*Int. J. Chem. Sci.: 10(1), 2012, 509-518*
*ISSN 0972-768X*
*www.sadgurupublications.com*

# SYNTHESIS, SPECTRAL, CYCLIC VOLTAMMETRIC AND ANTIMICROBIAL STUDIES OF COPPER (II) COMPLEXES WITH TETRADENTATE BIS-BENZOMIDAZOLE BASED DIAMIDE LIGAND

**MAGAN PRASAD* and YOGESH K. SHARMA**

Department of Chemistry, M. S. J. College, BHARATPUR – 321001 (Raj.) INDIA

## ABSTRACT

A new tetradentate bis-benzimidazole based diamide ligand, N-butyl-N,N'-bis-(2-methyl-benzimidazolyl)-benzene-1,3-dicarboxamide[B–GBBA] has been synthesized and utilized to prepare Cu (II) complexes of general composition $[Cu(B\text{-}GBBA)X_2].nH_2O$ where X is an exogenous anionic ligand ($X = Cl^-$, $NO_3^-$). These complexes were prepared in the molar ratios of metal : ligand (1 : 1) and characterized by elemental analysis, IR, UV spectroscopic and other analytical techniques. Cyclic voltammetric measurements of the complexes display quasi reversible redox wave due to the Cu (II)/Cu (I) process. The distorted octahedral geometry with monomeric composition was proposed for both the complexes on the basis of these studies. These complexes have been screened for their antimicrobial activities against bacteria, *E. coli* and *S.aureus* and were found to exhibit considerable activity.

**Key words**: Benzimidazole, Diamide, Ligand, Exogenous, *E. coli*, *S. aureus*.

## INTRODUCTION

The ability of copper containing metalloproteins to reversibly bind and activated dioxygen has been of the focus of continued interest in bioinorganic chemistry[1]. We have initiated a study of metal complexes with bis-(benzimidazole) based diamide ligand, where the bound copper (II) is in a distorted octahedral environment with anodic $E_{½}$ value[2]. The novel ligating system, N-butyl-N, N'-bis-(2-methyl-benzimidazolyl)-benzene-1, 3-dicarboxamide, [B–GBBA] is being reported for the first time, which incorporates both; a benzimidazole and amide functionality. Catechol oxidase[3], a copper containing enzyme catalyzes the oxidation of o-diphenols to quinones. The copper centres in this enzyme are bound to imidazole nitrogen of histidine and have a nitrogen-oxygen donor environment. In

*Author for correspondence; E-mail: maganprasad@gmail.com

the recent past, a considerable interest has been shown in the preparation of synthetic models of this enzyme[4,5]. The ligand, B-GBBA provides benzimidazole nitrogen and carbonyl oxygen as a donor group and generates an opportunity to synthesize Cu (II) complexes having functional similarities to the above mentioned enzyme. Metal complexes with GBBA ligand have been widely studied because of their industrial, antifungal, antibacterial and other biological applications. Analogy to these observations, we have synthesized the butylated derivative of GBBA ligand and prepared the copper (II) complexes as these types of complexes have not been prepared and studied so far.

The present investigation is concerned with the synthesis and characterization of copper (II) complexes with (B-GBBA) based ligand derived from refluxing and stirring of benzimidazolyl amide based ligand[6].

Copper (II) is a necessary element for some biological operation in human body, animal and plants. Studies on copper (II) complexes with chelating ligand incorporating pyridine, imidazole and benzimidazole have been of great interest in the recent years[7,8]. This is mainly because of their relevance to the histidine coordinated metalloproteins. The interaction of molecular oxygen with metalloenzyme is currently an area of considerable activity[9,10]. This prompted us to synthesize the copper (II) complexes with the ligand B-GBBA.

## EXPERIMENTAL

### Materials and methods

All the chemicals used were of analytical grade and the solvents used for spectral studies were of spectroscopic grade. The IR spectra of ligand and its complexes were recorded on a Bruker Spectrophotometer in 4000-400 $cm^{-1}$ region. Electronic absorption spectra were obtained on a UV-VIS spectrometer, UV 570433 using a prepared methanol solution in the 200-1000 nm. The $^1H$ NMR Spectral analyses were performed on a Bruker-Advance 400 MHZ Spectrophotometer using $CDCl_3$ as solvent. Cyclic voltammetric measurements were carried out using a BAS CV 50W electrochemical analyzing system ($E_{1/2}$ measured to an accuracy of ± 1.0 mV). Magnetic susceptibility measurements were taken in CAHN 2000 magnetic balance.

