International Journal on Recent Researches in Science, Engineering & Technology (IJRRSET)
A Journal Established in early 2000 as National journal and upgraded to International journal in 2013 and is in existence for the last 10 years. It is run by Retired Professors from NIT, Trichy. Journal Indexed in JIR, DIIF and SJIF.
Available online at: www.jrrset.com
ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105
JIR IF : 2.54
SJIF IF : 4.334
Cosmos: 5.395

Volume 11 Issue 5 – May 2023 - Pages 1-13

OPTIMIZATION OF GMAW WELDING PARAMETERS TO IMPROVE MECHANICAL PROPERTIES

Saravanan S, Nagaraj G, TamilarasanC, Martin Golda MaryB
Department of Mechanical Engineering, Sethu Institute of Technology, Virudhunagar, India

ABSTRACT

In this project work, multi criteria optimization of Gas Metal Arc Welding (GMAW) parameters are carried out to yield good mechanical strength of welded joints. Most of the failures are occurred on the welded elements due to improper welding parameters setting. The strength of welded joints in GMAW depends on several input process parameters such as welding current, welding voltage, gas flow rate and electrode feed rate. Wrong selection of these process parameters will lead to bad quality welds. So there is a need to control the process parameters to obtain good quality welded joints. For getting the better values of these parameters, it needs to conduct experiments by varying the input process parameters. are affecting the strength of the welded joints. Nine experimental runs based on an L9 orthogonal array of Taguchi method are performed to derive objective functions to be optimized within experimental domain. To achieve this Grey Relational Analysis (GRA) is used. The significance of the influencing factors on the mechanical properties of the welded joint has also been evaluated quantitatively by the analysis of variance method (ANOVA). In this project Aluminum6063 material is used as a base material.

1.1 Introduction

Welding is a material joining process. It is joints the two similar (or) dissimilar material by heating the suitable temperature with (or) without the use of filler material. Welding can be done with or without the application of pressure. Welding is used for making permanent joints. It is used in almost metal industries working. Many different energy sources can be used for welding, including a gas flame, an electric arc, a laser, an electron beam, friction, and ultrasound. While often an industrial process, welding may be performed in many different environments, including open air, under water and in outer space. Welding is a potentially hazardous undertaking and precautions are required to avoid the accidents like, burns, electric shock, vision damage; inhalation of poisonous gases and fumes.

Welding technology advanced quickly during the early 20th century. After that several modern welding techniques were developed, including manual methods like shielded metal arc welding, semi-automatic and automatic processes such as gas metal arc welding, submerged arc welding, flux-cored arc welding and electro slag welding. Developments continued with the invention of laser beam welding, electron beam welding, electromagnetic pulse welding and friction stir welding in the latter half of the century. Today, the science continues to advance. Robot welding is commonplace in industrial settings, and researchers continue to develop new welding methods and gain greater understanding of weld quality.

1.2 ProblemStatement

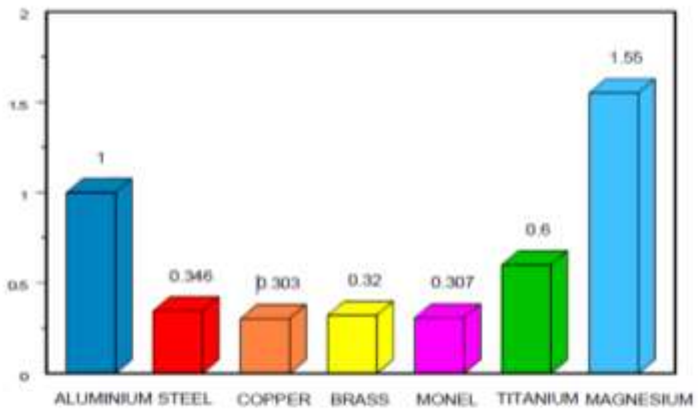
Aluminum 6063 is a low strength but very workable alloy with excellent corrosion resistance. It is not heat treatable. It is easily welded, however it is soft, and spalls when machined.

