Ministry of Education Department of Higher Education University of Pyay

Pyay University Research Journal

Vol. 11, No. 1

December, 2019.

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A Study on Superionic Conductivity of Li₂SO₄-Fe₂O₃ Nanocomposites

Win Kyaw¹, Myo Paing Htwe², Soe Soe Nwe³

Abstract

Nanocomposite salt-ceramic electrolyte with the formula (1-x) Li₂SO₄-xFe₂O₃ (where x = 0.1, 0.2 and 0.3) have been prepared by double sintering ceramic method. Starting materials of analytical reagent (AR) grade Li₂SO₄ and Fe₂O₃ were weighed with desired stoichiometric compositions. Phase formation temperature determination of the presintering sample was examined by TG-DTA technique. The presintered samples were made into circular shaped pellets and sintered at 500°C and 600°C for 2 h each. XRD technique was used to investigate the crystalline phase formation and to examine the lattice parameters of the samples. The crystallite sizes were estimated by using the most intense peaks in XRD patterns to investigate the nanocomposite system. Electrical conductivity of the samples was investigated in the temperature range 303 K–793 K to study the superionic conductivity. The superionic conductivity phase transition temperatures of the samples prepared at 500°C for 2 h were found as in the range of 483 K–523 K and for the samples prepared at 600°C for 2 h were found as in the range of 533 K–583 K.

Key words: (1-x) Li₂SO₄-xFe₂O₃ nanocomposite, TG-DTA, XRD, superionic conductivity

Introduction

There is a special interest in developing composite ceramic electrolytes with high chemical and thermal stability and low fabrication cost for application in intermediate temperature (400 °C–700 °C) fuel cell systems. The main focus of the most research initiatives has been directed at lowering the transition temperature to superionic state and increasing the conductivity of solid electrolytes [He, C.R., (2009)].

Enhancing the conductivity of ceramic electrolytes involves the dispersal of fine inert particles of insulator like Al_2O_3 , Fe_2O_3 , SiO_2 , etc., in the host matrix forming a two phase composite system [Kassim, A., (2011)]. The ionic conductivity of several solid electrolytes has been increased significantly, from 1 to 3 orders of magnitude, by dispersing fine, insulating particle of inert additive [Fang, T., (2004)]. This type of conductivity enhancement is called composite effect, and there are some theoretical models for explanation it, the interface mechanism, which involves space charge layer formation between the conducting and the insulating phase, enhanced conduction at the core of the interface, or an interfacial phase formation and effects of adsorbed surface moisture and impurities; the matrix mechanism, involves enhanced charge transportation along grain boundaries and dislocations, the stabilization of highly conducting metastable phases due to a homogeneous doping of the matrix [Fey, G.T.K., (2003)].

In the present work, the nanocomposite ceramic electrolytes with enhanced conductivity which have been prepared by double sintering ceramic method based on the Li_2SO_4 -Fe₂O₃ system. The nanocomposites with relative concentration x = 0.1, 0.2 and 0.3 in (1-x) Li_2SO_4 -xFe₂O₃ system were studied by temperature dependent electrical conductivity in the temperature range 303 K–793 K.

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Materials and Method

Preparation of Ceramic Electrolyte (1-x) Li₂SO₄-xFe₂O₃ System

Nanocomposite salt-ceramic electrolyte (1-x) Li₂SO₄-xFe₂O₃ system (where x = 0.1, 0.2 and 0.3) were prepared by double sintering ceramic method using analytical reagent (AR) grade Li₂SO₄ and Fe₂O₃. These oxides were weighed with desired stoichiometric compositions. The weighed powders were mixed and ground by an agate mortar for 1 h to be homogeneous and fine grain powders. The fine powders were presintered at 500°C for 2 h in vacuum chamber to obtain highly dispersed nanoparticles in the solid matrix. The presintered samples weremade into circular shape pellets under 70 MPa using hydraulic pellet-maker. Then, the pellet was sintered at 500°C and 600°C for 2 h each. Photographs of the weighed starting materials and experimental setup of sample preparation system were shown in Figure1.



(c) (d)

Figure 1. The weighed starting materials of $(1-x)Li_2SO_4-xFe_2O_3$ for (a) x = 0.1, (b) x = 0.2, (c) x = 0.3 and (d) experimental setup of sample preparation system

TG-DTA Measurement

Thermogravimetry and Differential Thermal Analysis (TG-DTA) methods are commonly used to solve analytical problems since they often provide an elegant and timesaving way of doing this. In the present work, SHIMADZU DTG-60H Thermal Analyzer at Universities' Research Centre (URC), University of Yangon, was used to investigate the phase formation temperature of the (1-x) Li₂SO₄-xFe₂O₃ (x = 0.1) sample. TG-DTA thermograms of the 4.579 mg mass of the sample were collected in the temperature range 30°C – 600°C under N₂ atmosphere with 50 ml min⁻¹. The speed of heating was chosen at the rate of 20°C min⁻¹ and kept constant in this measurement.

XRD Measurement

The crystalline phase formation of the (1-x) Li_2SO_4 -xFe₂O₃ (where x = 0.1, 0.2 and 0.3) samples prepared at 500°C and 600°C for 2 h each were investigated by PC-controlled rigaku multiflex Powder X-Ray Diffractometer using Ni-filter with CuK_{α}- radiation (λ = 1.54056 Å).

Temperature Dependent Electrical Conductivity Measurement

The as-prepared (1-x) Li₂SO₄-xFe₂O₃ (where x = 0.1, 0.2 and 0.3) samples were made into pellets by SPECAC hydraulic pellet-makerusing 70 MPa. The silver paste (conductive pen) was made over the sample to ensure good electrical contacts. The electrical resistances of the samples were observed in the temperature range of 303 K–793 K by the use of CAHO SR-T903 Temperature Controller. Thicknesses and the area of the pellets were 5.45 × 10⁻³ mand 1.14 × 10⁻⁴ m² respectively. The electrical resistances of the samples were measured by using FLUKE 45 Dual-display digital multi-meter. K-type thermocouple was placed near the sample to record real temperatures throughout the measurement. 300 W heater rods were used for heating elements. Experimental setup of electrical conductivity measurement was shown in Figure 2. The electrical conductivity σ of the sample has been calculated by using the formula $\sigma = l/RA$ where *l* is the thickness of the sample (m), *A* is the cross-sectional area of the samples or electrodes (m²), and *R* is the resistance (Ω).



Figure 2. Experimental setup of electrical conductivity measurement

Results and Discussion

Thermal Analysis

TG-DTA thermograms of the (1-x) Li₂SO₄-xFe₂O₃ (x = 0.1) sample were shown in Figure 3. In TG thermogram, one step mass variation (loss) was found in the temperature range 38.99° C - 601.56° C with 5.831%. Two endothermic peaks were found at 106.29° C and 584.16° C in DTA thermogram. The first peak indicated the dehydration of water because $0.9Li_2SO_4$ -0.1 Fe₂O₃ sample was a moisture sensitive material. The second peak represented the superionic phase transition of the sample.



Figure 3. TG-DTA thermograms of (1-x) Li₂SO₄-xFe₂O₃ (x = 0.1)

Structural Analysis

Powder XRD patterns of (1-x) Li_2SO_4 -xFe₂O₃ (where x = 0.1, 0.2 and 0.3) samples prepared at 500°C and 600°C for 2 h each were shown in Figure 4 and Figure 5. The collected diffraction lines were identified by using JCPDS data files of (i) Cat. No. 73-1250> Li_2SO_4 – Lithium Sulfate and (ii) Cat. No. 85-0599> Hematite – Fe₂O₃. As shown in observed XRD patterns, the collected diffraction lines were assigned with standard JCPDS and most of the lines were agreed with JCPDS data library.

XRD patterns showed that the (1-x) Li₂SO₄-xFe₂O₃ samples belong to monoclinic structure. The lattice parameters of the samples are evaluated by using crystal utility of the equation of $\frac{1}{d^2} = \frac{1}{\sin^2 \beta} \left(\frac{h^2}{a^2} + \frac{k^2 \sin^2 \beta}{b^2} + \frac{l^2}{c} - \frac{2hl \cos \beta}{ac}\right) = \frac{4 \sin^2 \theta}{\lambda^2}$, where θ is the diffraction angle, (hkl) is the Miller indices, *a*, *b*, *c* and β are the lattice parameters, and λ is the wavelength of incident X-ray.