### Synthesis of ligand, B-GBBA

A solution of GBBA, [N, N'-bis-(2-methyl-benzimidazolyl)-benezene-1,3-dicarboxamide)], (500 mg, 1.179 mmol) was suspended in 20 mL of dry DMF and stirred

for 4-5 hrs. with dry $K_2CO_3$ (325.4 mg, 2.358 mmol) on a water bath at 70-75°C. When turbidity was observed, n-butyl bromide (0.253 mL, 2.358 mmol.) was added and the solution was left for stirring for the next 72 hrs on a water bath at 70-75°C. Subsequently, the solvent was stripped off on a rotatory evaporator and the residue was extracted with $CHCl_3$ (insoluble part was rejected). Upon adding hexane to this filtrate, a white ppt. was deposited, which was washed with hexane, dried, recrystallized with (8 : 2) methanol-water solution and analyzed for the composition, $C_{32}H_{36}N_6O_2.CH_3OH.H_2O$. Yield, 61.0%, Anal. found (calcd.): C, 67.7 (67.5); H, 6.9 (7.2); N, 14.5 (14.3); $\lambda_{max}$ (nm): 286, 278, 243.

**Reactions:**

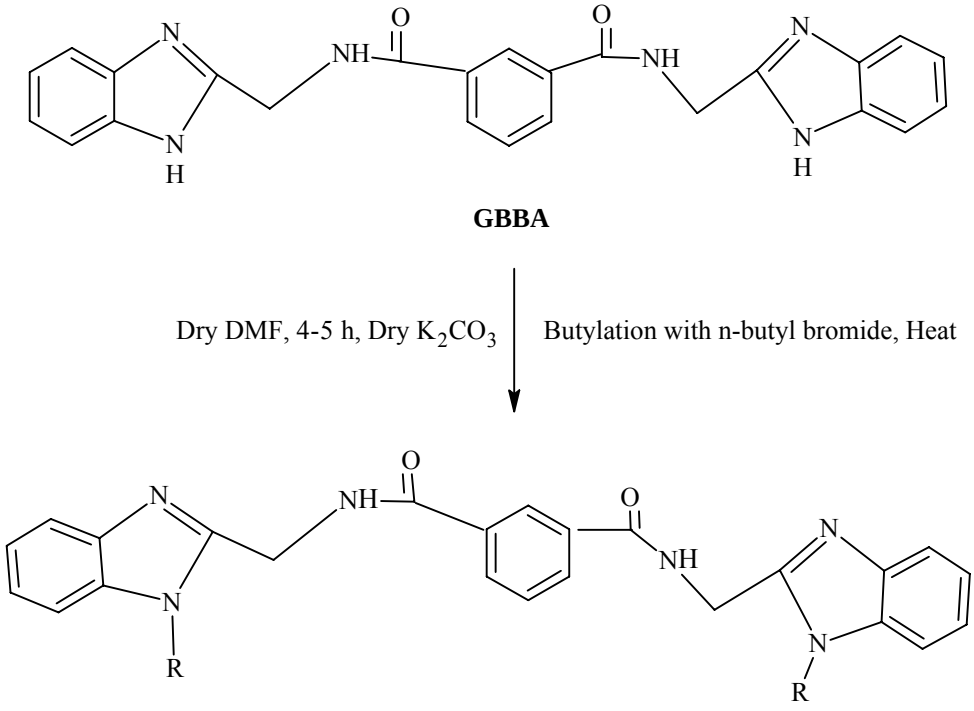



**Fig. 1: B-GBBA**

## Synthesis of metal complexes

A solution of metal salts with $Cl^-$ and $NO_3^-$ as anions in 10 mL. of methanol was added to ligand solution in 1 : 1 stochiometry with stirring of the above reaction mixture for 25-30 minutes at room temperature yielded greenish colored complexes, respectively. The

compounds obtained were filtered off, washed with methanol and dried over $P_4O_{10}$. These complexes were further characterized by analytical and spectral techniques.

$[CuCl_2(L)].3H_2O$: Yield, 78.5%. Anal. found (calcd.): C, 50.8 (51.0); H, 6.2 (6.0); N, 11.8 (12.0); Cu: 9.3 (9.1). $\lambda_{max}$ (nm): 903, 285, 277.

$[Cu(NO_3)_2(L)].4H_2O$: Yield, 74%. Anal. found (calcd.): C, 47.5 (47.2); H, 6.0 (5.8); N, 14.3 (14.1); Cu, 7.8 (8.0). $\lambda_{max}$ (nm): 810, 284, 276.