2.1 Chemical composition

- Silicon minimum 0.2%, maximum 0.6% by weight
- Iron no minimum, maximum 0.35%
- Copper no minimum, maximum 0.10%
- Manganese no minimum, maximum 0.10%
- Magnesium minimum 0.45%, maximum 0.9%
- Chromium no minimum, maximum 0.10%

International Journal on Recent Researches in Science, Engineering & Technology (IJRRSET)
A Journal Established in early 2000 as National journal and upgraded to International journal in 2013 and is in existence for the last 10 years. It is run by Retired Professors from NIT, Trichy. Journal Indexed in JIR, DIIF and SJIF.
Available online at: www.jrrset.com
ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105
JIR IF : 2.54
SJIF IF : 4.334
Cosmos: 5.395
Volume 11 Issue 5 – May 2023 - Pages 1-13

- Zinc no minimum, maximum 0.10%
- Titanium no minimum, maximum 0.10%
- Other elements no more than 0.05% each, 0.15% total
- Remainder Aluminum..



The stem bark physically, using a metal brush. Then, the fibers were washed in refined water in order to eliminate the residue particles Figure 1.depict a typical EV tree, harvested stem bark, and extricated fibers, respectively.

Physical property estimation

An Aluminum alloy is an alloy primarily of pure aluminum, mixed with different alloying elements that give rise to an entire range of materials, each of which is designed to maximize a particular characteristic such as strength, ductility, formability, machinability, or electrical conductivity.

Characterization:

Thermal Conductivity:

The thermal conductivity, κ, of 99.99% pure aluminium is 244 W/mK for the temperature range 0-1000C. It is 61.9% of the IACS, and again because of its low specific gravity its mass thermal conductivity is twice that of copper. Thermal conductivity can be calculated from electrical resistivity measurements using the formula κ =5.02λT x 10-9 +0.03.

International Journal on Recent Researches in Science, Engineering & Technology (IJRRSET)
A Journal Established in early 2000 as National journal and upgraded to International journal in 2013 and is in existence for the last 10 years. It is run by Retired Professors from NIT, Trichy. Journal Indexed in JIR, DIIF and SJIF.
Available online at: www.jrrset.com
ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105
JIR IF : 2.54
SJIF IF : 4.334
Cosmos: 5.395
Volume 11 Issue 5 – May 2023 - Pages 1-13

Where, κ is the thermal conductivity, λ is the electrical conductivity and T the absolute temperature in degrees Kelvin; this method is usually used to derive the values quoted in reference books. The thermal conductivity is reduced slightly by the addition of alloying elements. The combined properties of high thermal conductivity, low weight and good formability make aluminium an obvious choice for use in heat exchangers, car radiators and cooking utensils while in the cast form it is extensively used for I/C engine cylinder heads

Corrosion Resistance: Aluminium has a higher resistance to corrosion than many other metals owing to the protection conferred by the thin but tenacious film of oxide. This oxide layer is always present on the surface of aluminium in oxygen atmospheres. The famous statue of Eros in London's Piccadilly Circus is an example of the corrosion resistance; after an inspection following eighty years of exposure to the London atmosphere, the statue showed only surface corrosion. The formation of the oxide is so rapid in the presence of oxygen that special measures have to be taken in thermal joining processes to prevent the oxide instantly forming while the process is being carried out.

Melting Temperature: The melting point of aluminium is sensitive to purity, e.g. for 99.99% pure aluminium at atmospheric pressure it is 6600C. But this reduces to 6350C for 99.5% commercial pure aluminium. The addition of alloying elements reduced down to 5000C for some magnesium alloys under certain conditions. The melting point increases with pressure in a straight line relationship to 9800C at 50 kbar.

Alloy 6061: Heat treatable, easily welded, with very good corrosion resistance and finishing characteristics. Very commonly used for architectural products.

6061-O: Annealed (or "soft", bendable condition).

6061-T4: Heat treated and naturally aged.

6061-T6: Heat treated and artificially aged.

6061-T65: Heat treated and artificially aged.

