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Data System for AlN Single Crystal Growth

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Abstract. Aluminum nitride (AlN) is a typical representative of the third generation semiconductor materials. To increase the efficiency of managing experimental data for AlN single crystal growth, this paper purposes a multitasking system based on browser/server (B/S) architecture. The system uses serial communication, LAN communication, relational database system, B/S software architecture and other technologies to achieve data collection, data storing, data retrieval, data analysis and user access. Through statistical analysis of experimental data and results, the system assists researchers to find the key factors (e.g. temperature gradient and supersaturation pressure) of AlN single crystal growth. As a result, the system helps to grow large size AlN single crystals.

1. Introduction

Aluminum nitride (AlN), GaN, ZnO, diamond, etc. are referred as the third generation semiconductor materials. Due to the characteristics of high field penetration, high thermal conductivity, and wide electronic band gap, the third generation semiconductor materials are suitable for applications such as deep ultraviolet ray, deep ultraviolet detection, high power device, sterilization, etc. [1]. The AlN with a direct electronic band gap of 6.2 eV, has a very broad application prospect. Research on large-sized AlN single crystal growth has received increasing attention. At present, the internationally recognized method of large-sized AlN single crystal growth is physical vapor transport (PVT) method [2]. Using PVT method to prepare AlN single crystal, the key factors are the crucible structure, temperature gradient and supersaturation pressure [3]. The recording and analysis of these parameters are important in AlN single crystal growth.

The common recording methods of AlN single crystal growth are paper recording and paperless recorders. However, paper recording has problems of incomplete data, and poor robustness. Paperless recorders cannot achieve data retrieval and analysis. The experimental data of AlN single crystal growth has four parts: experimental scheme, thermometers data, characteristics and morphology of AlN single crystal. Achieving centralized management and analysis of data is significant for AlN single crystal growth [4]. The system proposed in the paper uses computer technologies such as serial



communication, LAN communication, B/S software architecture, etc. to achieve centralized management and analysis of data.

2. Requirements Analysis

The purpose of the system is to increase the efficiency of AlN single crystal growth research and to ensure the safety and integrity of the data. System management, data management and data analysis are the three major functional parts of the system [5]. System management includes the management of log and user. The log module records user access, request receipts and replies, and exceptions. The user management is to provide user registration and access control services [6].

Data management is the core function. Data acquisition and data retrieval are two main modules for data management. Data acquisition includes the collections of data from thermometers, experimental scheme, morphology and characteristics of the AlN crystal. Data retrieval module screens experimental records based on key factors including nucleation density, grain size and experimental period. The flow diagram of data management is shown in Fig. 1.

Data analysis mainly provides statistical functions of grain size, nucleation density and experimental periods. Experimental comparison and analysis are important work in the research of AlN single crystal growth [7]. Data recorded in each experiment is connected and displayed. The data visualization provides researchers with intuitive references for experimental adjustments [8]. The flow diagram of data analysis is shown in Fig. 2.