## RESULTS AND DISCUSSION

### Electronic and $^1$H NMR spectroscopy

The electronic spectra of the complexes were taken in methanol. The free ligand show two strong bands in the UV region at 278 and 286 nm. These bands are assigned to the л-л* transitions characteristic of benzimidazole group. The spectra of complexes also show two strong bands at 284-285 and 276-277 nm corresponding to л-л* transition. The bands are slightly blue shifted with lowered extinction coefficients[11]. A broad but much less intense d-d band is observed in the region 800-1000 nm (Fig. 2) characteristic of tetragonal geometry and is assigned to $^2T_{2g} \rightarrow {}^2Eg$ transition. On the basis of electronic spectra, a distorted octahedral geometry around Cu (II) ion is suggested[12].

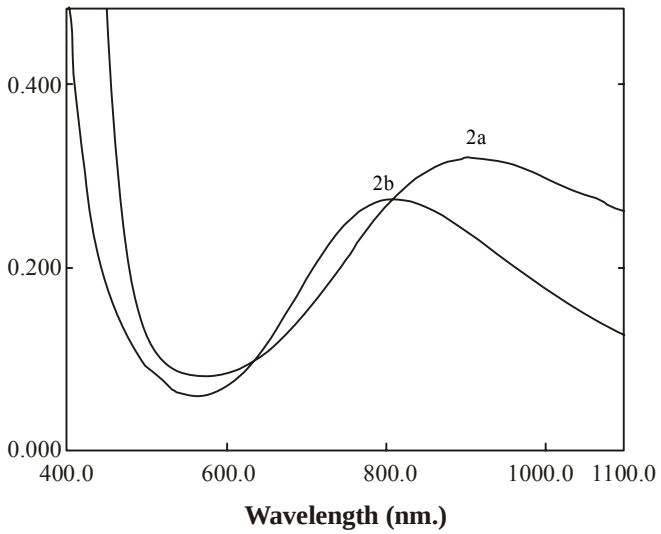



**Fig. 2: Optical spectrum in the range 400-1100 nm of [Cu (II) (B-GBBA) $Cl_2$].$3H_2O$ and [Cu (II) (B-GBBA) $(NO_3)_2$].$4H_2O$ in methanol**

The $^1$H NMR spectrum of ligand, B-GBBA in $CDCl_3$ shows signal for both; aliphatic and aromatic protons with theoretically predicted splitting. A signal is observed between 9.43 and 8.5 ppm corresponding to N-H amide proton and multiplets in the range 7.1-7.8 ppm arise due to the benzimidazole ring protons characteristic of an AA 'BB' pattern. The linker benzene ring protons are found at 7.5, 8.1 and 8.5 ppm for the ligand. The $-CH_2^-$ group attached to the benzimidazole ring gives rise to a doublet between 4.2 and 4.9 ppm to coupling with the amide NH protons. The N-butyl chain in our ligand was found at 0.96, 1.33– 1.77 and 3.73 ppm.

**IR spectroscopy and cyclic voltammetry**

The free ligand, B-GBBA has characteristic IR Bands at 1640, 1544 and 1461 $cm^{-1}$. These are assigned to amide I (mainly $\nu_{C=N}$ amide stretch), amide II (mainly $\nu_{C=O}$ amide stretch) and benzimidazole ($\nu_{C=N-C=C}$) stretching frequencies, respectively[13]. The benzene ring bands appear at 736 $cm^{-1}$ (due to benzimidazole ring) and at 691 $cm^{-1}$ (linker benzene). $\nu_{N-H}$ Stretching bands arise at 3296 and 3185 $cm^{-1}$ due to the amide NH and benzimidazole NH, respectively. On complexation, a decrease in the amide I stretching frequency and increase in amide II stretching frequency has been observed, which is in accordance with the coordination of the ligand through amide carbonyl oxygen. Shifts in N-H stretching frequencies are due to the hydrogen bonding. A broad band in the range 3250-3400 $cm^{-1}$ ($\nu_{O-H}$ stretch) indicates the presence of coordinated/lattice water molecules. Characteristic stretching frequencies for coordinated anions are also observed. The nitrate complex shows bands at 1378-1385 and 820-825 $cm^{-1}$ due to $\nu_{O-N-O}$ sym and $\nu_{O-N-O}$ antisym stretching of the coordinated nitrate group[14]. The most important IR spectral bands for the ligand and their metal complexes are shown in Table 1.