International Journal on Recent Researches in Science, Engineering & Technology (IJRRSET)
A Journal Established in early 2000 as National journal and upgraded to International journal in 2013 and is in existence for the last 10 years. It is run by Retired Professors from NIT, Trichy. Journal Indexed in JIR, DIIF and SJIF.
Available online at: www.jrrset.com
ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105
JIR IF : 2.54
SJIF IF : 4.334
Cosmos: 5.395
Volume 11 Issue 5 – May 2023 - Pages 1-13

6061-T6511: Heat treated and artificially aged

Alloy 6063: This heat treatable is specifically designed for extrusions, very popular for architectural shapes 6063-T52: Cooled from an elevated temperature shaping process and artificially aged

Morphological investigation: Morphological investigation was performed on the outside parts of the fibers to examine the surfaceprofileonthemandwhetherthesurfacesofthefibersareeitherharshorsmooth. Scanning electron microscopy (SEM) was used to study EVFs and different components present ontheirsurfaces.VEGA3(TESCANOXFORD)SEMwasusedwithspeedingupvoltageof20kVforthemorphologicalinvestigation.Gentlygold-coveredfibersampleswereutilizedtoobtainSEMimagesofhigh-resolution

Thickness	Filler Wire Size	Amps	Volts	Gas Flow (cfh)
1/16” 1/8” 3/16” 1/4” 3/8”	.030” .030” – 3/64” .035” – 3/64” 3/64” – 1/16” 1/16”	70 – 110 120 – 150 130 – 210 170 – 225 225 – 300	15 – 20 20 – 24 22 – 26 24 – 28 26 – 29	25 30 30 – 35 40 50

Table1.Parameters for GMAW

Methods

Taguchi Method: Taguchi method uses the S/N ratio to analyze the experimental results, because this ratio represents both the average (mean) and the variation (scatter) of the results. This method stresses the importance of studying the response variation using the S/N ratio, resulting in minimization of quality characteristic variation due to uncontrollable parameters. S/N ratios are calculated based on the smaller the better [Eqn. (1)] and the larger the better concepts [Eqn.

International Journal on Recent Researches in Science, Engineering & Technology (IJRRSET)
A Journal Established in early 2000 as National journal and upgraded to International journal in 2013 and is in existence for the last 10 years. It is run by Retired Professors from NIT, Trichy. Journal Indexed in JIR, DIIF and SJIF.
Available online at: www.jrrset.com
ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105
JIR IF : 2.54
SJIF IF : 4.334
Cosmos: 5.395
Volume 11 Issue 5 – May 2023 - Pages 1-13

(2)], depending on the quality parameters.

$$\frac{S}{N} = -10\log(\textstyle\sum_{i=1}^{n} y^2) \quad (1)$$

$$\frac{S}{N} = -10\log\left(\textstyle\sum_{i=1}^{n} \frac{1}{y_i^2}\right) \quad (2)$$

wherei = experiment number, n = number of experiments, and y_i= value of parameter for the ith experiment.

Experiment	A	B	C	D
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

Table 2, L9 Orthogonal array

MULTIPLE-CRITERIA DECISION ANALYSIS:

Multiple-criteria decision-making or multiple-criteria decision analysis (MCDA) is a sub-discipline of operations research that explicitly considers multiple criteria in decision-making environments. Whether in our daily lives or in professional settings, there are typically multiple conflicting criteria that need to be evaluated in making decisions. Cost or price is usually one of the main criteria. Some measure of quality is typically another criterion that is in conflict with the

International Journal on Recent Researches in Science, Engineering & Technology (IJRRSET)
A Journal Established in early 2000 as National journal and upgraded to International journal in 2013 and is in existence for the last 10 years. It is run by Retired Professors from NIT, Trichy. Journal Indexed in JIR, DIIF and SJIF.
Available online at: www.jrrset.com
ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105
JIR IF : 2.54
SJIF IF : 4.334
Cosmos: 5.395
Volume 11 Issue 5 – May 2023 - Pages 1-13

cost. In purchasing a car, cost, comfort, safety, and fuel economy may be some of the main criteria we consider. It is unusual that the cheapest car is the most comfortable and the safest one. In portfolio management, we are interested in getting high returns but at the same time reducing our risks. Again, the stocks that have the potential of bringing high returns typically also carry high risks of losing money. In a service industry, customer satisfaction and the cost of providing service are two conflicting criteria that would be useful to consider.