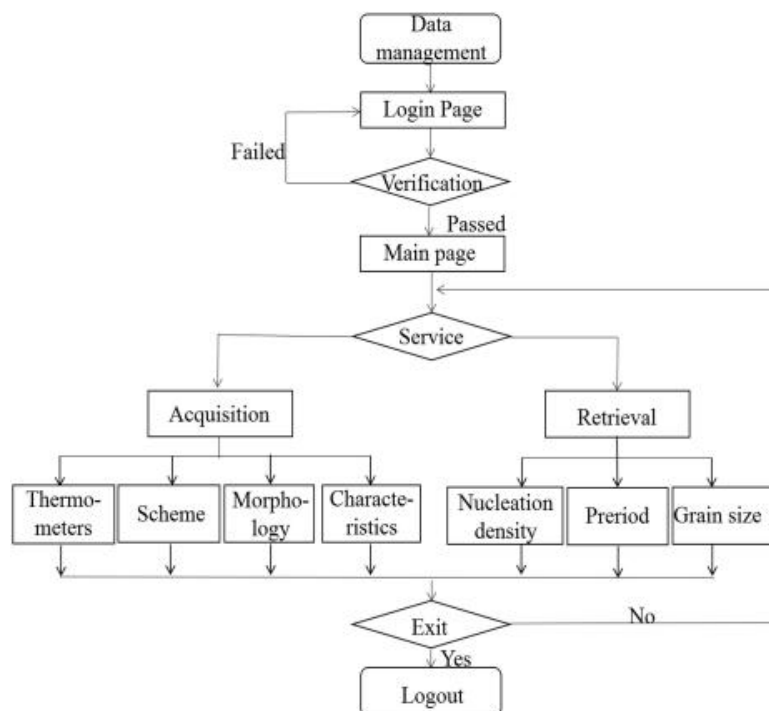


Figure 1. Flow diagram of data management

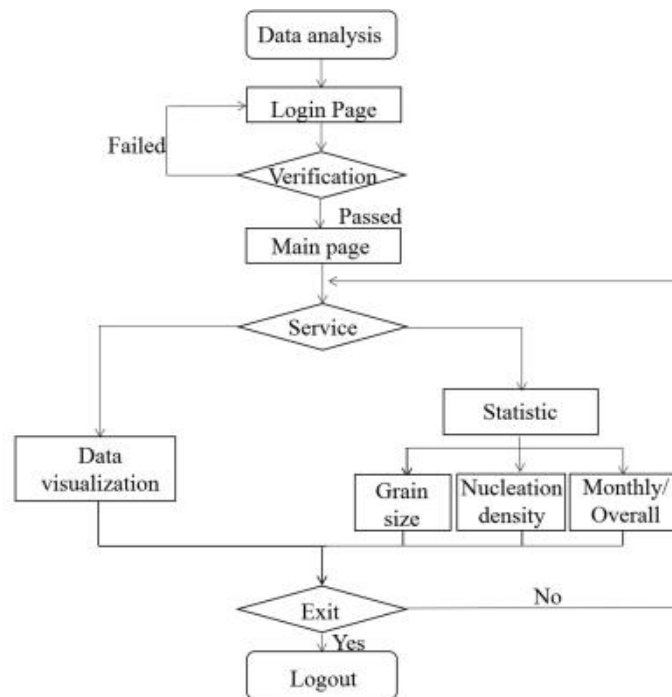


Figure 2. Flow diagram of data analysis

3. System Design

The hardware includes three thermometers, a master server and a slave server, as is shown in Fig. 3. Three thermometers measure the temperature of crucible in different locations. The master server collects experimental data and provides services to the user. The slave server is used to back up data from the master server. The master-slave replication of the database is implemented between the master server and the slave server [9].

The network solution adopts serial communication and Ethernet communication [10]. The thermometers data is transmitted to the master server through RS485 serial ports [11]. The Ethernet consisting of category 5 (Cat 5) twisted pair cables and a switch implements the communication among users, the master server and the slave server. The Cat 5 twisted pair cables provide the throughput of 100Mbps which satisfies transmission needs of the system data.

The application adopts Web three-tier structure which consists of the user interface layer, the business logic layer and the data access layer [12], as is shown in Fig. 4. The business logic layer is responsible for dealing with logic tasks and dispatching other parts of the application. The user interface layer is used to resolve display tasks. The data access layer is designed to handle data manipulation. The data recorded by the system has a low probability of redundancy and data inconsistency, and there is no high concurrent read and write situation. Therefore, the MariaDB database management system is deployed for data storing [13].