Crystallite sizes below roughly 100 nm can be evaluated using powder diffraction technique. The fine particle nature of the crystalline powder is reflected in the X-ray line broadening. The crystallite sizes of the samples were estimated by using the Scherrer formula, 0.92

$$D = \frac{0.5\pi}{B \cos \theta}$$
, where D is the crystallite size (nm), λ is the wavelength of incident X-ray (Å), θ

is diffraction angle of the peak under consideration at FWHM (°) and B is observed FWHM (radian). In the present work, the FWHM of the strongest peak (I = 100%) of the planes for each of the collected XRD patterns used to calculate the crystallite size. The obtained crystallite sizes showed the samples were nanosized materials or nanocomposite materilas. The lattice parameters and the crystallite sizes of the samples were listed in Table 1.

Electrical Conductivity Study

Electrical conductivity of a salt-ceramic composite with temperature obeys an Arrhenius expression, $\sigma = \sigma_0 \exp(-E_a/kT)$ where σ is the conductivity, σ_0 is the preexponential factor, E_a is the activation energy for ionic conduction, k is the Boltzmann constant and T is the absolute temperature. Arrhenius plots of the variations of dc electrical conductivity of the (1-x) Li₂SO₄-xFe₂O₃ (where x = 0.1, 0.2 and 0.3) samples prepared at 500°C and 600°C for 2 h each are shown in Figure 6 and Figure 7. According to the theory of ionic conductivity, the slope of the electrical conductivity in each of the figure, for example in (1-x) Li₂SO₄-xFe₂O₃ (x = 0.1) at 500°C, corresponding to the activation energy for creating of defect states due to the ionic motions of the sample. As shown in Figure 6 and 7, temperature dependent electrical conductivity of the samples increased with the increase in temperature. The obtained activation energies were tabulated in Table 2.

Experimental results showed that the samples exhibited as superionic conductors at high temperature due to their electrical conductivity $\sigma \ge 10^{-3}$ S m⁻¹. The superionic phase transition temperature $T_{t1} - T_{t2}$ of the samples prepared at 500°C (483 K – 523 K) increased with the increase of preparation temperature at 600°C (533 K – 583 K). The observed behavior in ln σ vs 1000/T curve of the samples indicate that the charge carrier density which are generated as a consequence of thermal activated process of lattice defects, is increased up to end point temperature by increasing the concentration of the ceramic Fe₂O₃. Thus, the dc electrical conductivities of the samples prepared at 600°C were greater than that of the samples prepared at 500°C.





(c)

Figure 4. XRD patterns of (1-x) Li_2SO_4 -xFe₂O₃ where (a) x = 0.1, (b)x = 0.2 and (c) x = 0.3 samples prepared at 500°C for 2 h





(b)



Figure 5. XRD patterns of (1-x) Li_2SO_4 -xFe₂O₃ where (a) x = 0.1, (b)x = 0.2 and (c) x = 0.3 samples prepared at 600°C for 2 h

Table 1.	The lattice	parameters	and o	crystallite	sizes o	of (1-x)	Li ₂ SO ₄ ·	-xFe ₂ O ₃	(x =	0.1, 0.2
	and 0.3) sa	mples								

Preparation	Sample	Lattice parameters	D (nm)
Temperature (°C)	(Contents x of Fe_2O_3)		
500	0.1	a = 7.6636 Å, $b = 5.6431$ Å, $c = 8.4180$ Å, $\beta = 100.63^{\circ}$	26.72
	0.2	a = 5.9224 Å, $b = 7.6531$ Å, $c = 8.2123$ Å, $\beta = 108.96^{\circ}$	39.89
	0.3	a = 7.5721 Å, $b = 5.6885$ Å, $c = 8.3255$ Å, $\beta = 120.10^{\circ}$	49.95
600	0.1	a = 8.2343 Å, $b = 4.9792$ Å, $c = 8.4880$ Å, $\beta = 108.00^{\circ}$	29.65
	0.2	<i>a</i> =8.7941 Å, <i>b</i> = 7.5794 Å, <i>c</i> = 8.2021 Å, β = 109.57°	38.37
	0.3	a = 8.1939 Å, $b = 4.9532$ Å, $c = 8.4229$ Å, $\beta = 107.72^{\circ}$	52.22



Figure 6. Arrhenius plots of the variations of dc electrical conductivity of (1-x) Li_2SO_4 -xFe₂O₃ (x = 0.1, 0.2 and 0.3) samples prepared at 500°C



Figure 7. Arrhenius plots of the variations of dc electrical conductivity of (1-x) Li_2SO_4 -xFe₂O₃ (x = 0.1, 0.2 and 0.3) samples prepared at 600°C

Preparation Temperature (°C)	Sample (Contents x of Fe ₂ O ₃)	$E_a (\mathrm{eV})$
500	0.1	0.1814
-	0.2	0.2439
-	0.3	0.2663
600	0.1	0.3652
-	0.2	0.4042
-	0.3	0.4357

Table 2. Activation energies of (1-x)Li₂SO₄-xFe₂O₃ (x = 0.1, 0.2 and 0.3) samples

Conclusion

Salt-ceramic electrolyte system of (1-x) Li₂SO₄-xFe₂O₃ (where x = 0.1, 0.2 and 0.3) nanocomposites were prepared by double sintering ceramic method. TG-DTA thermograms indicated that the superionic phase transition temperature of the samples. XRD patterns showed that the samples were analogous to monoclinic structure and composed of Li₂SO₄ and Fe₂O₃ nanosized materials. Electrical conductivity of the samples was found to be increased with the increase in temperature and concentration of Fe₂O₃. The activation energy of the samples increased with the increase in temperature and concentration of Fe₂O₃. From the experimental results, the (1-x) Li₂SO₄-xFe₂O₃ (x = 0.1, 0.2 and 0.3) samples prepared at 600°C are more suitable for the applications of solid electrolyte materials in rechargeable battery than the samples prepared at 500°C due to the high temperature superionic conductivity.

Acknowledgements

We wish to express our sincere thanks to Dr Aung Aung Min, Rector-in-charge, Pyay University and Dr Thwe Linn Ko, Pro-Rector, Pyay University, Pyay, Myanmar, for their kind permission to carry out this work.

References

- He, C.R. and Wang,W.G. (2009). Aluminium Doped Ni/YSZ Anode Materials for Solid Oxide Fuel Cells, Journal of Fuel Cells, 9 (5), 630.
- Kassim, A., Rosli, M.Y. and Min, H.S. (2011).UV-Visible Studies of Chemical Bath Deposited Nise Thin Films, International Journal of Chemical Research, **3** (1), 21.
- Fang, T., Duh, J.G.and Sheen, S.R. (2004). LiCoO₂ Cathode Material Coated with Nanocrystalline ZnO for Li-ion Batteries, *Journal of Thin Solid Films*, **469-470**, 361.
- Fey, G.T.K., Chen, T.G. and Subramanian, V. (2003). Eletroanalytical and Thermal Stability Studied of Multidoped Lithium Nickel Cobalt Oxides, *Journal of Power Sources*, **119**, 658.

The Design of Weather Forecasting Model for the Personal Weather Station

Aung Zaw Oo¹, Myo Aung², Ye Chan³,

Abstract

This research aims at designing and constructing a personal weather station and artificial neural network model to forecast temperature, relative humidity, atmospheric pressure and possibility to rain. DHT22 temperature and humidity sensor module, BMP085 pressure sensor, 3-cup anemometer, wind vane, tipping bucket type rain gauge measurement unit are used as main sensors for designing weather station. Acquisition and processing of sensors' data are performed by ATmega 2560 microcontroller and the processed data are uploaded to the server via mobile network by SIM 900 A GSM module. Long short-term memory (LSTM) auto-encoder neural network model is proposed for mapping the past weather data into the future. Constructed model is trained using Keras neural network library with TensorFlow-backend. The model predicts temperature, pressure and humidity. The average accuracy of the LSTM models is 0.94.

