and by LADA.[8] The latter work will be reported here. The experimental difficulty is the control of Hg vapor associated with HgTe. HgTe does not evaporate congruently[9] and the Hg partial pressure over HgTe is so high that it can re-evaporate from the as-grown HgTe layers even at low (~ 100°C) temperatures. In this work, we have successfully grown this superlattice by LADA. Section 2.0 presents experimental details with emphasis on the uniqueness of LADA and the procedures taken to circumvent the Hg confinement problem. Section 3.0 presents preliminary results on material characterization. Optical transmission measurements were used to

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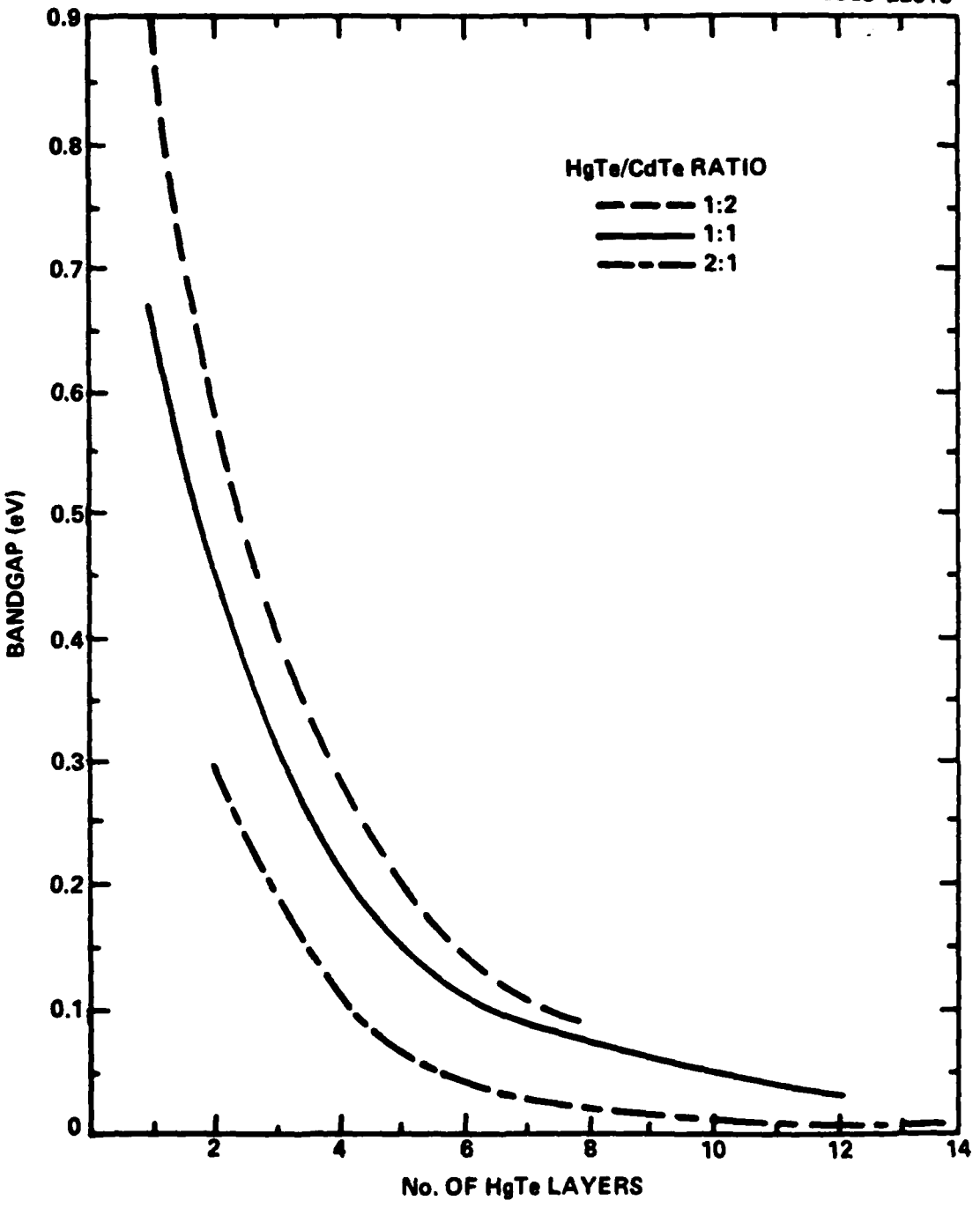

Fig. 1 Variation of bandgap with the thickness of HgTe layers in a HgTe/CdTe superlattice (from Ref. 4).

show the gap narrowing effect due to superlattice formation. Section 4.0 presents Hall measurements data. In a collabration with Prof. Ong of University of Southern California (his effort was supported by U.S. Air Force AFOSR 78-3530), some detailed electrical characterizations were made as a function of temperature and magnetic field intensity. One superlattice exhibited 2-D transport behavior. This is the first reported observation of 2-D behavior in a HgTe/CdTe superlattice. Results on the 2-D transport behavior have been submitted to Phys. Rev. Lett. for publication.[8]

2.0 EXPERIMENTAL

2.1 General Description of LADA

LADA is the acronym for Laser Assisted Deposition (and Annealing). It is a novel vacuum thin film deposition technique developed at Rockwell International Science Center.

In a conventional evaporative technique such as MBE, superlattice consisting of binary or ternary systems were grown by sequentially manipulating mechanical shutters in front of elemental sources. In LADA, the compounds (e.g., HgTe, CdTe) were used. Their evaporations were induced by pulsed laser irradiation. Periodical growth was facilitated by scanning the laser beam over the multiple sources. This section will give an overview on LADA technique and its uniqueness. Finally, the LADA approach to multilayer growth will be described.

Figure 2 shows a LADA apparatus. It consists of a vacuum chamber and a pulsed laser. The chamber is pumped with a Hg-diffusion pump with liquid nitrogen cooled trap and freon cooled baffle. Hg backpressure can be varied from the base pressure of 3×10^{-7} torr up to 1.2×10^{-4} torr by throttling a valve connecting to a Hg source. The presence of a Hg backpressure is essential for HgTe growth.

