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Characteristics of Temperature Control of CdTe Crystal Growth Furnace by Vertical Bridgman(VB) Method

Choe Sam Hyok, *Chon Chang Won* and *Kim Ryong Jin*

For the CdTe crystal growth by Vertical Bridgman (VB) Method, we made an apparatus for temperature control which sets a temperature control curve in advance for a furnace and grows and anneals crystals simultaneously. We also realized the PID automatic temperature control.

1. Apparatus for Temperature Control of a CdTe Crystal Growth Furnace

CdTe(CT) is widely used as λ-ray detection material because of its high λ-ray adsorption ability [1, 2].

What is important here is to grow high-quality CdTe crystal, for which temperature control and heat annealing should be done correctly [3].

First, an apparatus to enhance the accuracy of temperature control was made.

When growing CdTe crystal by VB method, the temperature is as high as 1 050℃. To measure this temperature, we used chromel-alumel thermocouple. Signals from this were converted into digital signal with AD conversion, input into a computer to sense the temperature.

As high AD conversion bits is essential in enhancing the accuracy of temperature control, the temperature control apparatus was made using AD7705, 16bit AD converter.

The AD7705 is the 16 bit serial data output AD conversion device with 2 analog input channels which adjusts gain programmatically.

The AD7705 pin configuration is shown in Fig. 1. The function of each is given below;

SCLK: Serial Clock

MCLK IN: Master Clock Signal Input of 500kHz～5MHz

MCLK OUT: Master Clock Signal Output

$\overline{\text{CS}}$: Chip Select

$\overline{\text{RESET}}$: Reset

AIN2(+): Positive Input of the Analog signal(+)

AIN1(+):Positive Input of the Analog signal(+)

AIN1(-): Negative Input of the Analog signal(-)

GND: Ground Reference Point

VDD: Supply Voltage

DIN: Serial Data Input

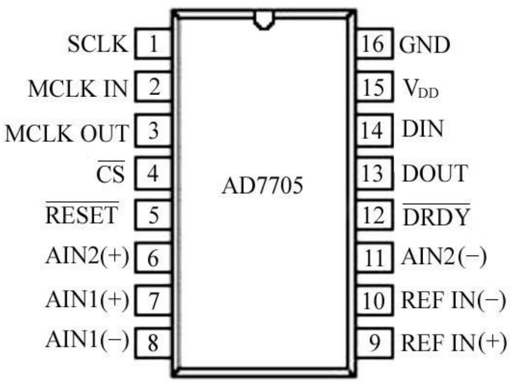

Fig. 1. AD7705 pin configuration

DOUT: Serial Data Output
$\overline{DRDY}$: Digital Data Output Status Indication
AIN2(-): Negative Input of the Analog signal (-)
REF IN(-): Reference Input(-)
REF IN(+): Reference Input(+)

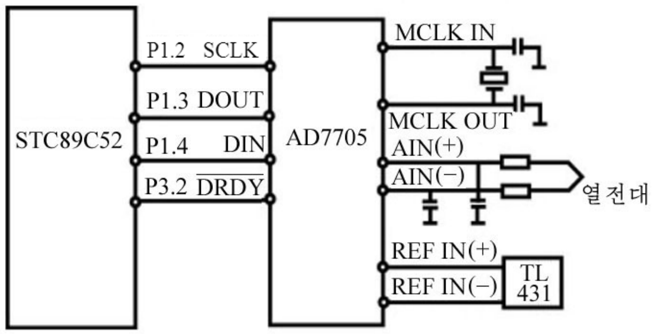

Fig. 2. STC89C52 to AD7705 interface

AD conversion was made by connecting one-chip microcontroller STC89C52 to the AD7705. The interface is shown in Fig. 2.

As is shown in the diagram, the STC89C52 outputs the serial clock signals via P1.2 pin, transmits and receives serial data signals via P1.3 pin and P1.4 pin. When the AD conversion is finished in AD7705, the data signals are input to the microcontroller via P3.2 pin, and then it reads the serial data from P1.3 pin and knows the value of the AD conversion. The algorithm for driving the AD7705 is shown in Fig. 3.