Key words: weather station, neural artificial network, LSTM auto-encode model

Introduction

The aim of this research is to construct a personal weather station and the weather forecasting model using deep learning methodologies, to forecast the accurate weather condition using data from personal weather station. DHT 22 temperature and humidity measurement sensor, BMP 085 pressure sensor, three-cup anemometer, wind vane and rain gauge sensor are used as measurement modules in constructed personal weather station. These sensors are connected to ATmega 2560 microcontroller. Domain name is registered with a web hosting company to setup the private database server. Domain name of constructed database server is set up as "www.azo-weather.com". Personal weather station measures temperature, wind speed, wind direction, relative humidity, atmospheric pressure and rain fall. Weather data measurements are taken at every three hour time interval and uploaded to database server via the internet access using SIM 900 A GSM module. Current weather information and historical data are shown on the created website (www.azo-weather.com).

To forecast weather, forecasting model is set up using deep learning method based on artificial neural network (ANN). LSTM auto-encoder model forecasts the temperature, humidity and atmospheric pressure. Forecast area is chosen to Pyay, Bago Division, Myanmar. Twelve year weather data collected from a weather website are used as train and test datasets. Weather data download from personal weather station are used as test datasets only. LSTM auto-encoder model is tested and validated to forecast weather using these datasets.

Materials and Methods

Personal weather station is a set of weather measuring instruments (sensors) which is operated by a private. Constructed personal weather station measures wind speed, wind direction, rainfall, temperature, relative humidity and atmospheric pressure. Domain name is also created from a web hosting company to set up the database server. The data acquired from sensors are sent to database server via the internet by using SIM 900 A GSM (Global System for Mobile Communications) module. Figure 7 shows the constructed personal weather station. Figure 8 shows the internal circuit diagram of personal weather station. Figure 9 shows complete circuit diagram of personal weather station.

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Wind Speed Measurement

The three-cup anemometer is a wind speed measuring device as shown in Figure 1. Wind speed measurement is done from the rotating speed of wind cups. As the anemometer cups rotate, a single magnet on the anemometer closes a reed switch which is reflected on the output, completing the circuit.

Wind Direction Measurement

Wind vane shown in Figure 2 is used to measure wind direction. It has eight reed switches and each of reed switches connected to a different resistor. The vane's magnet closes only one switch when it passes over the reed switch, but it can close two neighbouring reed switches when it's positioned halfway between them. This allows the wind vane to have 16 possible combinations of resistance and allowing up to 16 different positions to be indicated for direction shown in Table 1. A 10 k Ω external resistor is used to form a voltage divider circuit, to produce a voltage output that can be measured with an analog to digital converter of microcontroller.

Precipitation Measurement

Personal weather station uses tipping buckets type rain gauge sensor to measure precipitation. Tipping bucket rain gauge is shown in Figure 3. It has one reed switch. One terminal of anemometer's reed switch is connected data pin D2 of ATmega 2560 microcontroller and 5 V DC power supply via 10 k Ω resistor. Other terminal of reed switch is connected to ground.

Temperature and Humidity Measurement

The DHT 22 is a digital temperature and humidity sensor. It has an operating temperature range of -40°C to +80°C and ± 0.5 °C accuracy. An operating humidity range is from 0 to 100% RH and $\pm 2\%$ to $\pm 5\%$ accuracy. Figure 4 shows the photo of DHT22 temperature and humidity sensor. 5 V DC power is connected to V_{CC} of DHT 22 sensor. Pin 2 of DHT 22 is connected to the data pin D4 of microcontroller.

Atmospheric Pressure Measurement

To measure atmospheric pressure BMP 085 sensors is used. Pressure and temperature data are provided as 16 bit value via the I2 C interface with the calibrated data. The BMP085 offers a pressure measuring range of 300 to 1100 hPa with accuracy down to 0.02 hPa. BMP 085 presser sensor is shown in Figure 5. SDA pin of BMP 085 is connected to SDA pin 20 of ATmega 2560 microcontroller and SCL pin of BMP 085 is connected to SCL pin 21 of microcontroller.

Design of Data Communication Gateway

Data communication gateway is a device which works in the center of the communication line and supports a path for device-to-cloud communication. SIM 900A GSM module shown in Figure 6 is a specialized type of modem which accepts a SIM card, and operates over a subscription to a mobile operator, as a mobile phone. It is used as data communication gateway device to send data to internet database server. This gateway reads data from the sensor's data and transmits it to a destination server across the internet. Rx and Tx pins of SIM 900A GSM module are connected to pin 18 and pin 19 of microcontroller. GSM module can be controlled by microcontroller by using AT-command.



Figure 1 Photo of three-cup anemometer



Figure 3 Photo of rain gauge sensor



Figure 5 BMP085 barometric presser sensor



Figure 2 Photo of wind vane



Figure 4 DHT22 sensor



Figure 6 SIM900A GSM module



Figure 7 Photograph of personal weather station



Figure 8 Internal circuit of weather station

Wind Direction (Abbreviation)	Wind Direction (Degree)	Resistance of Wind Vane for 16 Positions (kΩ)	Output Voltage of Wind Vane (V)
N	0	33.00	3.84
NNE	22.5	6.57	1.98
NE	45.0	8.20	2.25
ENE	67.5	0.89	0.41
Е	90.0	1.00	0.45
ESE	112.5	0.69	0.32
SE	135.0	2.20	0.90
SSE	157.5	1.41	0.62
S	180.0	3.90	1.40
SSW	202.5	3.14	1.19
SW	225.0	16.00	3.08
WSW	247.5	14.12	2.93
W	270.0	120.00	4.62
WNW	292.5	42.12	4.04
NW	315.0	64.90	4.33
NNW	337.5	21.88	3.43

 Table 1 Wind Direction Calculation by using Output Voltage of Wind Vane



Figure 9 Completed circuit diagram of personal weather station

Weather Sensors Calibration

To measure win speed, anemometer calibration is performed with Anemometer-840003. Figure 10 shows calibration curve of wind velocity. Regression coefficients m (the gradient of the line) is 0.062, the intercept of the line is 0.2646 and coefficient of determination R^2 is 0.9954 for anemometer calibration. As coefficient of determination is close to 1, the calibration has good correlation between two sensors. The relationship between the cup anemometer factor K and wind velocity V is shown in Equation (1).

(1)

(2)

$$K = \frac{V}{2\pi f_r R_{rc}}$$

Using calculation result, the relation between wind speed V and cup frequency f can be described as

$$V = K \,\omega R_{rc} = 0.062 \, f$$

Wind directions are calculated from output voltage of wind vane circuit and according to output voltages, 16 positions of wind directions are calculated.

In rain gauge calibration, 1.77 cm^3 is required to make the buck tip down. The surface area of rain collector is 50 cm² and 1.77 cm³ of collected rain (single tip of bucket) is equivalent to 0.354 mm of rain fall. That is why, 0.354 mm precipitation causes the rain gauge circuit generate one pulse signal. Figure 12 shows precipitation calibration.

DHT 22 temperature and humidity sensor is calibrated with UT 331 (Digital Thermo-Hygrometer) sensor. Regression coefficients m is 1.02, the intercept of the line is 0.21 and coefficient of determination R^2 is 0.9996 for temperature calibration. Regression coefficients m is 0.99, the intercept of the line is 0.22 and coefficient of determination is 0.9999 for humidity calibration. As coefficient of determination is close to 1, calibration gets the good correlation. Figure 13 shows DHT 22 sensor calibration with reference meter. Figure 14 and 15 shows the calibration curves of the temperature and humidity with a reference meter.



Figure 10 Calibration curve of wind velocity



Figure 12 Precipitation calibration



Figure 11 Wind speed calibration



Figure 13 DHT22 calibration with reference meter (UT331 Digital Thermo-Hygrometer)



Figure 14 Calibration curve of the temperature with a reference meter



Domain Name Registration and Creation of Database Server

To start a website, it is needed to set up a domain name. To store weather data in database server and to show historical data, domain name is bought from a global web hosting company, Fastcomet (https://www.fastcomet.com). Database server is created in the domain of www.azo-weather.com. MySQL database system is used in server. To access data from internet access, server name, user name, password and database name are set correctly according to server setting. Server name is "azo-weather.com" and user name is "azo-weath_user1".