Substrates were mounted on a molybdenum holder wetted with Ga for uniform thermal contact. During the early stage of the program, (111)A CdTe substrates were used. In the latter stage, superlattices were deposited on a (111) oriented CdTe buffer layer grown on (100) GaAs substrates. Details of this heteroepitaxial system have been reported recently.[10]

Undoped CdTe bulk crystals and HgTe polycrystals were used as sources. CdTe was purchased from II-VI Inc. HgTe was synthesized in-house by homogenizing and reacting a stoichiometric mixture of Hg and tellurium at 720°C. Source materials were placed on separate holders side-by-side 3 cm apart. The holder rotated at 1 Hz.

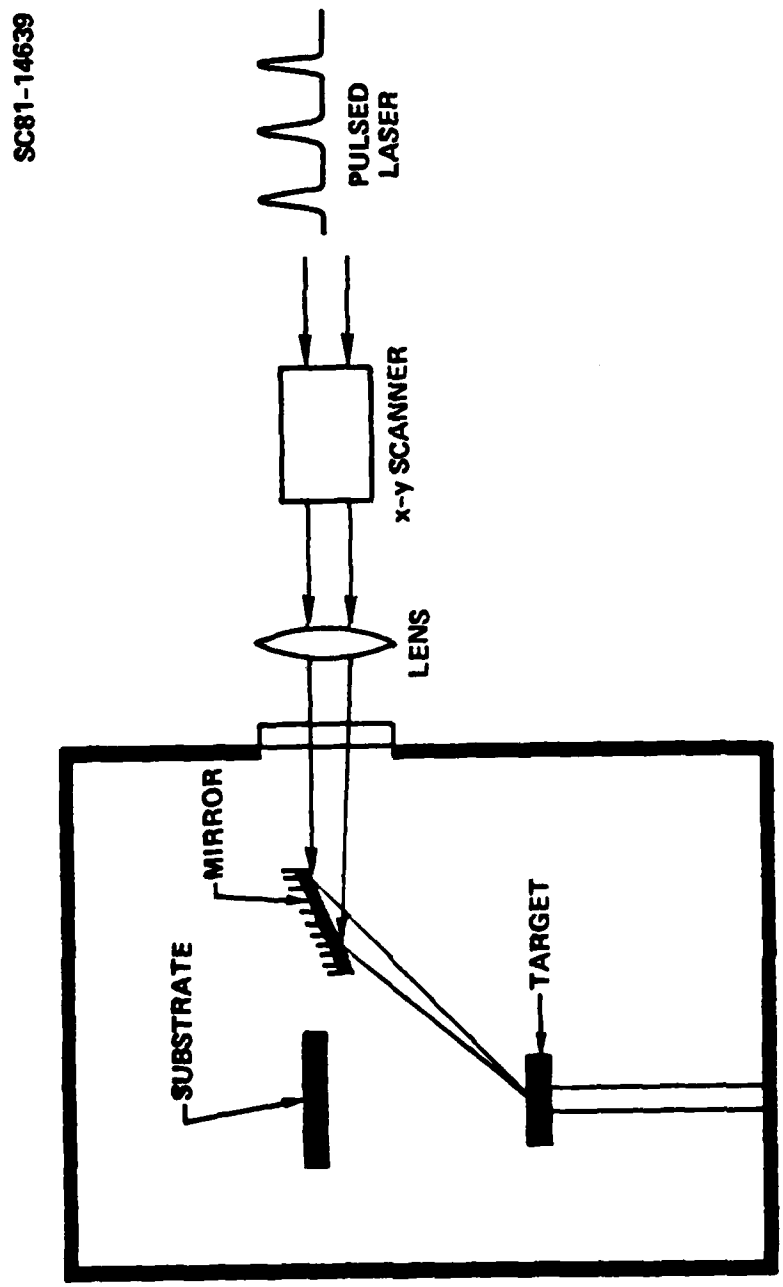

Fig. 2 Schematic drawing of a LADA apparatus.

A pulsed YAG laser was used as the power source for evaporation. Pulse trains were directed and focussed onto the source materials. A pair of galvanometric mirrors were used to scan the laser beam. The scanners are a vital part for depositing superlattices, because their motions controlled the superlattice parameters. Typical pulse rate was about 6 kHz, pulse duration of 200 ns and a peak power density in the 10^6 W/cm^2 range.

2.2 Evaporation of HgTe and CdTe by Pulsed Laser Radiation

Interactions between high power laser pulses and CdTe (HgTe) are short but very strong. The vaporization mechanism is different from that of a thermal evaporative process.

When high power laser pulses irradiate on the surface of a source material, the radiation energy is absorbed by a shallow surface layer. Most of this energy is converted to heat. For poor thermal conductors such as HgTe and CdTe, heat redistribution by conduction is slow, therefore, the heating is localized. After the onset of a laser pulse, surface temperature increases rapidly to reach a peak value, followed by relaxing to the original surface temperature before the arrival of the next laser pulse. Laser heating can generate very high peak temperature and short thermal cycles. Combination of these effects makes materials evaporate congruently and dissociatively.

HgTe evaporates non-congruently under equilibrium condition.[9] The mechanism was described by preferentially depleting Hg from the surface, while more Hg continuously diffused from the bulk to the surface to supplement the loss. In pulsed laser evaporation, Hg and tellurium evaporated simultaneously due to high peak temperatures. The thermal cycles are so short that the surface material is evaporized before Hg from the bulk can out-diffuse. Therefore, congruent evaporation occurred. Same process has also been observed for $Hg_{1-x}Cd_xTe$ ($x = 0.2$ and $x = 0.3$) alloys.[11] The phenomenon is reminiscent to flash evaporation[12] but more flexible and precise.