ANALYSIS OF VARIANCE (ANOVA)

Analysis of variance is a statistical analysis tool that separates the total variability found within a data set into two components that's random and systematic factors. The random factors do not have any statistical influence on the given data set, while the systematic factors do. The ANOVA test is used to determine the impact independent variables have on the dependent variable in a regression analysis. This is obtained first by computing the sum of squares.

ANOVA can be useful for determining influence of any given input parameter from a series of experimental results by design of experiments for machining process and it can be used to interpret experimental data. A concept may be represented that any high dimensional function may be broken down into a subset of terms as.

$$f(x) = f_0 + \sum_{i=1}^{n} f_i(x_i) + \sum_{j=1+1}^{n} f_{i,j}(x_i, x_j) + f_{1,2,\dots\dots\dots n}(x) \quad (1)$$

Where n represents number of inputs,fo is a constant (bias term) and other terms on right hand side represent univariate, bivariate, trivariate, etc., functional combinations of input parameters.

ANOVA partitions total variation into its appropriate components. Total sum of squares term can be defined as

$$SST = \sum y_i^2 \text{ for } i = 1, 2\dots.n \quad (2)$$

This can be given as

$$SST = SSm + SSe \quad (3)$$

where, SSm= nM2 and SSe = Σ(yi-M)2 are mean sum of squares and error sum of

International Journal on Recent Researches in Science, Engineering & Technology (IJRRSET)
A Journal Established in early 2000 as National journal and upgraded to International journal in 2013 and is in existence for the last 10 years. It is run by Retired Professors from NIT, Trichy. Journal Indexed in JIR, DIIF and SJIF.
Available online at: www.jrrset.com
ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105
JIR IF : 2.54
SJIF IF : 4.334
Cosmos: 5.395
Volume 11 Issue 5 – May 2023 - Pages 1-13

squares respectively, with

$M = 1/n \sum y_i (i=1, 2,\ldots, n)$.

In case of two-way ANOVA, when interaction effect of main factors affects output values, total variation may be decomposed into more components as

$$SST = SSA+SSB+SSAB+ SSe \quad (4)$$

where, SSA = (A1-A2) and SSB = (B1-B2) are variations due to factors A and B respectively, while $SSAB = \Sigma(AB)\, i^2/n_{ABi}$ for i = 1, 2, ..., k is variation due to interaction of factors A and B, where k represents number of possible combinations of interacting factors and n_{ABi} is number of data points under this condition.

While performing ANOVA, degrees of freedom should also be considered together with each sum of squares. In ANOVA studies with certain test error, error variance determination is very important. Obtained data are used to estimate F value of Fisher test (F-test). Variation observed (total) in an experiment attributed to each significant factor or interaction is reflected in percent contribution (P), which shows relative power of a factor or interaction to reduce variation. Factors and interactions with substantial P play an important role.

Results and discussion:

Experimental Results:

Using the L9 orthogonal array the GMAW was performed and the tensile strength and Hardness were determined. The obtained results are shown in table.

Experiment	Current (amps)	Voltage (v)	Gas flow rate (lit/min)	Speed (mm/min)	Experiment Data	
					UTS (Mpa)	Hardness (RHN)
1	250	25	24	350	147	150.4
2	250	27.5	27	375	155	143.2

International Journal on Recent Researches in Science, Engineering & Technology (IJRRSET)
A Journal Established in early 2000 as National journal and upgraded to International journal in 2013 and is in existence for the last 10 years. It is run by Retired Professors from NIT, Trichy. Journal Indexed in JIR, DIIF and SJIF.
Available online at: www.jrrset.com

ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105
JIR IF : 2.54
SJIF IF : 4.334
Cosmos: 5.395

Volume 11 Issue 5 – May 2023 - Pages 1-13

3	250	30	30	400	83	143.8
4	275	25	27	400	150	151.6
5	275	27.5	30	350	101	162.4
6	275	30	24	375	150	134.2
7	300	25	30	375	136	139.8
8	300	27.5	24	400	71	115.4
9	300	30	27	350	156	157.6

Table 3, Experimental Results

DATA PREPROCESSING

The first step is to normalize the S/N ratio of the experimental data. Normalization is a transformation performed on a single data input, to distribute the data evenly and to scale it into an acceptable range for further analysis.