With database management systems, database table is created in database (azoweath_testdata), to store weather data. Name of constructed database table is "PWD". Field names (columns) are id, Time, Temperature, Wind_Speed, Win_Direction, Humidity, Rain and Pressure. Figure 16 shows the constructed data table structure in MySQL server. A primary key is a special relational database table column designated to uniquely identify all table records. In created database, "id" is set as primary key. Figure 17 shows database table in database server.

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6	Humidity	int(11)			No	None							No. Change	Drop	- More
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Figure 16 Constructed data table structure in MySQL server

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Figure 17 Database table in database server

Weather Webpage and Data Visualization

Database server at website 'www.azo-weather.com' was set up and upload data from weather station are recorded in the database of that server. Figure 18 shows home page of www.azo.weather.com with clickable buttons link to subpages which shows the historical weather data of temperature, humidity, atmospheric pressure, wind speed and precipitation and also displays those data on the real-time chart.

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Figure 18 Constructed weather website (www.azo-weather.com)

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Figure 19 Historical data table shown on webpage (http://azo-weather.com/azopwtable.php)

Artificial Neural Network

An artificial neural network (ANN) is a computational model which is interconnected by the way biological nervous systems, such as the brain, process information. It is based on the connected nodes, called artificial neurons and transmits a signal to other neurons. An artificial neuron gets a signal and processes it. Artificial neural networks compose of input and output layers, as well as a hidden layer consisting of units which transform the input into output. Figure 20 shows a simple neural network.



Figure 20 Simple neural network model

LSTM Structure

Long short-term memory (LSTM) is a recurrent neural network architecture applied in the field of deep learning. Each LSTM unit is composed of a cell, an input gate, an output gate and a forget gate. The cell recognizes the values and the three gates regulate the information into and out of the cell. LSTM cell has two states, the hidden state and the internal cell state where the hidden state corresponds to the short-term memory component and the cell state corresponds to the long-term memory.

$$i_t = \sigma \left(W_i \cdot h_{t-1} + V_i \cdot x_t + b_i \right) \tag{3}$$

$$o_t = \sigma \left(W_o \cdot h_{t-1} + V_o \cdot x_t + b_o \right) \tag{4}$$

$$f_t = \sigma (W_f. \ h_{t-1} + V_f. \ x_t + b_f)$$
(5)

$$\tilde{C}_t = tanh (W_c . h_{t-1} + V_c . x_t + b_c)$$
 (6)

$$C_t = i_t \odot C_t + f_t \odot C_{t-1} \tag{7}$$

$$h_t = o_t \odot \tanh(\mathcal{C}_t) \tag{8}$$
$$z_t = h_t \tag{9}$$

$$z_t = h_t$$



Figure 21 Repeating module in an LSTM contains four interacting layer

Creating LSTM Auto-encoder Model

LSTM auto-encoder is a type of self-supervised learning model which can learn a compressed representation of input data. In this research, LSTM auto-encoder models are setup and performance of model is examined with loss and accuracy of training process. LSTM autoencoder consists of encoder part and decoder part. An encoder part consists of two LSTM layers, while decoder part consists of two LSTM layers. Encoder has two layers with 128 neurons and 64 neurons. Decoder has two layers with 128 neurons and 64 neurons. LSTM auto-encoder neural networks are defined in Keras as a sequence of layers. Dense layer is a fully connected layer of neurons, used to make prediction and a value of 128 hidden neurons have been designed in dense layer to train the model. The repeat-vector layer repeats the final output vector from the encoding layer as a constant input to each time step of the decoder. Time distributed dense layer applies a same dense (fully-connected) operation to every time step of a 3D tensor.



Figure 22 LSTM auto-encoder model

Collecting Data Sources and Datasets

To forecast weather parameters, weather data are collected from two sources, first source is from online weather page and second source is from constructed personal weather station. First weather data sets, three-hour interval of weather data (temperature, wind speed, wind direction, cloud, relative humidity, precipitation and atmosphere pressure) are collected from a weather website (https://www.worldweatheronline.com). The research area is chosen as Pyay area. Collected data covers a time period from the July 2008 to December 2019. Second weather data set are collected from constructed personal weather station, covers a time period from January 2019 to December 2019.

Results and Discussion

Temperature, Humidity and Pressure Forecasting

LSTM model forecasts the temperature, relative humidity and atmospheric pressure. This model has same feature (variables) for input and output. 30680 online data (from August 2008 to December 2018) are downloaded from "www.worldweatheronline.com" and saved as CSV file format to use as train and test data. Training dataset consists of 27752 samples (taken from August 2008 to December 2017) and 30672 samples (from August 2008 to December 2018). Test datasets consists of 2904 samples (taken from 1st January 2019 to 31st December 2019) are used as test data by setting the eight data points for look back data and one data point for future predict value. In this experiment, two test datasets which are online datasets and datasets from personal weather station were used. The model gives satisfactory results for both data sets and Table 2 shows the loss and accuracy comparison of experiments using 200 epochs for eight look back time stamps to predict one next time stamp.

There are four experiments for training and testing of LSTM model. In experiment 1, weather data from 2008 to 2017 are used for training the model and weather data in 2018 are used to verify the model prediction results for 2018. In experiment 2 to 4, dataset from 2019 are used as test data. According to the result shown on Table 2, accuracy is depended on number of training samples. Minimum and Maximum training accuracy are 0.9365 and 0.9449 respectively. The experiment 4 is carried out using test data set collected from constructed weather station and the accuracy is found to be 0.9428.

Experiment	Feature	Train Data	Test Data	Train Sample	Test Sample	Train Loss	Test Loss	Train Accuracy	Test Accuracy
1	T,H,P	2008 to 2017	2018	27752	2904	0.0009	0.0012	0.9466	0.9365
2	T,H,P	2008 to 2017	2019	27752	2904	0.0009	0.0020	0.9461	0.9404
3	T,H,P	2008 to 2018	2019	30672	2904	0.0009	0.0020	0.9467	0.9449
4	T,H,P	2008 to 2018	2019	30672	2904	0.0034	0.0078	0.9476	0.9428

Table 2 Loss and Accuracy of First LSTM Auto-encoder Model

T = Temperature, H = Humidity, P = Pressure



Figure 23 Loss and accuracy with 200 epochs (Experiment 4, Personal weather station data)

Visualization of Forecasting Data

Temperature, humidity and pressure forecasting result from 1^{st} December 2019 to 5^{th} December 2019 are taken to show by charts. Comparison charts for observed data and forecast data are shown in Figure 24, 25 and 26. Maximum error % for temperature, humidity and pressure forecasting are 8%, 5% and 0.2% respectively. According to results, error % is in an acceptable range and the model can be applied to weather forecasting.



Figure 24 Temperature forecasting (1-12-2019 to 5-12-2019)



Figure 25 Humidity forecasting (1-12-2019 to 5-12-2019)



Figure 26 Atmospheric Pressure forecasting (1-12-2019 to 5-12-2019)

Conclusion

Personal weather station network has been constructed to contribute the local weather data and to have it publicly viewable on the website. The artificial neural network weather forecasting model has also been developed to provide a localized short-term forecast using collected data. Weather station is designed using low cost weather measurement sensors, microcontroller and GSM module. Measured weather data from 1st January 2019 to 31st December 2019 were uploaded to database server in websites "www.azo-weather.com". Historical and present weather data are shown on that website. Train and test processes of neural network model were made with different datasets. To reduce the training time, data processing were performed on both central processing unit (CPU) and graphical processing unit (GPU). The processing time is 40 times faster than CPU only test. LSTM auto-encoder models is trained and tested with different datasets. For test datasets of year-2019, train and test accuracy are 0.9476 and 0.9428 respectively. The neural network model has good forecasting performance as accuracy differences for all testing processes are very small and average accuracy is 0.94.

Acknowledgements

We wish to express our sincere thanks to Dr Aung Aung Min, Rector-in-charge, Dr Thwe Linn Ko, Pro-Rector, Pyay University, Dr Soe Soe Nwe, Professor and Head, Department of Physics, Pyay University and Dr San San Swe, Professor, Department of Physics, Pyay University, for their kind permission to carry out this research paper.