High peak temperatures can also induce dissociative evaporation, i.e., the source materials HgTe and CdTe vaporize as atoms:

$$HgTe \rightarrow Hg + Te$$

$$CdTe \rightarrow Cd + Te \quad .$$

On the contrary, in conventional thermal evaporation, they vaporize to form atoms for the group II elements and molecules for the group VI elements, e.g.,

$$HgTe \rightarrow Hg + 1/2\ Te_2$$

$$CdTe \rightarrow Hg + 1/2\ Te_2 \quad .$$

Therefore, in the deposition of compounds, the predominant process in LADA is atom-atom recombination. In conventional evaporative techniques, it is the atom-molecular reaction. Atom-atom recombination has a few advantages. It does not need any activation energy to break the bond of the group VI molecules. In addition, the reaction is always exothermic. The amount of released energy is equal to the bond energy of the formed compound. This energy will be dissipated in the vicinity of the deposition site and provides localized heating to the as-grown film. In fact, in the MBE of III-V compounds, recent developments have shown that the use of atomic beam group V elements also yield better quality films.[13]

2.3 Deposition of HgTe and CdTe - Effect of Hg Backpressure

Because of the low sticking coefficient of Hg (less than 10% values of the sticking coefficients of Cd and Te), the deposited HgTe films are Hg deficient. Excess tellurium will segregate into a free tellurium phase mixed in with the HgTe zincblende structure. The deficiency can be compensated by carrying out the deposition in a Hg backpressure. The maximum Hg backpressure attainable in our system is 1.2×10^{-4} torr. Under this condition and a deposition rate of 1.5 μm/hr, the films grown at 100°C was found to be single phase HgTe. X-ray diffraction spectrum shows only one peak at $2\theta = 23.8°$,

corresponding to (111) planes of HgTe with a zincblende structure. This is the first demonstration of depositing a single phase HgTe from a single evaporative source.

At this point, we have established the need of a high Hg backpressure for depositing HgTe films. The Hg backpressure cannot be modulated, and it is present at all times during the growth of HgTe/CdTe superlattice. During the growth cycle for CdTe layers, the incident fluxes of Cd and Te atoms at the substate were about 10^{15} atoms/cm^2-s. The Hg flux from the 1.2×10^{-4} torr Hg ambient is approximately 3×10^{16} atoms/cm^2-s which is an order of magnitude higher than the Cd and Te flux. Some intriguing questions quickly surface. What is the effect of Hg on CdTe growth? Will Hg be incorporated into the film to form $Hg_{1-x}Cd_xTe$ alloy? These questions are relevant to the scheme used in this work to grow the HgTe/CdTe superlattice.

A simple experiment was designed to elucidate these questions. In this experiment, we deposited two CdTe films on glass substrates at 60°C under different ambient conditions. The first film, 9000A thick, was deposited in 3×10^{-7} torr of vacuum free of Hg vapor. The second film, 7000A, was deposited under same laser and substrate conditions but in an ambient of 1.2×10^{-4} torr Hg backpressure. The Hg contents in these films in the form of $Hg_{1-x}Cd_xTe$ alloy were determined by comparing the locations of their optical absorption edges. If Hg was incorporated to form the $Hg_{1-x}Cd_xTe$ alloy, the bandgap would be reduced and the absorption edge would be shifted to a longer wavelength. Figure 3 shows the absorption edge of these two films measured at room temperature. Both films show periodical interference extrema and not well defined cut-on wavelength. We take the interception with the steepest slope as the location of the bandgap. The first film has a gap value of 1.55 eV which is in good agreement with bulk CdTe. The second film has a gap value of 1.47 eV which indicates a < 3% incorporation of Hg or a composition of $Hg_{0.03}Cd_{0.97}Te$. This result suggests the formation of Cd-Te bond being much more favorable than Hg-Te bond. These films were deposited at 60°C. At higher temperatures, even less Hg will be incorporated. The growth