**Table 1: IR spectral bands for the ligand (L) and their metal complexes ($cm^{-1}$)**

| Ligand/Complex | $\nu_{NH}$ amide | $\nu_{NH}$ benzimidazole | $\nu_{CO}$ amide | $\nu_{CN}$ amide | $\nu_{C=N-C=C}$ benzimidazole | Special peaks |
|---|---|---|---|---|---|---|
| [B-GBBA (L)] | 3256 | ----- | 1643 | 1544 | 1461 | |
| $[CuCl_2$ (L)].$3H_2O$ | 3212 | ----- | 1614 | 1555 | 1447 | |
| [Cu $(NO_3)_2$(L)]. $4H_2O$ | 3221 | ----- | 1616 | 1550 | 1449 | $\nu_{-O-N-O}$ 1378 |

The cyclic voltammograms of all complexes were recorded in DMSO solution and has been shown in Table 2. A three electrode configuration composed of Pt-disk working

electrode, a Pt-wire counter electrode and $Ag/AgNO_3$ reference electrode was used for measurements. The cyclic voltammograms of the complexes are shown in Fig. 3a and 3b, respectively. All the complexes display quasi reversible redox wave due to the Cu (II)/Cu (I) process. The $E_{½}$ values of [Cu $(NO_3)_2$(L)] and [$CuCl_2$(L)] were found to be -106 mV and -27.5 mV, respectively. Anodic shift in $E_{½}$ values indicate the retention of the anion in the coordination sphere of Cu (II). The $E_{½}$ values vary anodically in the order $Cl^- > NO_3^-$. This indicates that bound chloride stabilizes the Cu (II) state, while bound nitrate destabilizes it.

**Table 2: Cyclic voltammetric data**

| Complex | Scan rate (mV/Sec.) | Supporting electrolyte | Solvent | Oxidation potential (mV) | Reduction potential (mV) |
|---|---|---|---|---|---|
| [$CuCl_2$ (L)].$3H_2O$ | 100 | $Ag/AgNO_3$ | DMSO | +81 | -136 |
| [Cu $(NO_3)_2$(L)].$4H_2O$ | 100 | ---do--- | --do-- | +70 | -283 |
| L = B-GBBA ligand | | | | | |

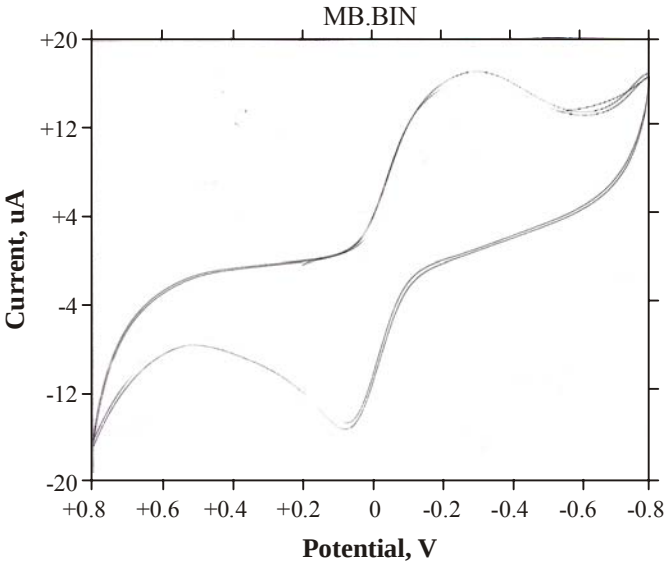



**Fig. 3a: Cyclic voltammogram of (B-GBBA) $Cl_2$].$3H_2O$ in DMSO. Scan rate 100 mV/sec.**

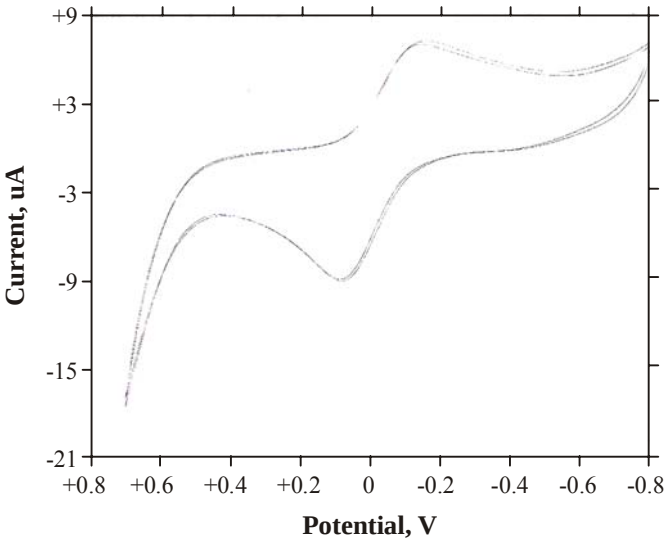



**Fig. 3b: Cyclic voltammogram [Cu (II) (B-GBBA) $(NO_3)_2$.] $4H_2O$ in DMSO. Scan rate 100 mV/sec.**

## Magnetic susceptibility measurements

The magnetic susceptibilities of the complexes at room temperature were determined by using a CAHN 2000 magnetic balance and are reported in Table 3. The solid state magnetic moment at room temperature for the Cu (II) complexes showed magnetic moment values slightly greater than 1.73 BM expected for one unpaired electron, which offers possibility of an octahedral geometry[15] and the monomeric nature of the complexes.