References

- Gers, F., (2016). "Long Short-Term Memory in Recurrent Neural Networks Long Short-Term Memory," No. 2001, pp. 1–103.
- Hahn, P., (2019). "Artificial intelligence and machine learning," Vol. 51, No. 1.
- Hwang, S., Jeon, G., Jeong, J., and Lee, J. Y., 2019. "A novel time series based Seq 2 Seq model for temperature prediction in firing furnace process," Procedia Comput. Sci., Vol. 155, no. 2018, pp. 19–26,.
- IBM Corporation, (2010). "Data Servers, Databases, and Database Objects Guide," .
- Liu, T., (2016)."Digital Humidity and Temperature sensor," Adfruit, pp. 1-5.
- Majumder, M., (2015). "Artificial Neural Network,". Available: https://en.wikipedia.org/wiki/Artificial_neural_network.
- Pindado, S., Cubas, J., and F. Sorribes-Palmer, (2014). "The cup anemometer, A fundamental meteorological instrument for the wind energy industry. Research at the IDR/UPM institute," Sensors (Switzerland), Vol. 14, No. 11, pp. 21418–21452.
- Venugopalan, S., Rohrbach, M., Donahue, J., Mooney, R., Darrell, T., and K. Saenko, (2015). "Sequence to sequence -Video to text," *Proc. IEEE Int. Conf. Comput. Vis.*, Vol. 2015 Inter, pp. 4534–4542.
- Xie, Y., Zhou, L. Le.Y., and V. V. Raghavan, (2018). "Deep Learning for Natural Language Processing," Vol.38.

Mechanical Characterization of Fibre Mixed Clay Bricks

Soe Soe Thin¹, Mar Lar Aye², Hla Ohn Mar³, Naw Htoo Lar Phaw⁴

Abstract

The main purpose of this research was to investigate the fibre content effect of heat treated clay bricks on the mechanical properties. Waste fibre materials from water *Hyacinth* plants were added into a mixture of clay and water thoroughly. The modified mixture was molded and then dried under sunshine. The dried clay bricks were baked with traditional high temperature kiln. The newly bricks were tested with the universal testing machine for their compressive strength and bending strength respectively. From the tested and calculated results, the compressive strength and flexural modulus increased with increasing the fibre to clay weight ratio with x:(100-x) and 2x:(100-2x) but decreased in 3x:(100-3x). (where x = 0.4 wt% for water *Hyacinth* fibre (S).

Key words: compressive strength, bending strength

Introduction

The firing process could affect the physical and mechanical properties, colours and appearance of the manufactured brick. An effort to recycle and incorporate the natural wastes in the construction industry, especially used in the manufacturing of building materials. Brick is one of the most accommodating masonry units due to its properties. Currently, due to the demand of bricks as building materials, many researchers have investigated the potential wastes that can be recycled or incorporated into fired clay bricks. Owing to the flexibility of the brick composition, different types of waste have been successfully incorporated into fired clay bricks. Masonry is very weak in tension because it is composed of two different materials distributed at regular intervals and the bond between them is weak. Therefore, masonry is normally provided and expected to resist only the compressive forces.

In Pyay District, the traditional bricks made by the mixture of mud and chaff for construction of buildings are used. Bricks from that area pass through the second value of compressive strength. To get more flexible strength, those bricks were prepared by adding water-*hyacinth* fibre. We have made that research to improve the mechanical properties such as compressive strength and flexible (bending) strength and to get more resilient from the weather and disaster. In this research, clay bricks with fibre of water *Hyacinth* have been used.

Experimental Procedure

The water-*hyacinth* fibres were dried under sunshine naturally. Thickness of water-*hyacinth* -fibre used this research is about 2 mm. The dried fibres were cut into small pieces of about 1 mm or 2 mm. After cutting, the dried fibres were weighed with SHIMADZU digital electronic balance. The weight ratios of fibre that mixed with the mud were shown in table 1.

Firstly, five molds with the dimensions of 23.2 cm \times 11.1 cm \times 4 cm for compressive strength, five molds with 35.56 cm \times 10.6 cm \times 10.6 cm for bending strength and five molds with 45.72 cm \times 2.54 cm \times 2.54 cm for tensile strength measurements were made for this research.

In this research, mud and chaff were used as raw materials to make brick. A ditch of mud which is 5 square feet and 1foot depth from Hmawza village, Pyay township, Pyay

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district, Bago west region was thoroughly mixed with chaff for a night. In the morning, it was added and mixed again with chaff to prepare the soil for molding brick. That soil was tested by Energy Dispersive X-Ray Fluorescence (EDXRF) and X-Ray Diffraction (XRD) to know the composition of that soil.

The weighted water-*hyacinth* fibre and the pulverized mud were mixed thoroughly. That treated soil was transformed into bricks. Five sample bricks were dried in air and heated under sunlight for 15 days. Then, they were heat treated in the wood fire for 5 days.

And then, the compressive strength of brick samples was determined by compressive strength testing machine (GUNT) at Civil Engineering Department of Pyay Technological University (PTU) and the bending strength universal testing machine (UPM-4) from the structural laboratory at Department of Civil Engineering in Yangon Technological University (YTU). Figure 1 shows the procedure of the fibre mixed clay bricks.



Figure 1 The block diagram of preparation of brick with fibre

Table 1. The weight ratios of fibre mixed with the clay

Type of Test	Fibre Content(Gram)					
Type of Test	S1	S2	S 3			
Compressive Strength	4	8	12			
Bending Strength	3.08	6.16	9.24			



Figure 2 (a) Molds for compressive and bending strength (b) Bricks for compressive strength test and bending strength test



Figure 3 (a) Preparing bricks (b) Measuring compressive strength test (c) Measuring bending strength test

Experimental Results

Compressive Strength and Bending Strength Results

The heat treated clay bricks to test the compressive strength and bending strength were named S_1 for one weight ratio of water *Hyacinth* fibres, S_2 for two times of fibre content and S_3 for three times of fibre content of S_1 repectively.

Name of brick samples	Compressive strength (MPa)			
S1	3.063			
S2	3.375			
S3	3.273			

Table 1. Results of Compressive Strength

Table 2. Results of Bending Strength Modulus

Load(N)	Flexural Bending Modulus (MPa)						
	S1	S2	S3				
50	75.98	88.5	78.96				
100	92.36	94.7	86.06				
150	113.97	122.75	116.41				
200	119.25	125.87	117.48				



Figure 5 (a) Comparison of compressive strength vs different water-hyacinth fibre contents



Figure 5 (b) Comparison of bending strength modulus vs different water-hyacinth fibre contents

Conclusion

The values of compressive strength of brick samples made by the mixture of natural mud and paddy shell with inserting water-hyacinth fibre with different weight ratios are 3.063 MPa, 3.375 MPa and 3.273 MPa respectively. These values are very agreeable with the BIS (Bureau of Indian Standard 1077-1992) standard values of ordinary class clay brick.

The values of flexural strength of bricks possess the best grade bricks. From the above mentional results, the water-hyacinth fibre is the appropriate additive to prepare bricks with higher compressive strength and bending strength but not more than 2x weight ratio. The conventional bricks currently used in Hmawza township are safe in construction. To improve their mechanical property, the water-hyacinth fibre should be mixed. That fiber is abandent in our environment and highly productive rate.

Acknowledgements

We would like to express our sincere acknowledgement to all those who have helped us to complete this research. First and foremost, we would like to express our deepest gratitude to Dr. Aung Aung Min, Rector-incharge, Pyay University, and Dr. Thwe Linn Ko, Pro-rector, Pyay University, for their encouragement to do this research. Secondly, we would like to give our greatest thanks to Dr. Soe Soe Nwe, Professor (Head), Department of Physics, Pyay University and Dr. San San Swe, Professor, Department of Physics, Pyay University, for their encouragement, and comments on this research.

References

AK Aselina and M Abbas, AMM 421(2013)201-204.

- A Costigan and S Pavía, Proceedings of PROHITEC 09 Mazzolani editor(2009), Taylor and Francis Group, London, 1609-1615.
- CM Chan, World Academy of Science, Engineering and Technology International Journal of Civil and Environmental Engineering Vol:5, No:1 (2011) scholar.waset.org/1307-6892/4241.

.https:// www.gobrick.com.