Experiment no.	Data Preprocessing	
	UTS (Mpa)	Hardness (RHN)
1	0.9232	0.2248
2	0.9906	0.3683
3	0.1981	0.3559
4	0.9500	0.2015
5	0.4466	0.0000
6	0.9496	0.5581
7	0.8285	0.4384

International Journal on Recent Researches in Science, Engineering & Technology (IJRRSET)
A Journal Established in early 2000 as National journal and upgraded to International journal in 2013 and is in existence for the last 10 years. It is run by Retired Professors from NIT, Trichy. Journal Indexed in JIR, DIIF and SJIF.
Available online at: www.jrrset.com
ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105
JIR IF : 2.54
SJIF IF : 4.334
Cosmos: 5.395
Volume 11 Issue 5 – May 2023 - Pages 1-13

8	0.0000	1.0000
9	1.0000	0.0876

Table 4, Data Preprocessing

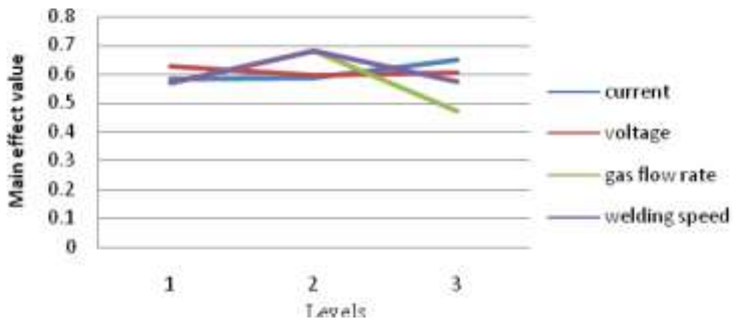


Figure2, Main Effect

ANALYSIS OF VARIANCE:

The purpose of the ANOVA is to investigate which welding parameters significantly affect the performance characteristic. This is accomplished by separating the total variability of the grey relational grades, which is measured by the sum of the squared deviations from the total mean of the grey relational grade, into contributions by each welding parameter and the error. That result shown in Table.

Parameter	D.O.F	Sum of square	Mean	F	% of contribution
Current	2	0.00864	0.00432	1.559	8.347
Voltage	2	0.00246	0.00123	0.440	2.376
Gas flow rate	2	0.0689	0.03445	12.430	66.563
Welding speed	2	0.02351	0.01175	8.487	22.703
Total	8	0.10351			

Error	4	0.0111	0.00277		

Table 5, ANOVA table

Conclusions

The aluminum plate 6063 was welded by GMAW process. The suitable welding parameter was selected by optimization techniques. Welding parameters like, welding current welding voltage, welding speed, gas flow rate were mainly consider for welding process. In this work Taguchi method and grey relational analysis are used to optimize the welding strength with the multiple performance characteristics. Grey relational analysis is used to convert the optimization of multiple performance characteristics into optimization of a single performance characteristic. The ultimate tensile strength and hardness of the welded material were obtained from L9 orthogonal array proposed by Taguchi. By use of GRA optimization technique the optimal parameter combination is determined by main effect of GRG and its parameter values are 300 Amp welding current, 25 Volt welding voltage, 27 lit/min gas flow rate and 375 mm/min welding speed for GMAW. Based on the above combination the confirmation test was conducted and their result of Tensile testing (UTS) is 157 Mpa and Hardness (RHN) is 129.8 in ‘B’ scale.

However, it is observed through ANOVA that the Gas flow rate is the most influential control factor among the welding process parameters investigated in the present work.