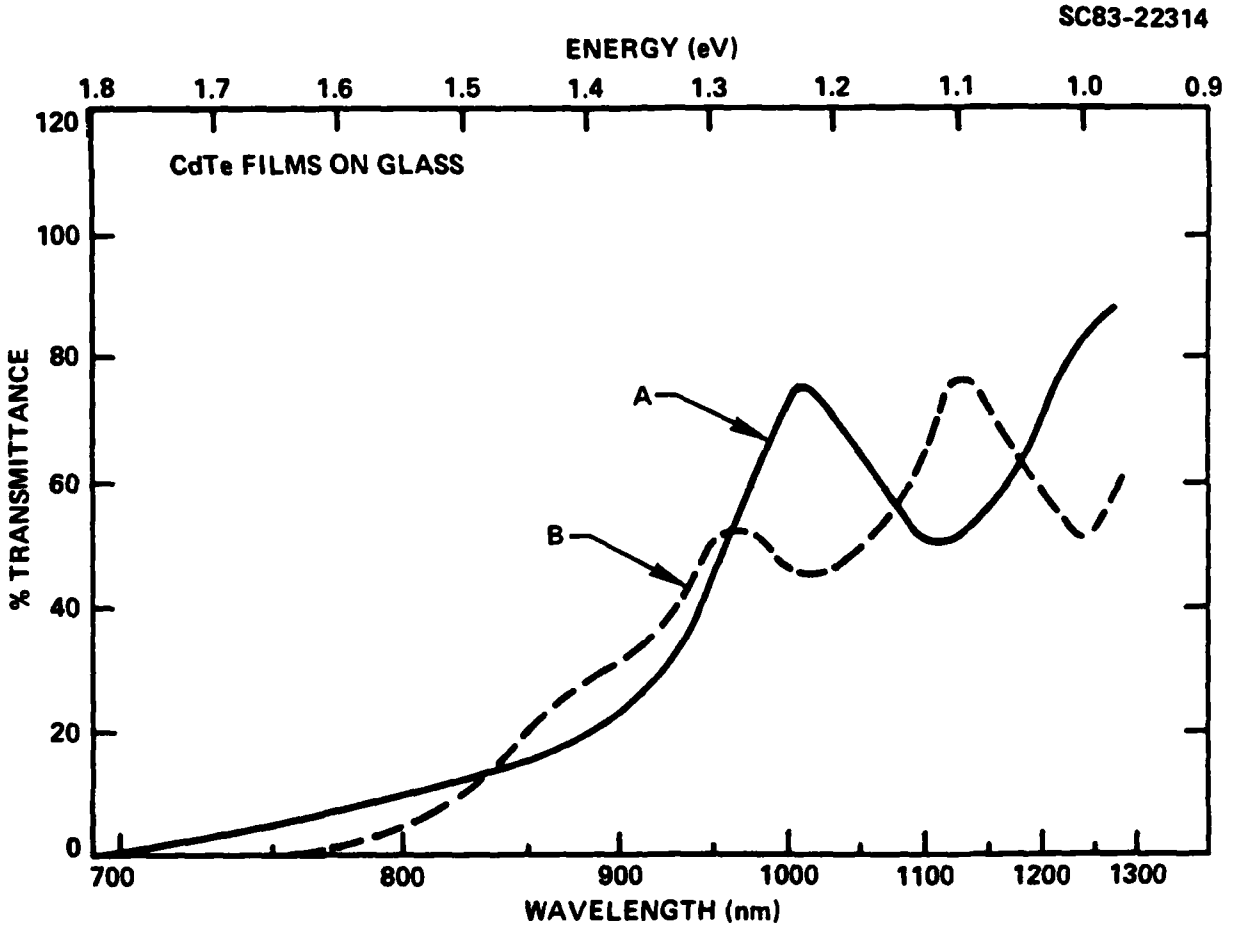

Fig. 3 Transmission spectra of two CdTe films deposited on glass substrates. Film A is 7000A thick deposited in the presence of 1.2×10^{-4} torr of Hg back pressure. Film B is 9000A thick, deposited in 3×10^{-7} torr Hg free vacuum.

temperature of HgTe/CdTe lattice used in this work was 100°C, therefore we can assume the Hg incorporation in the CdTe films to be negligible.

2.4 Scheme for Growing Superlattice

After establishing the deposition conditions of HgTe and CdTe, the growth of their superlattice is straightforward.

Instead of using mechanical shutters to periodically interrupt the beams, we used a set of mirror scanners to sequentially scan the laser beam over two sources. The response is nearly instantaneous, therefore multilayer deposition with good interfacial abruptness is possible. Optical modulation is faster and more flexible than mechanical modulation. In principle the superlattice parameters can be modified at any time during the course of the growth.

Figure 4 shows the beam movement over the two sources as originally proposed. The shaded areas are the regions rastered by the laser beam. The areas overlapping with HgTe and CdTe sources are A_H and A_C respectively. Therefore the ratio A_H/A_C determines the superlattice composition whereas the period of the rastering time determines the period thickness. This scanning pattern was used only briefly (for sample SL001 and SL002) before we quickly encountered some problems. The biggest problem is the difficulty in keeping the ratio A_H/A_C constant due to occasional jitter of the laser beam and a continual change of the source surface geometry. Lack of precise control of A_H/A_C ratio will result in non-uniformity in period thickness in the superlattice.

The new scanning pattern is shown in Fig. 5. The lower part of this figure displays the two sources placed side by side along the x direction. They rotate simultaneously. The upper half of the figure illustrates the two waveforms to drive the x and y mirrors. The y-axis mirror was driven with a sinusoidal wave. This enabled the focused beam to move back and forth along a line in the y-direction through the center of the sources. When this motion was coupled with source rotation, the entire source surface would be covered. The amplitude of the y-scan was kept low so that it avoided the laser beam

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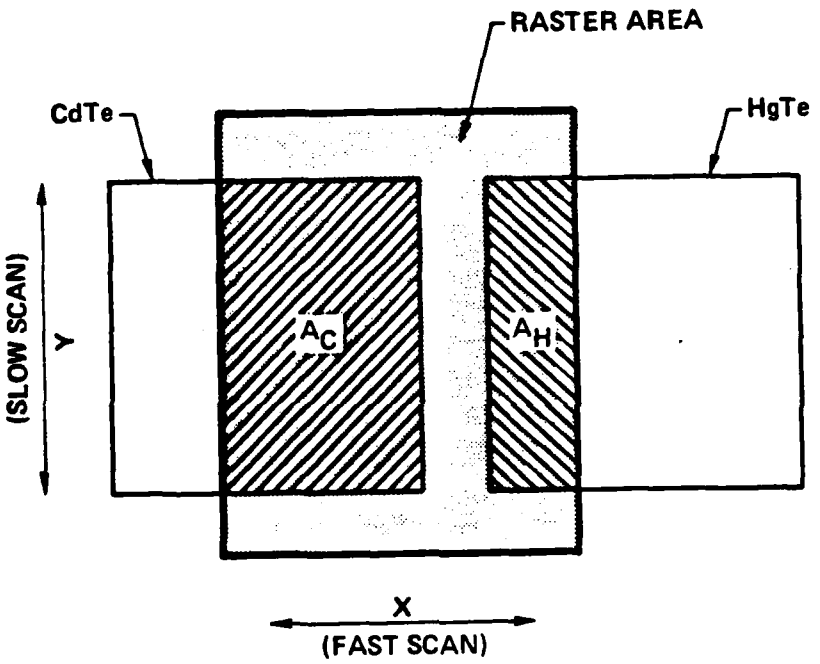

Fig. 4 Originally proposed scanning pattern over HgTe and CdTe to grow superlattices.

Fig. 5 Improved scanning pattern over HgTe and CdTe to grow superlattices.

from hitting the edge of the source. The x-axis mirror was driven with a square wave. It allows the laser beam to oscillate between two positions with T_H and T_C being the dwelling time on HgTe and CdTe sources respectively. The composition is determined by the ratio of the dwell times T_H/T_C which is much more stable than the ratio of area used in the original design. The period thickness is determined by the sum of T_H and T_C.

All films were grown at 100°C. In order to avoid Hg loss from the surface during its cooling down to room temperature, the top layer was always CdTe which provided some capping protection.