Synthesis and Characterization of Graphene Oxide by Improved Hummers Method

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Abstract

Graphene oxide (GO) was successfully synthesized by improved Hummers method. The oxidation process was identified by both visualization and characterization using Ultraviolet-visible (UV-vis), Fourier transform infrared (FT-IR) and X-ray diffraction (XRD) analysis. It was found that graphite could be transformed to GO by using oxidizing agents H_2SO_4 and H_3PO_4 . Besides, sonication process was a useful pathway to obtain graphite oxide to graphene oxide. The complete oxidation process was studied by color changing through visualization. XRD measurement interprets the essential parameters of interplanar spacing (d spacing), which indicates the information of oxidation, between the graphite powder to graphene oxide. The crystallite size of synthesized GO particles was calculated by Debye Schrrer formula.

Key words: graphite oxide, graphene oxide, improved Hummers method

Introduction

Graphene oxide (GO) was obtained from pristine graphite powder which is a chemically modified graphene containing oxygen functional groups such as epoxides, alcohols, and carboxylic acids. The presence of oxygen functional groups makes the inter layer spacing of GO larger than graphite. Therefore, GO has high specific surface area, high mesopore volume, and certain level of electrical conductivity. That is why GO is especially fitted for use in the production of transparent conductive films, flexible electronics, solar cells, chemical sensors and so on.

For the preparation of GO, firstly graphite powder can be synthesized with oxidizing agents as a source of graphite oxide. This graphite oxide can be changed into graphene oxide (GO) by using many thermal and mechanical methods of graphite oxide which is exfoliated to form a single layer of GO. Graphite oxide and GO are similar in chemical properties but different in its structure and properties (Dreyer D.R.etal., 2010). Graphite oxide can be described as group of layers graphene oxide. In this work, ultrasonic exfoliations of graphite oxide (sonication method) was applied to get a single layer of GO and it was an effective way to obtain graphite oxide to GO. There are four basic methods to synthesis GO such as Staudenmaier, Hofmann, Brodie and Hummers methods (Hwee *etal.*, 2012). Among them, Hummers method is commonly used and reliable method for the mass production of graphite oxide. In this work, the improved Hummers method has been applied for the preparation of GO because this method does not generate toxic gas and the temperature is easily controlled. Figure 1 shows the synthesis approach of graphite to graphite to graphene oxide (GO).

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Figure 1 Synthesis approach of GO

Materials and Methods

Synthesis of Graphite Oxide

In this synthesis, Graphite powder, H_2SO_4 and KMnO₄ were used as a GO source, solvent and oxidizing agent according to the improved Hummers method. Typically, graphite powder (1 g) was dissolved in concentrated H_2SO_4 (98%, 50 ml) and H_3PO_4 (5.5 ml) volume ratio (9:1) with stirring and then KMnO₄ (3 g) was slowly added to the mixture. The reaction mixture was then heated to 40° C for 6 h. After that, 100 ml of distilled water (DW) was slowly added to the reaction mixture in order to fully stop the oxidation process. Then, the slurry was quenched inside the ice bath. H_2O_2 (30 wt%, 10 ml) was slowly added to remove the excess KMnO₄. The resultant suspension of GO was separated by centrifugation and then the remaining solid was thoroughly washed with 1 M HCl followed by water and acetone to remove the sulfate and contaminations. The gel-like graphite oxide was dried by using oven at 60° C for 24 h to obtain the resultant graphite oxide powder. (Zaaba N I *etal.*, 2017)

Synthesis of Graphene Oxide (GO)

Subsequently, previous synthesized graphite oxide was filtered and washed with distilled water (DW), 1 M HCl and acetone. The filtered paste was dissolved in 100 ml of DW. And then, the solution was sonicated for 2 h to exfoliate the layers and centrifuged for 20 min each at 4000 rpm for five times. Finally, GO flakes or powder was obtained by being dried with the use of oven.

Characterization

Graphite, as prepared graphite oxide and GO were analyzed by using several techniques. The absorbance of graphene oxide (GO) solutions was detected by EVOLUTION 220 UV-Visible Spectrophotometer. FT-IR NICOLET iS5 spectrophotometer was used to characterize the presence of functional groups in as-prepared samples. X-ray diffraction (XRD) patterns of graphite, graphite oxide and graphene oxide were recorded by RIGAKU-RINT 2000 XRD machine to identify the crystal structure of synthesized samples.

Results and Discussion

(c) brown green (a) Black (b) dark green (d) brown (g) Brilliant brown or amber (f) reddish brown (e) light brown

Figure 2 Color changing of graphite to graphene oxide

In the preparation of the graphite oxide, color changing process can occur through visualization. The black color solution is due to the graphite's dark color (Figure 2a) and after KMnO₄ was slowly added to the solution, the color turned to dark green (Figure 2b) since the color of initial KMnO₄ is purple color but when it reacts with H₂SO₄, the reaction equation can be expressed as shown below. The mixing color of reaction gives dark green.

$$2KMnO_4 + 2H_2SO_4 \rightarrow Mn_2O_7 + H_2O + 2KHSO_4$$

Again, Mn_2O_7 can react further with H_2SO_4 and it can give the MnO_3^+ as shown below. Thus, the reaction color gives brown green.

$$Mn_2O_7 + 2H_2SO_4 \rightarrow 2[MnO_3]^+[HSO_4]^- + H_2O_3$$

Similarly, Mn_2O_7 decomposes at 40 °C and gives MnO_4^- and thus, the reaction color gives brown green (Figure 2c). Then the color changed to brown color after stirring for an hour at 40°C (Figure 2d). It became light brown color after stirring for 3 h (Figure 2e) and it did not change anymore for more hours. In the termination process of oxidation, the solution color changed as reddish brown since DW is poured into the mixture solution (Figure 2f). Finally, the complete oxidation state of graphite was brilliant brown yellow (amber) due to the addition of H_2O_2 to the solution in order to consume the residue manganese oxide. Thus, final product of pure graphite oxide color was amber (Figure 2g). Therefore, it was remarkable that the stoichiometric ratio of H₂SO₄ and KMnO₄were essential parameters to complete the oxidation process.

UV-Vis Result

Figure 3 shows that, the strong absorption peak of GO is at 230 nm and it is quite similar with the work reported by (Hidayah N. M. S.etal., 2017) where the absorption peak was at 238 nm.

Visualization





Figure 3 UV-vis spectrum of graphene oxide (GO)

FT-IR Result

The presence of different types of oxygen functional groups in graphite and graphene oxide were confirmed by their FT-IR spectra. Figure 4 illustrated the FT-IR spectra of graphite oxide and graphene oxide (GO). The broad peaks observed around 3300 cm⁻¹ were due to stretching vibration of O-H groups. The peak at 1712 cm⁻¹ was due to stretching vibration of C=O. The peak at 1629 cm⁻¹ could be attributed to the bending vibration of O-H group. The peaks at 1024-1036 cm⁻¹ were due to C-C stretching. Two additional peaks occurred at 1155 cm⁻¹ and 885 cm⁻¹ of graphite oxide were due to C-O group and C-H group.



Figure 4 FT-IR spectrums of Graphite oxide and GO

XRD Result

XRD was used to investigate the crystal phase and to determine the interlayer spacing and crystallite size of graphite and GO. The 2θ peak of graphite powder was found out at 26.588° from Figure (5). This peak confirmed that the interlayer distance of graphite powder was 3.3498 Å. For GO, the 2 θ peak shifted to 10.796°, which indicated that the graphite was fully oxidized into GO with an interlayer distance of 8.1879 Å as shown in Figure (6). The values of interplanar spacing (d) and crystallite size (D) of graphite powder and GO are shown in Table 1. The crystallite size of Graphite and GO was found out to be 68.99 nm and 10.1 nm calculated by Debye Schrrer Formula as follows:

$D = k\lambda / \beta cos\theta$

where λ is X-ray wavelength (1.5405 Å), D represents the average crystallite size, β is line broadening in radians and θ is Bragg's angle and k is Scherer's constant (0.89).