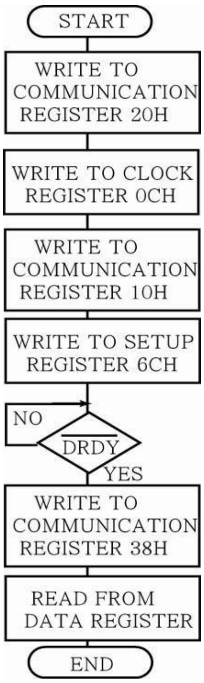

Fig. 3. Algorithm for driving AD7705

2. Temperature Control in Crystal Growing and Heat Annealing

In VB method, the quality of the crystal is enhanced by growing CdTe crystal in 1 050℃ and treating with heat/annealing the grown crystal in various temperatures, thus eliminating Cd vacancies [3].

We set in advance a time-temperature curve for the crystal growth furnace and realized highly accurate PID automatic temperature control. In order to ensure high precision through the whole process of temperature control, P, I, D coefficients according to temperature should be determined correctly.

We determined the P, I, D coefficients by measuring the thermal inertia of the furnace at intervals of 100℃/at every 100℃ and as for the P, I, D coefficients of non-measured temperatures by linear interpolation of the determined PID coefficients. The measured P, I, D coefficients are shown in Table.

Table. The measured P, I, D coefficients at different temperatures

Coefficients	Temperature/℃									
	100	200	300	400	500	600	700	800	900	1 000
K_P	0.003	0.011	0.029	0.093	0.321	1.575	3.092	5.871	12.828	27.352
K_I	1079.7	351.0	158.0	69.0	25.8	9.6	5.8	3.6	2.0	1.6
K_D	269.9	87.7	39.5	17.3	6.5	2.4	1.4	0.9	0.5	0.4

Fig. 4 shows the interpolation curve of K_P, K_I, K_D respectively.

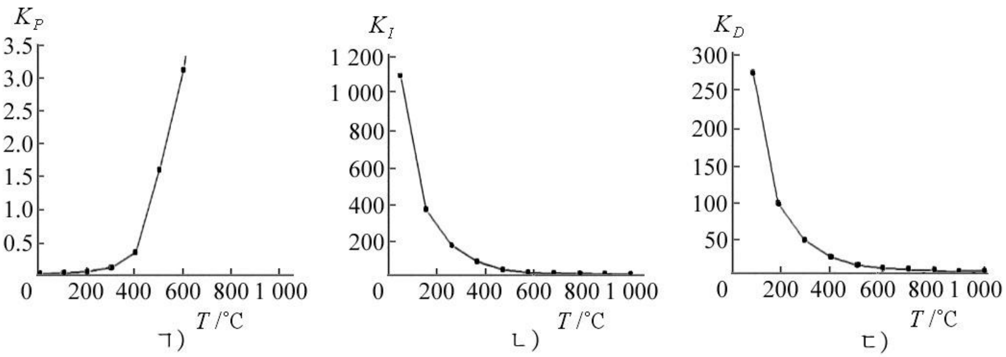

Fig. 4. K_P, K_I, K_D curves v.s. temperature
a) K_P curve, b) K_I curve, c) K_D curve

Based on this, we regulated the temperature of the growing and heat-treating/annealing of the crystal growth furnace.

Fig. 5 shows the temperature control curve of growing and heat-treating of CdTe crystal growth furnace.

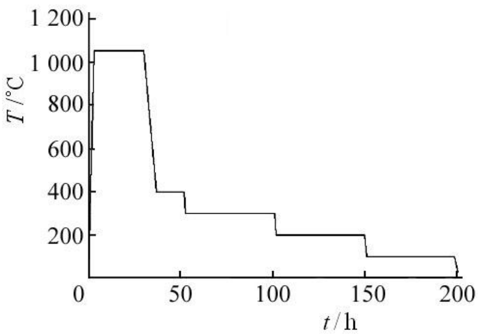

Fig. 5. The temperature control curve of growing and annealing of CdTe crystal growth furnace

As a result of the temperature control, the control precision was ±0.1℃ in the region of temperature maintenance and in the region of rising or falling temperature ranged from ±0.1℃ to ±0.5℃ with the temperature gradient.

We have developed the device for automatic control of the temperature of CdTe crystal growth furnace by VB method, and performed the temperature control on growing and annealing process. As a result of the temperature control, the control precision was ±0.1℃ in the region of temperature maintenance and in the region of rising or falling temperature ranged from ±0.1℃ to ±0.5℃ with the temperature gradient.

References

[1] R. Grill et al.; IEEE Tranc. Nucl. Sci., 52, 1925, 2005.

[2] R. Grill et al.; J. Electron. Mater 34, 939, 2005.

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