3.0 RESULTS AND DISCUSSION

3.1 Multilayer Structures

Six HgTe/CdTe superlattices were grown. Table 1 lists the basic information about their growth. Substrate temperatures were 100°C and Hg backpressure was 1.2×10^{-4} torr. Total thicknesses were determined from the cleaved cross sections. They varied from 1 μm to 5 μm. The period thickness is taken by dividing the total thickness with the number of cycles of the x-scanner movements. Therefore, it is only an average value. We do not have any information concerning the thickness variation.

Table 1
Parameters of HgTe/CdTe Superlattices

	SL001	SL002	183 AG	172 AG	170 AG	197 AG
Substrate	CdTe	CdTe	CdTe/GaAs	CdTe/GaAs	CdTe	CdTe/GaAs
Total d (μm)	3.5	1.8	5	5	5.2	1
Number of Pairs	1080	497	155	65	78	53
<d> HgTe (A)	15	16	110	300	460	-
<d> CdTe (A)	17	20	210	400	200	-

Composition (i.e., HgTe/CdTe ratio) was determined by three independent techniques. In the first technique, HgTe and CdTe source pellets were weighed before and after the deposition. The HgTe/CdTe ratio in the superlattice layer was taken as the molar ratio of this weight loss. It was only used for sample number SL001 and SL002. In other runs, CdTe source was also used for depositing a CdTe buffer layer, therefore this simple approach was not applicable. In the second technique, a piece of superlattice was annealed

in a Hg overpressure at 410°C for 6 hours; the long heat treatment completely intermixed the multilayers to form an alloy film of the same Hg/Cd ratio. The composition was then determined from the location of its absorption edges measured at room temperature. This approach was used for all samples except No. 172 AG. In the third method, the composition was determined by EDAX. Since the probing depth of this technique is about 1 μm, it was only used for films of more than 2 μm thick in order to avoid interference from the CdTe substrate. Precautions were taken on sample preparation for EDAX analysis. Their edges were slightly polished on a low-angle mount to expose some multilayers. The probing electron beam was scanned in a direction perpendicular to these exposed layers in order to "see" an equal number of HgTe and CdTe layers. The results of composition determined by these three methods are close. This good agreement has the following implications.

1. The agreement between the first technique and other techniques indicates that under the growth condition, Cd and Te have the same sticking coefficient. Every Te atom not bonded to Cd will react with Hg to form HgTe.

2. The agreement between the second technique and other techniques indicates that the thermal treatment introduced a complete alloying. Besides, there is no appreciable amount of diffusion at the CdTe substrate/superlattice interface, otherwise the absorption edge would have been shifted toward shorter wavelengths (this conclusion has later been confirmed by 2-D transport data).

In order to observe these very thin multilayers, we devised a low angle etch technique[13] to reveal the structure in greater detail. It is described in the following:

A piece of the sample was mounted on a glass slide with wax. The superlattice side was facing down. The sample was then etched from the substrate side in Br_2/methanol solution until it was etched through to form a

hole. The edge of the hole has a very small slope. On one sample, we used Dekatak surface profiling to measure the angle of the edge. It was only 2.4 degrees. Therefore, the cross section of the superlattice at this edge was magnified and became visible. Figure 6 shows the low angle etched cross section of a superlattice with 50 pairs of HgTe/CdTe each having a nominal thickness of 700Å. The etch rate of HgTe in bromine/methanol solution is faster than that of CdTe. Therefore, one does not see the HgTe layers in these low angle etched cross sectional view. The cross sectional view actually consists of steps of CdTe. The narrow black bands are the shadows of these steps. This was confirmed by scanning Auger spectroscopy (SAM) for the lack of Hg signal across the cross sections. All superlattices have (111) orientation as determined by x-ray diffraction.

All the superlattice layers are (111) oriented and show a single peak in the x-ray diffraction spectra. The width of this peak is a measure of crystallinity. Sample 183 AG shows the narrowest peak with FWHM value of 0.4° (instrument limit). However, the diffraction spectrum is too noisy that we could not see any satellite peaks originated from the superlattice structure.

3.2 Optical Transmission and Band Gap Variation

The major objective of this work is to observe the bandgap variation due to changes in period thickness and compositions. Optical absorption edge measurements were used to derive this information. We do not have a data base broad enough to fully test the theory, but our measurements do offer some qualitative agreement. We have shown that for the same composition (i.e., Hg to Cd ratio), the superlattice always has a narrower bandgap than an alloy.

Optical transmissions were measured at room temperature. For wavelengths shorter than 2.1 μm spectra were taken on a Perkin-Elmer dual beam spectrometer. For longer wavelengths, spectra were taken on a Fourier Transform IR spectrometer. Figures 7, 8 and 9 show spectra of the as-grown superlattice layers. In some cases, spectra of the annealed samples were also

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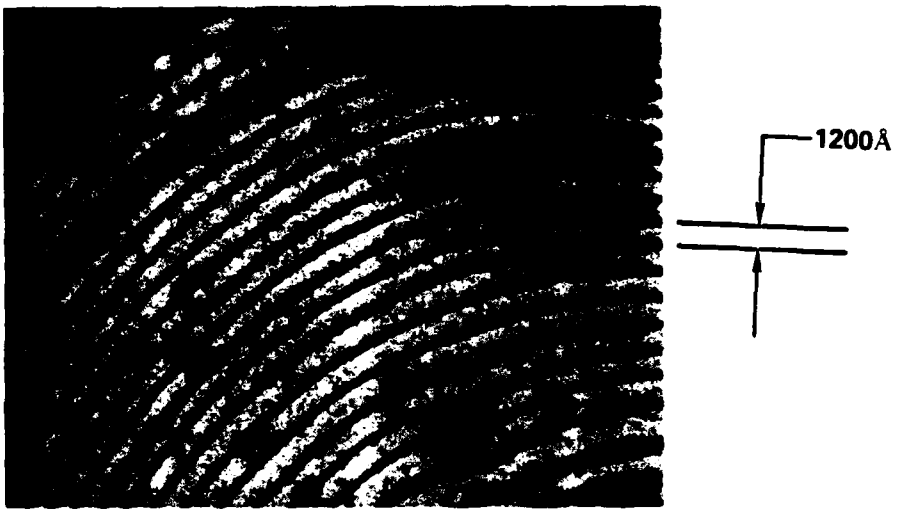

CROSS SECTION OF AN ANGLE-ETCHED SAMPLE

Fig. 6 Cross section of a low angle etched HgTe/CdTe superlattice.