 Table 1
 The result of interplanar spacing (d) and crystallite size (D) of graphite powder and GO

Sample	2-theta (degree)	FWHM (degree)	d spacing (Å)	D (nm)
Graphite	26.588	0.174	3.3498	68.99
GO	10.796	0.780	8.1879	10.1



Figure 5 XRD spectrum of graphite powder



Figure 6 XRD spectrum of graphene oxide (GO)

Conclusions

In this study, graphene oxide (GO) was synthesized by improved Hummers method through sonication process. The structural properties of graphene oxide were analyzed by three characterization techniques including UV-vis, FT-IR and XRD results. Firstly, the maximum peak 230 nm from strong absorption UV-vis spectrum suggested that the synthesized product was GO nanoparticles. Secondly, FT-IR results additionally supported that the compound identification of GO. Finally, the comparative results of interplaner spacing between graphite powder and GO nanoparticles measured XRD confirmed that the transformation of graphite to GO. The visualization results essentially informed that the color changing of each reaction process in each reaction time which was remarkable to assist the final formation of fully oxidized graphene nanoparticles. In conclusion, based on different characterization results, the final product was GO nanoparticles according to structural properties were agreed with GO.

Acknowledgements

We are greatly thankful to Dr Aung Aung Min, Rector-in-charge, Dr Thwe Linn Ko, Pro-rector and Dr Soe Soe Nwe, Professor and Head, Department of Physics, Pyay University, Dr San San Swe, Professor, Department of Physics, Pyay University, for their encouragement to accomplish to this work.

References

- Dreyer D.R, S. Park, C. W. Bielawski, and R. S. Ruoff, "The chemistry of graphene oxide," *Chem. Soc. Rev.*, Vol. 39, No. 1, 2010, pp. 228–240.
- Hidayah N.M.S, L. Wei-Wen, L. Chin-Wei L, N. Z. Noriman, K. Cheng-Seong, U. Hashim, and H. Cheun Lee, (2017). "Comparison on graphite, graphene oxide and reduced graphene oxide: Synthesis and characterization," American Institute of Physics, 1892, 1-8.
- Hwee Ling Poh, Filip Šaněk, Adriano Ambrosi, Guanjia Zhao, Zdeněk Sofer and Martin Pumera, (2012) "Graphenes prepared by Staudenmaier, Hofmann and Hummers methods with consequent thermal exfoliation exhibit very different electrochemical properties," Nanoscale 4, 11, 3515-3522.
- Zaaba N.I., K.L.Foo, U.Hasjim, S.J.Tan, Wei-Wen Liu, C.H. Voon. (2017). Synthesis of Graphene Oxide using modified Hummers Method: Solvent Influence. Procedia Engineering 184, 469-477.

Optical and Photoconductance Studies of Spray Pyrolysis Prepared CdS Thin Films

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Abstract

Cadmium Sulphide, CdS thin films were prepared on the glass substrates for different spray times, 10 s, 20 s and 30 s at the deposition temperature 300°C by spray pyrolysis technique. Crystalline phase formations of these films were investigated by X-ray diffraction (XRD) technique. XRD patterns showed that films have polycrystalline nature with a hexagonal structure. Direct band gap values of 2.40–2.58 eV were obtained from optical absorption spectrum. The optical parameters studied the absorbance and transmittance spectra, refractive index, extinction coefficient and optical conductivity. A process for forming a reflecting silver coating on the glass substrates was prepared by pouring method. CdS thin films were grown on Ag coated glass substrate. The time response of photoconductance for the CdS/Ag samples were examined.

Key words: CdS thin films, spray pyrolysis technique, XRD, optical, photoconductance

Introduction

Cadmium sulfide (CdS) is a II-VI compound semiconductor. It is a mixture of covalent and ionic types [Rose, D.H., (1999)]. Two types of crystal structures, cubic zincblend and hexagonal wurtzite, are observed in these compounds. Structure type of the deposited crystals depends on the substrate temperature; at low substrate temperature it becomes zincblend whereas at a high temperature one hexagonal wurtzite type is seen. CdS has been the most widely used as window layer for solar cell application because of its high band gap energy of 2.43 - 2.4 eV at room temperature, which makes it more transparent in the wavelength region of 450–700 nm.

Thin film has a two dimensional structure, i.e., it has a very large ratio of surface to volume, and created by the process of condensation of atoms, molecules or ions [Aicha, A.R., (1998)]. Most of the electronic devices require reliable ohmic contacts for electrical signals to flow into and out of the device, and highly stable metal-semiconductor rectifying contacts as the active region[Benramache, S., (2013)]. In both cases one must know how to fabricate reliable and efficient metal contacts which have high yield and stability. Thus, it is clear that knowledge of these devices can be used for the development of future technology. CdS thin films can be prepared by several different deposition techniques such as, spray pyrolysis, thermal evaporation, close space sublimation, sputtering, electrolysis, molecular beam epitaxy (MBE), screen printing, chemical deposition, etc.[Patidar, D., (2008)]. The chemical deposition is among the least expensive methods with respect to expenditure of chemicals and energy, and convenient for large area depositions on a variety of substrates. Thermally evaporated and annealed CdS film is the most similar one to the single-crystal CdS from the view point of spectral transmission characteristics among thermal evaporation, chemical deposition by solution growth and spray pyrolysis techniques. Deposition techniques and substrate temperature have a strong effect on the electrical and structural properties of CdS thin films.

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In this study, CdS thin films were prepared by spray pyrolysis technique. The structural parameters of the films were obtained by XRD analysis. Optical band gap value of the films was determined from the absorption spectrum.

Materials and Method

Growth of CdS Thin Film

The glass substrates $(1.0 \text{ cm} \times 1.0 \text{ cm} \times 0.1 \text{ cm})$ were cleaned with HCl : H₂O (1:2) for 1h to remove native oxide and thoroughly rinsed in deionized water for a few minutes. The substrate is then immersed in acetone for 10 min and ethyl alcohol for 10 min to remove impurities. After that, it is rinsed by deionized water for a few minutes and subsequently dried at room temperature. The spray solution consists of a mixture of aqueous solution of cadmium chloride [CdCl₂] and aqueous solution of thiourea [(NH₂)₂CS] in the molar ratio of 1:1 as starting solution. Deionized water was used as solvent. These solutions were mixed thoroughly and the final solution was sprayed onto preheated glass substrate kept at 300°C. The optimum distance between nozzle and the substrate lies between 13 cm to 18 cm. Filtered air at a pressure of 40 psi was used as the carrier gas. The temperature of the glass substrate is fixed and thickness of the CdS film is changed by the spray time. A series of samples were prepared for different spray times (10 s, 20 s, 30 s). All these spray times on the sample were grown successively under the same condition. When the solution is sprayed, the following reaction takes place at the surface of the heated substrate.

 $CdCl_2 + (NH_2)_2 CS + 2H_2O \rightarrow CdS + 2NH_4Cl \uparrow + CO_2\uparrow$

In this reaction, a mist of a spray solution was driven to the surface of a heated substrate where a pyrolytic reaction takes place, leaving a solid CdS film plus some volatile compounds, NH_4Cl and CO_2 . After deposition, the films were cooled at an ambient temperature slowly. The transparent and homogeneous orange-yellow thin films were deposited. The selected samples for different spray time were shown in Figure 1.



Figure 1. Films of CdS samples in (a) 10 s (b) 20 s and (c) 30 s spray times

XRD Measurement

The crystal structure and orientation of the films were investigated by X-ray diffraction (XRD) method. XRD patterns of the as synthesized sample was recorded on a Rigaku X-ray Diffractometer using Cu-K_{α} line (λ = 1.54 Å) operating at 40 kV. The 2 θ scanning range was from 10° to 70°.

Optical Measurements of CdS Thin Films

Optical studies were carried out on a Shimadzu UV-VIS Recording spectrophotometer. Films deposited on a glass substrate were used and absorption and transmission spectra were recorded against plain glass as the reference. The film properties investigated their absorbance and transmittance spectra, band gap, refractive index, extinction coefficient, optical conductivity were made for calculation of optical properties. Optical absorption of CdS films was studied in the wavelength range of 300-700 nm. The optical band gap energy E_g of CdS

thin films was evaluated from the analysis of the absorption spectrum. It was determined by plotting $(\alpha hv)^2$ vs hv and extrapolating the straight portion to the energy axis.

Experimental Setup of Photoconductance Measurements

The photoconductance of CdS/Ag film has been determined using Personal Computer (PC) interfaced Fluke View Forms Method/189 TRUE RMS multimeter. The electrical conductance data of thin films have been studied with the help of fluke meter. The electrical conductance of CdS/Ag thin films were measured as a variation of the combination of light (200W) and dark current. The film was illuminated for a certain interval of time.