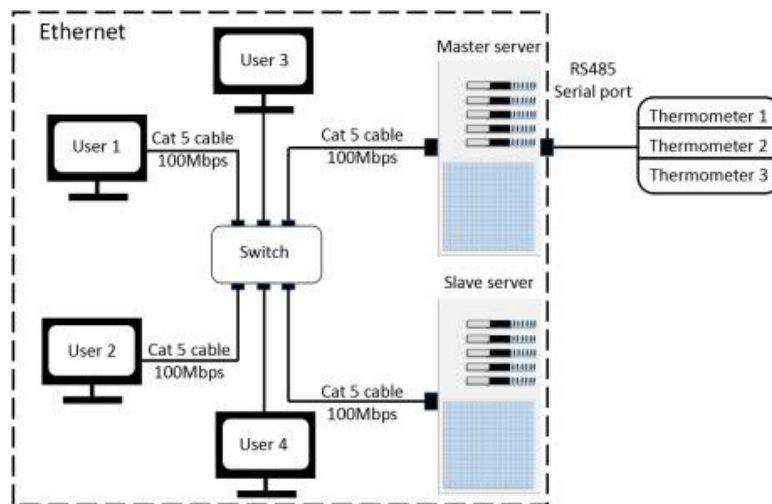


Figure 3. System architecture diagram

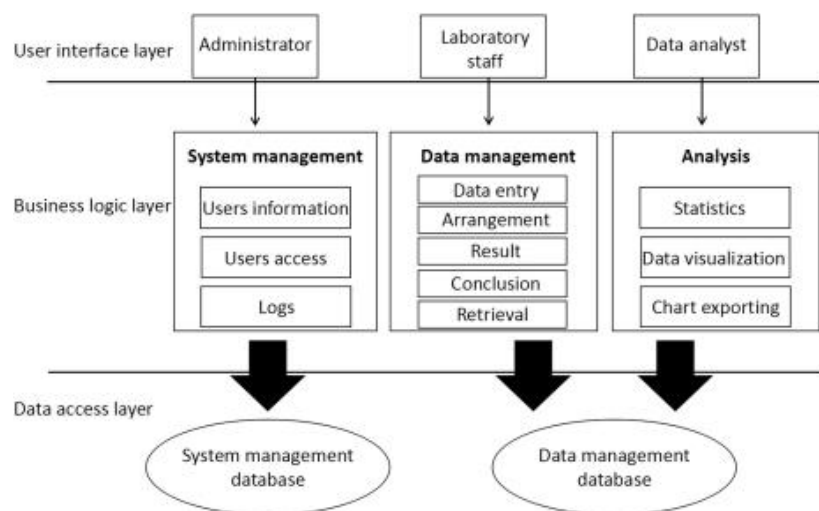


Figure 4. Application architecture diagram

4. Technical Implementation

The thermometers connect to the master server via an RS485 bus, and real-time data transmission is achieved by a program written in C language [14]. The master-slave replication mechanism of MariaDB is implemented between the master server and the slave server to realize data backup [15].

The application of the system is written in PHP, JavaScript and HTML. In experimental scheme page, user submits experimental scheme including different parameters such as temperature and humidity of the laboratory, equipment, experimental personnel and so on. Analysis page shows the statistical results which are grouped by grain size, nucleation density and periods. The data retrieval component performs screening functions according to different conditions (e.g. grain size, nucleation density and experimental period), as is shown in Fig. 5. Data recorded in each experiment is connected and displayed in the detail page. The characteristics of crystal and experimental scheme are shown in Fig. 6. The data of infrared thermometers, the morphology of AlN crystal and a testing result are shown in Fig. 7. The system compares the experimental parameters of similar results, finds the

common points of the experimental parameters, and provides a reliable reference for adjusting experimental scheme, which will help shorten the research period of AlN single crystal growth(e.g. combined with Fig. 5 and Fig. 7, temperature gradient is the key factor for AlN single crystal growth).