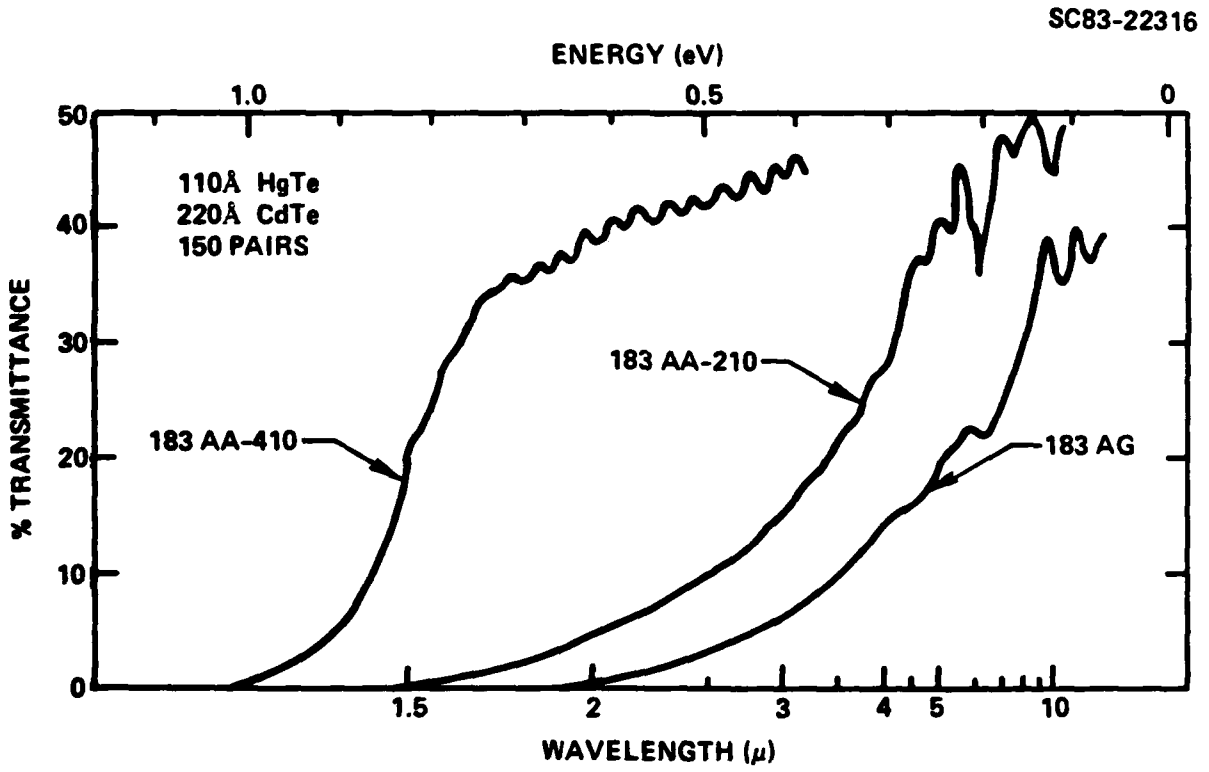

Fig. 7 IR transmission spectra of an as-grown superlattice layer, and the same layer after annealing in Hg overpressure at 210°C (1 hr) and 410°C (6 hr).