Once the photoconductance was saturated and the illumination was cut off after this particular interval of time. The set-up for the measurement of photoconductance had been designed as shown in Figure 2. In black box, the samples were placed perpendicular to the light bulb. The light falls onto the sample directly. The light exposure time was controlled by the shutter between the light bulb and sample. The light bulb and the sample were 10 cm away. Silver electrodes were used to conduct the current on the surface of CdS film with the contact separation about 1mm. Two electrodes of the sample were joined with fluke meter. The current passed through the contacts by applying voltage source.



Figure 2. The block diagram showing photoconductance measurement set-up

Results and Discussion

Structure Analysis

Structural properties of as deposited CdS thin films were investigated by X-ray diffraction technique. The presence of sharp structural peaks in these X-ray diffraction patterns confirmed the polycrystalline nature of the film. The average crystallite sizes in deposited films were obtained from a Debye-Scherre's formula. The crystallinity of the films was improved with thickness. Diffractograms of films produced for different spray times (10 s, 20 s and 30 s) are shown in Figure 3. XRD analysis showed that the films had highly oriented crystallites of the classical hexagonal structure or Wurtzite type, with a preferred orientation along the c- axis and (002) direction perpendicular to the substrate plane. This behavior was more intense for all samples obtained, where the peak at about 26.6° is present. The structural and morphological parameters are listed in Table 1.The crystallite size was found that it increased with increasing spray time. The average crystallite size of the film lies between 25.36 nm – 29.59 nm.

It can be concluded from the structural analyses that the films are found to be in the single phase of CdS and the identification of the peaks indicate that the film is polycrystalline. The experimental d-values and JCPDS (Joint Committee on Powder Diffraction Standards) d-values are in relatively good agreement and show hexagonal structure. The variation of crystallite size and FWHM of CdS thin films with different spray times were shown in Figure 4 (a) and (b).



Figure3. XRD patterns of CdS thin films for different spray times



Figure 4. The variations of (a) crystallite size and (b) FWHM of CdS thin films for different spray times

 Table 1. Variation of structural parameters, system and average crystallite size of CdS thin films for different spray times

SampleName	SprayTime (s)	LatticeConstants (Å)	System	Average Crystallite Size (nm)
CdS-1	10	a = b = 4.1728 c = 6.7395	Hexagonal	25.36
CdS-2	20	a = b = 4.1083 c = 6.6872	Hexagonal	29.4
CdS-3	30	a = b=4.1062 c= 6.7101	Hexagonal	29.59

Optical Property and Photoconductance Study

Figure 5 (a) shows the plot of transmittance T% against wavelength λ for CdS thin films. Absorbance versus wavelength of incident radiation and absorption αt against wavelength λ for CdS thin films are shown in Figure 5 (b). The energy band gap of deposited films was determined by using the reflection spectra. The theory of optical transmission gives the relationship between the absorption coefficient α and the photon energy hv as,

$$\alpha = -\frac{1}{d} \ln \frac{1}{T}$$
 where *d* is film thickness (µm). The optical absorption gives the relationship

between the absorption coefficient α and the photon energy hv as $\alpha = \frac{A(hv - Eg)^{1/2}}{hv}$ where E_g

is energy band gap (eV). The variation of $(\alpha hv)^2$ as a function of incident photon energy hv is plotted in Figure 6. The optical band gap energy (E_g) for the samples studies the varies from 2.40 to 2.58 eV. The variation of refractive index (n), extinction coefficient (k), optical conductivity (σ) and band gap energy (E_g) was given in Table 2. The high value of n, k and σ for the CdS thin films was found to be at energy (hv) equal to 1.0 eV.The optical films' two parameters were correlated with each other, when the refractive index increases, the value of the optical gap decreases.

For normal reflectance $R = (n - 1)^2 / (n + 1)^2$, the relationship between refractive index and reflectance for semiconductors and insulators when $k^2 << n^2$.

$$n = \frac{1 + \sqrt{R}}{1 - \sqrt{R}}$$

where R is the normal reflectance; using the above relation the refractive index n was determined. Figure 7 shows the plot of refractive index n with the incident photon energy hv.

The optical conductivity was determined by using the $\sigma = \frac{\alpha nc}{4\pi}$ where c is the velocity of light. The increased optical conductivity at high photon energies is due to the high absorbance of CdS thin film in that region. The extinction coefficient k as a function of wavelength λ and absorption coefficient α were given by, $k = \frac{\alpha \lambda}{4\pi}$. The variations of extinction coefficient k with the photon energy (hv) and the variation of optical conductivity σ with hv are plotted in Figure 8. The rise and fall in the extinction coefficient is due to the variation in the absorbance. It is clear from Figure 8 that photoconductance drops exponentially with time and saturates

after a few seconds. Initially, it decreases rapidly and then becomes slower before reaching to steady state value. After attaining the steady state, light was turned off and the decay of photoconductance was measured as the function of time. Initially, the photoconductance decay is quite fast and then becomes slower as time elapse. A persistent photoconductance is also observed which takes time to decay. This is attributed to light induced effect in this material.



Figure 5. Plots of (a) transmittance and (b) absorbance spectra of CdS thin films for different spray times



Figure 6. Plots of (a) absorption (αt) vs wavelength (λ) for CdS thin films in different spray times and (b) the variation of ($\alpha h\nu$)² as a function of incident photon energy



Figure 7. Plots of (a) Refractive index and (b) extinction coefficient versus incident photon energy of CdS thin films for different spray times



Figure 8. (a) Plots of optical conductivity σ against hv for CdS thin films and (b) variation of photoconductance with time of CdS/Ag thin film (for Spray time = 10s)

Table 2.	Variations of refractive index n, extinction	n coefficient k	, optical	conductivity	σ
	and band gap energy hy of CdS films				

Sample	Refractive index	Extinction coefficient	Optical conductivity(sec ⁻¹)	Band gap energy (eV)
CdS-1	2.01	2.06	2.13	2.58
CdS-2	2.12	2.15	2.75	2.52
CdS-3	2.50	2.77	3.45	2.40



Figure 8. Variations of photoconductance with time of CdS/Ag thin filmsfor spray time (c) 20 s and (d) 30 s

Conclusion

The CdS thin films were prepared by spray pyrolysis method. The films were deposited onto glass substrates for different spray times, 10 s, 20 s and 30 s at constant deposition temperature 300°C. As a result of the structural investigation, it was found that CdS thin films were the polycrystalline nature with a hexagonal structure and have (002) sharp diffraction peak. The XRD patterns which indicate CdS films have a hexagonal phase with 25.36–29.59 nm average crystallite size. The optical band gap of the films was found to be in the range of 2.40–2.58 eV. It is clear from the figure of variations of photoconductance with time of the films that photoconductance drops exponentially with time and saturates after a few seconds. Initially, it decreases rapidly and then becomes slower before reaching to steady state value. After attaining the steady state, light was turned off and the decay of photoconductance was measured as the function of time. Initially, the photoconductance is also observed which takes time to decay. This is attributed to light induced effect in this material. According to these results, CdS films could be a promising material for use as window layer of heterojunction solar cells and applications in optical devices.

Acknowledgements

We wish to express our sincere thanks to Dr Aung Aung Min, Rector-in-charge, Pyay University and Dr Thwe Linn Ko, Pro-Rector, Pyay University, for their kind permission to carry out this research paper.

References

- Aicha, A.R., Riad, E. and Barlow, F.D. (1998). Thin Film Technology Handbook. New York: McGraw-Hill.
- Benramache, S., Arif, A., Blahssen, O. and Guettaf, A. (2013). Study on the correlation between crystallite size and optical gap energy of doped ZnO thin film. *Journal of Nanostructure in Chemistry*, **3** (80), 1-6.
- Patidar, D., Rathore, K.S., Saxena, N.S., Sharma, K. and Sharma, T.P. (2008). ENERGY BAND GAP AND CONDUCTIVITY MEASUREMENT OF CdSe THIN FILMS. *Chalcogenide Letters*, **5** (2), 21-25.
- Rose, D.H. and Sheldon, P. (1999). Fabrication Procedures and Process Sensitivities for CdS/CdTe Solar Cells. *PROGRESS IN PHOTOVOLTAICS: RESEARCH AND APPLICATIONS*, 7, 331-340.