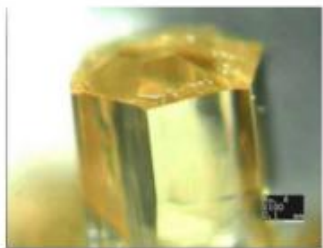
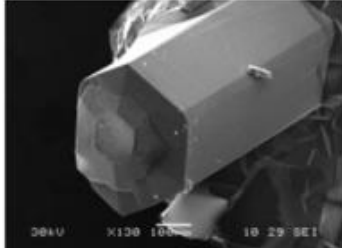
Retrieval condition	
Date	2018-10-01~2018-10-31
Grain size	mm
Nucleation density	1
Result	
	
Date : 2018-10-17	Date : 2018-10-15
Grain size : mm	Grain size : mm
Nucleation density : 1	Nucleation density : 1

Figure 5. Example of retrieval result

The detail information of the experiment	
Date	2018-10-09
Weather	Sunny
Room temperature (°C)	25
Humidity (%)	68
Experimenter	Vincent
Purpose	Seed growth
Location	Laboratory 103
Equipment	AlN crystal growth furnace
Experimental Condition1	Double drive heating, normal pressure
Experimental Condition2	T < 2350°C
Characteristics	
Grain size	cm
Nucleation density	1
Conclusion	Ideal for nucleation, further seed induction

Figure 6. Experimental information of a sample

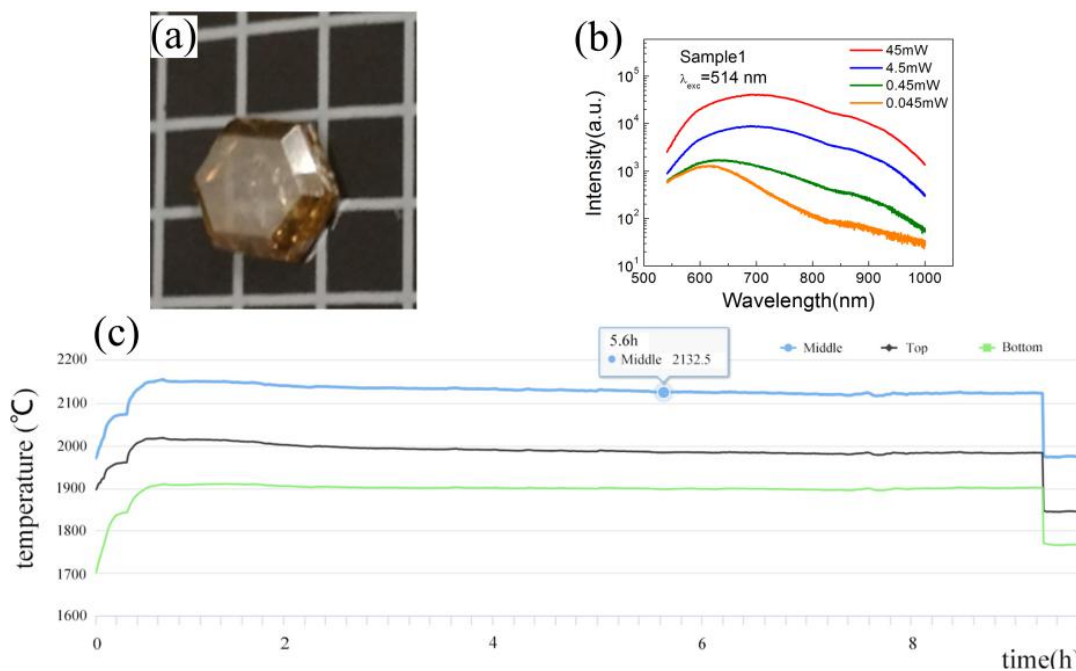


Figure 7. (a) Morphology of some AlN crystals. (b) Raman spectra. (c) Temperature-Time curve at different positions of the crucible.

5. Conclusion

Management and analysis of experimental data is benefit for the research on AlN single crystal growth. In this article, a data system has been proposed, which includes the functions of complete data recording, data visualization and accurate data screening. It provides convenience for experimental comparison and analysis. Then through examples, it is found that technological parameters and the test data of AlN crystals are recorded, compared and analyzed by the system. The system improves the efficiency and accuracy of data management.

6. References

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