References

1. Ajit Hooda, Ashwani Dhingra, and Satpal Sharma, "Optimization of MIG Welding Process Parameters to Predict Maximum Yield Strength in AISI 1040," International Journal of Mechanical Engineering and Robotics Research, Vol. 1, No. 3, (2012), pp. 203-213.
2. Shih Jing-Shiang, Tzeng Yih-Fong, Yang Jin-Bin, "Principal Component Analysis for Multiple Quality Characteristics Optimization of Metal Inert Gas Welding Aluminum Foam Plate," Materials and Design, Vol. 32, (2011), pp. 1253–1261.
3. Mohd. Shoeb et al., "Effect of MIG Welding Input Process Parameters on Weld Bead Geometry on HSLA Steel," International Journal of Engineering Science and Technology, Vol. 5, No. 01, (2013), pp. 200-212.
4. K. Manikya Kanti, P. Srinivasa Rao, "Prediction of Bead Geometry in Pulsed GMA Welding Using Back Propagation Neural Network," Materials Processing Technology, Vol. 200, (2008), pp. 300–305.
5. Alexandre Saldanha do Nascimento and Diandro Bailoni Fernandes, "Methodology for Determination of Parameters for Welding MIG with Variable Polarity," Journal of Welding International, Vol. 23, No. 6, (2009), pp. 473-480.
6. Jair Carlos Dutra, Regis Henrique Goncalves e Silva, "Melting and Welding Power Characteristics of MIG–CMT versus Conventional MIG for Aluminium 5183," Journal of Welding International, Vol. 29, (2015), pp. 181-186.
7. Borrego, Costa, Jesus, Loureiro, Ferreira, "Fatigue Life Improvement by Friction Stir Processing of 5083 Aluminium Alloy MIG Butt Welds," Theoretical and Applied Fracture Mechanics, Vol. 70, (2014), pp. 68–74.
8. Danut Iordachescu, Luisa Quintino, Rosa Miranda, and Gervasio Pimenta, "Influence of Shielding Gases and Process Parameters on Metal," Materials and Design, Vol. 27, (2006), pp. 381–390.
9. C. L. Lin, "Use of the Taguchi Method and Grey Relational Analysis to Optimize Turning Operations with Multiple Performance Characteristics," Materials and Manufacturing Processes, Vol. 19, No. 2, (2004), pp. 209–220.
10. S.R. Meshram, N.S. Pohokar, "Optimization of Process Parameters of Gas Metal Arc Welding to Improve Quality of Weld Bead Geometry," Business and Enterprise Applications, Vol. 5, No. 1, (2013), pp. 46-52.
11. Irullappasamy Siva et al., "Grey Optimization of Process Parameters of Surface Modification of Coconut Sheath Reinforced Polymer Composites," Journal of Polymer Engineering, Vol. 33, (2013), pp. 665-672.
12. Tewari, Ankur Gupta, Jyoti Prakash, "Effect of Welding Parameters on the Weldability of Material," International Journal of Engineering Science and Technology, Vol. 2, (2010), pp. 512-516.

International Journal on Recent Researches in Science, Engineering & Technology (IJRRSET)
A Journal Established in early 2000 as National journal and upgraded to International journal in 2013 and is in existence for the last 10 years. It is run by Retired Professors from NIT, Trichy. Journal Indexed in JIR, DIIF and SJIF.
Available online at: www.jrrset.com

ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105

JIR IF : 2.54
SJIF IF : 4.334
Cosmos: 5.395

Volume 11 Issue 5 – May 2023 - Pages 1-13

13. Her-Yueh Huang, "Effects of Activating Flux on the Welded Joint Characteristics in Gas Metal Arc Welding," Journal of Materials and Design, Vol. 31, (2010), pp. 2488-2495.
14. Dinesh Mohan Arya, Vedansh Chaturvedi, and Jyoti Vimal, "Parametric Optimization of MIG Process Parameters Using Taguchi and Taguchi Analysis," International Journal of Research in Engineering & Applied Sciences, Vol. 3, Issue. 6, (2013), pp. 1-17.
15. Chandresh N. Patel, Sandip Chaudhary, "Parametric Optimization of Weld Strength of Metal Inert Gas Welding and Tungsten Inert Gas Welding by Using Analysis of Variance and Grey Relational Analysis," International Journal of Research in Modern Engineering and Technology, Vol. 1, Issue. 3, (2013), pp. 48-56.
16. Pawan Kumar et al., "Process Parameters Optimized of an Aluminum Alloy with Pulsed Gas Tungsten Arc Welding (GTAW) Using Gas Mixtures," Material Science and Applications, Vol. 2, (2011), pp. 251-257.