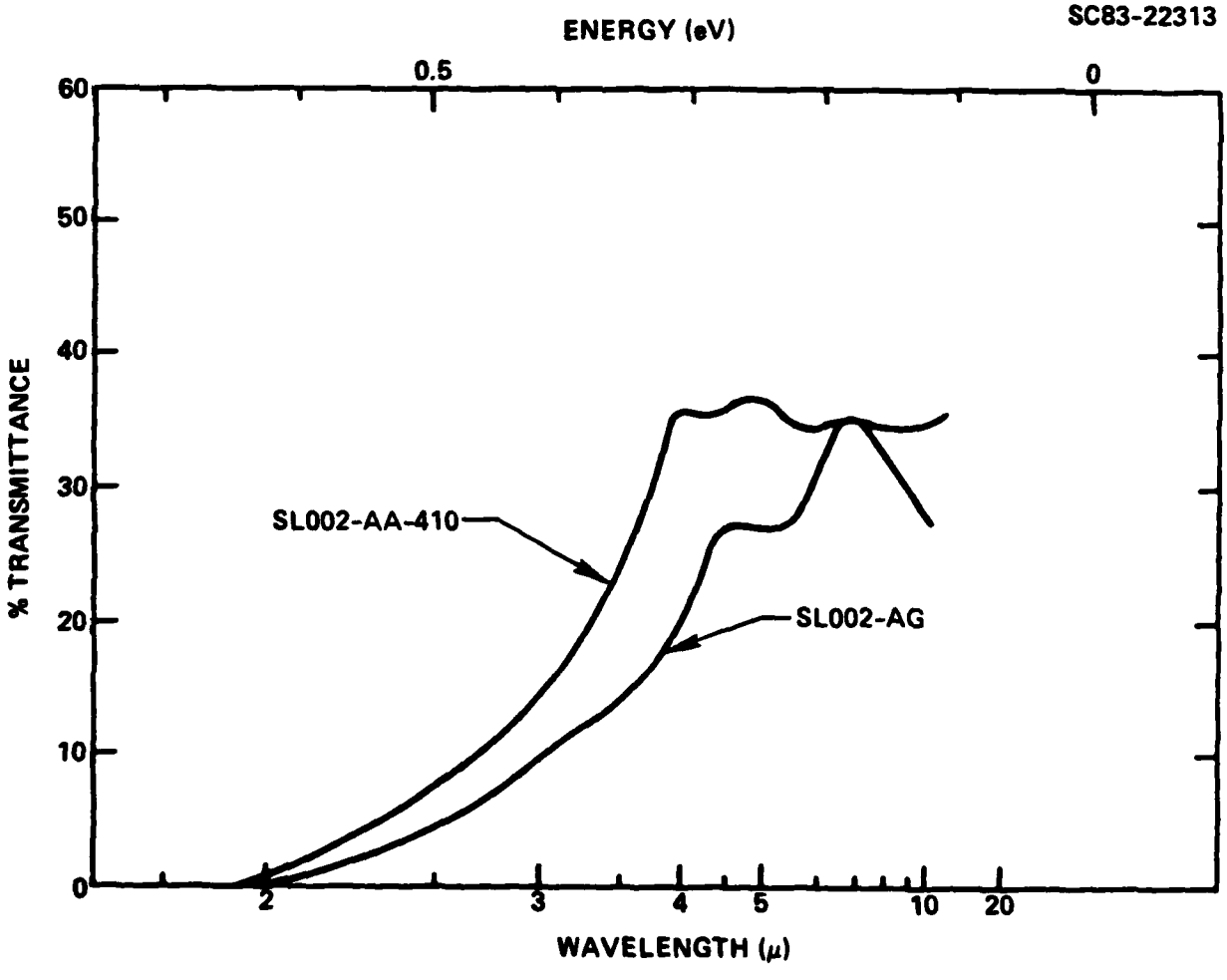

Fig. 8 IR transmission spectra of superlattice before and after annealing at 410°C for 6 hr.

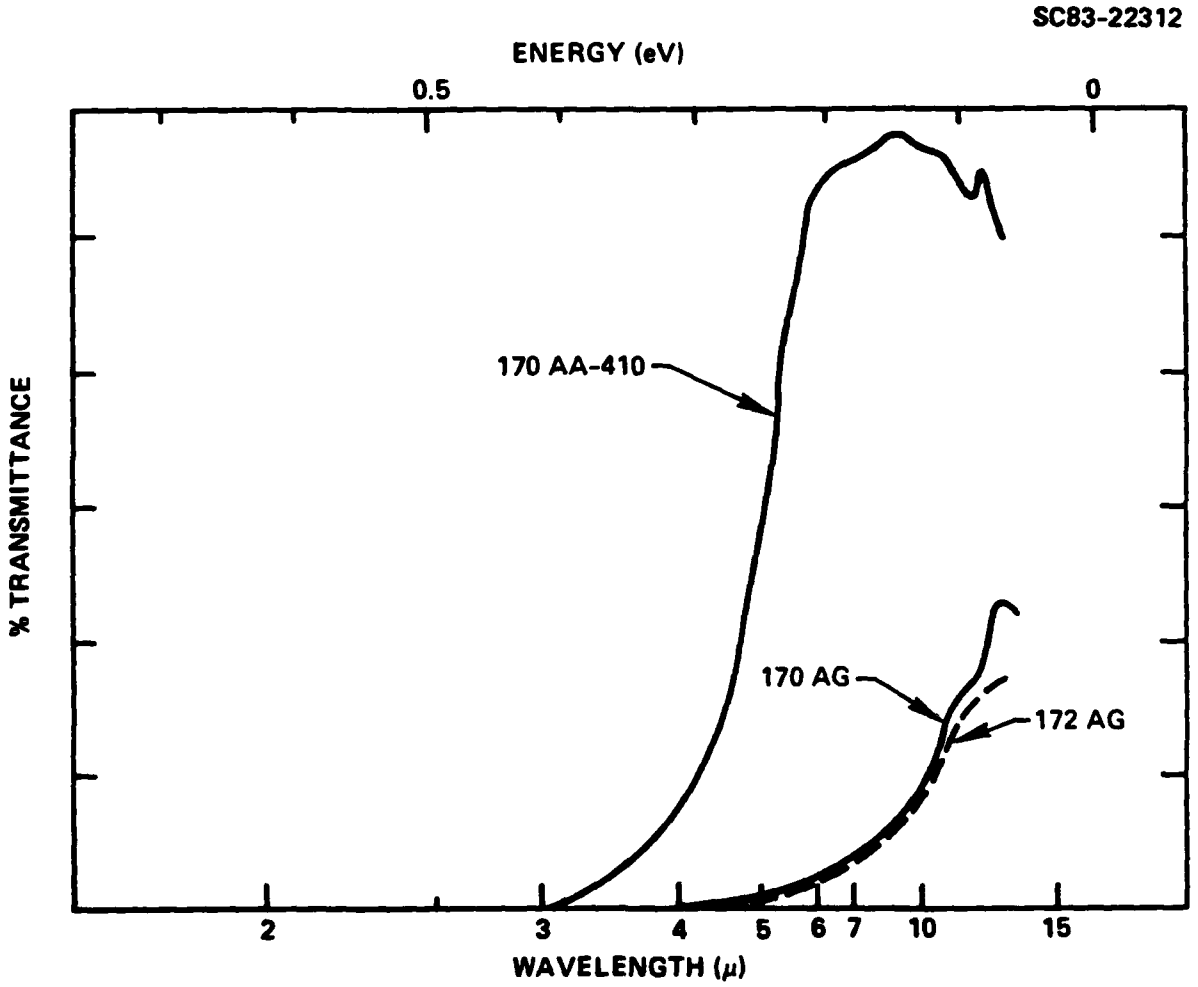

Fig. 9 IR transmission spectra of a superlattice layers 170 AG, 172 AG and a superlattice layer after thermal annealing at 410°C for 6 hr.

included for comparison. Typical annealing conditions was 410°C for 6 hours in Hg overpressure. Low angle etch samples were prepared on the annealed pieces, the multilayered structures were no longer visible. In one case (No. 183 AG), we also annealed the sample for 10 hours and no difference was seen in the transmission spectrum.

Figure 7 shows spectra of sample No. 183 AG both before and after annealing under different conditions. The total thickness of the superlattice layer is 5 μm. Each period is made of 110A HgTe and 210A CdTe nominally. In these spectra, we take the intercept with the steepest slope as the location of the absorption edge. The alloy shows an absorption edge at 1.35 μm corresponding to a 0.9 eV bandgap. For the as-grown superlattice layer, the absorption is stronger and the absorption edge is less well defined. By taking the intercept with the steepest slope, it yields a value of 2.65 μm corresponding to a 0.48 eV bandgap. In this case, the gap is narrowed by more than 400 meV due to superlattice formation. For this configuration, the theories would predict a bandgap of about 0.1 eV which is much narrower than we observed optically. Another piece of the sample was annealed at 210°C for 1 hour. This annealing condition was chosen to simulate the MBE growth condition by Faurie.[7] In his study, he grew superlattice at 200°C and determined the interdiffusion to be less than 40A. Indeed, in our 210°C annealed sample, the multilayered structures were still clearly visible in a low angle etched sample. However, absorption edge is shifted toward shorter wavelength corresponding to a slight widening of bandgap to 0.53 eV. Electrical properties of this particular superlattice sample also contains many interesting features. Details will be discussed in Section 4.0.

Figure 8 shows transmission spectra of another sample (No. SL002). This sample was made with a very short scanning period, meaning that the periodic layers, if any, will be very thin. The nominal value is only about 30A. There is very little shift between the spectra of the as-grown and the annealed film. Results of SL001 are very similar.

We have also deposited superlattices with thick periods and thick HgTe layers. Examples are shown in Fig. 9. Three transmission spectra are compared: an as-grown film No. 170 AG, the same film after annealing, and another superlattice film No. 172 AG. The difference between these superlattices is the thickness of HgTe layers. Each period in sample 170 AG contains 460A of HgTe and 200A of CdTe. Each period in sample 172 AG contains 300A of HgTe and 400A of CdTe. These transmission spectra are practically identical, an implication that the superlattice properties will remain unchanged when HgTe layers become very thick. These absorptions are again much stronger than the alloy (annealed) film and the rise in the absorption edge is weak. In comparison to the alloy film, the bandgap are shifted from 0.3 eV to 0.15 eV.

Our observations are qualitatively consistent with the theoretical predictions. The bandgaps measured from optical absorption edges for superlattices are always narrower than the alloys of the same composition. Quantitatively, there is a large discrepancy. The observed bandgaps are much wider than the theoretical prediction. This can be due to a number of factors including crystalline imperfection such as thickness variation, interdiffusion between HgTe and CdTe. We do not have any definite answer at this point.

3.3 Electrical Properties

Hall measurements at 77K and 300K were made by the standard four point Van der Pauw technique. Results are summarized in Table 2.

All samples show n-type conduction. Most of them have low mobilities and high carrier concentrations. Sample 183 AG shows the most interesting results. At 77K, the as-grown superlattice layer has a mobility of 12,000 V/cm^2-s. The mobility value decreased after the superlattice was destroyed by annealing at 210°C and 410°C.

In collaboration with Prof. N.P. On of University of Southern California, electrical properties of some samples were characterized in detail. The objective was to study the transport mechanism and to observe two-dimensionally confined carrier motions.

Table 2
Electrical Properties

Sample No.	300K		77K		Two-Dimensional Transport Behavior
	n (cm^{-3})	μ (cm^2/V-s)	n (cm^{-3})	μ (cm^2/V-s)	
SL001 (AG)	1.5×10^{16}	84	1.4×10^{16}	102	--
SL002 (AG)	Not measured				
170 (AG)	5.7×10^{17}	2222	2.8×10^{17}	111	No
170 (AA-410°C)	9×10^{17}	1050	3×10^{16}	1041	
172 (AG)					
172 (AA-410°C)	1×10^{18}	3100	1×10^{18}	3703	--
183 (AG)	1.75×10^{16}	8000	0.8×10^{16}	12000	Yes
183 (AA-210°C)	2×10^{16}	5508	1.5×10^{16}	7308	No
183 (AA-410°C)	1.7×10^{16}	5782	1.1×10^{16}	8237	--
197 (AG)	1×10^{17}	1442	9×10^{16}	2068	--

(1) AG denotes as-grown layer, AA denotes annealed layer at a specific temperature.
(2) Carrier concentrations are obtained by assuming all layer pairs being activated.

Measurements were made from 300K down to 0.5K and in magnetic field intensities up to 13 tesla. Three samples were examined. In the first sample (No. 170 AG) with 460A thick HgTe layer, No. two-dimensional carrier confinement was observed. In the second sample (No. 183 AG), the HgTe layer was thinner (110A), 2D behavior was observed for the first time in this superlattice system. After the sample was annealed at 210°C for 1 hour, the multilayered structure was still visible. However, the interdiffusion between HgTe and CdTe layers broadened the quantum wells that the 2D transport behavior was lost.

Preliminary results of this collaborative work has been presented at APS meeting in Los Angeles, 1983. It has been submitted to Phys. Rev. for publication.

4.0 CONCLUSIONS

In this work, we have demonstrated the growth of HgTe/CdTe superlattice by a novel laser assisted deposition technique (LADA). This technique uses HgTe and CdTe compounds as sources. High power laser pulses vaporize these materials congruently and dissociatively. Multilayer structures were grown by scanning the laser beam sequentially over the multiple sources. The superlattice parameters can be readily varied.

Optical transmission spectra were used to locate the absorption edge and determine the bandgap. The spectra were compared to those of the annealed films which are the alloy with the same compositions as the starting superlattice materials. We observed the effect of band narrowing due to superlattice formation.

Electrical properties were also characterized. For superlattice with thin (~ 100Å) HgTe layers, two-dimensionally confined carrier motions were observed for the first time in this system.

In summary, this effort has established that HgTe/CdTe superlattices can be constructed by LADA. Future effort on such superlattices can go beyond the feasibility demonstrations and optimize the growth conditions for more detailed studies of the SL properties, and particularly towards examining the device applicatikons for these very interesting material systems.

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