**Table 3: Magnetic susceptibility data at room temperature (300 K)**

| Complex | $\mu_{eff.}$/atom (B.M.) |
|---|---|
| $[CuCl_2 (L)].3H_2O$ | 1.76 |
| $[Cu (NO_3)_2(L)].4H_2O$ | 1.75 |
| L = Ligand | |

## Antimicrobial Studies

All the complexes were screened *in vitro* for their antimicrobial activity against bacteria and fungi. The antibacterial activities were tested by disc diffusion method at 30.µg/mL. concentration and muller Hinton Agar media (Hi media) used as a reference compound, *E. coli* and *S. aureus* used as the bacterial test organism. All the new complexes

were also screened for antibacterial activities against *E. coli* and *S. aureus*. Both the Cu (II) complexes have shown moderate activities against *E. coli* and *S. aureus* (Fig. 4a and 4b). As compared to chloro complex, nitrato complex was found to show greater antimicrobial activity against *E. coli* as shown in Table 4.

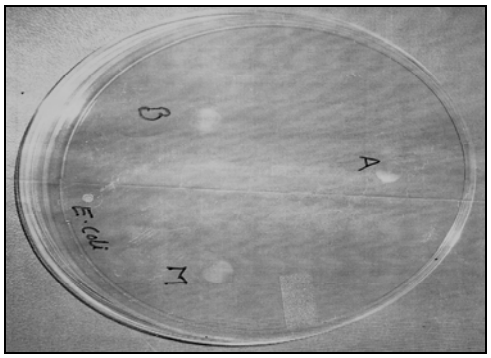



**Fig. 4a: Antibacterial activity of [Cu (II) (B-GBBA)$Cl_2$].3$H_2O$ in Hinton Agar media**

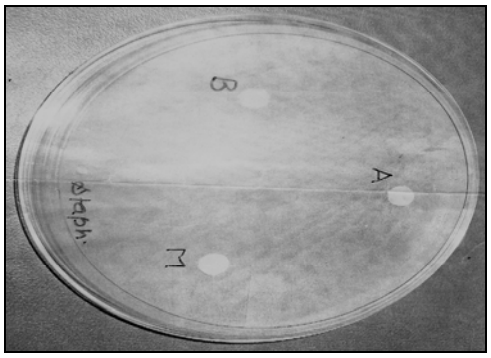


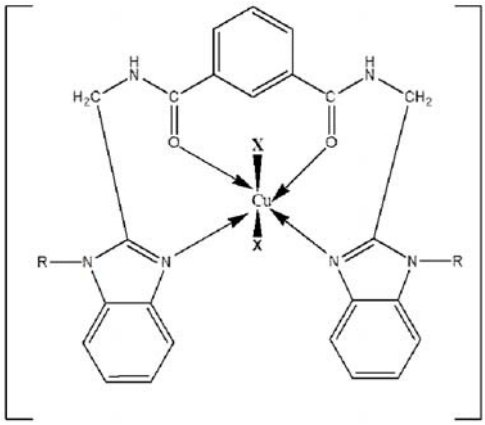

**Fig. 4b: Antibacterial activity of [Cu (II) (B-GBBA) ($NO_3$)$_2$].4$H_2O$ in Hinton Agar media**

**Table 4: Antimicrobial studies**

| S. No. | Compound | Diameter of zone of inhibition (mm) for *E. coli* | | Diameter of zone of inhibition (mm) for *S. aurous* | |
|---|---|---|---|---|---|
| | | 50 ppm | 100 pm | 50 ppm | 100 ppm |
| 1 | [$CuCl_2$(L)].3$H_2O$ | - | 04 | - | 02 |
| 2 | [Cu($NO_3$)$_2$(L)] .4 $H_2O$ | 02 | 06 | - | 02 |

L = Ligand

On basis of the above studies, the proposed structure of the Cu (II) complexes are depicted as distorted octahedral geometry as shown in Fig. 5.




Where X = $Cl^-$ and $NO_3^-$

**Fig. 5: Proposed structures of the metal complexes**

## ACKNOWLEDGEMENT

The authors are grateful to Prof. Pavan Mathur, Deptt. of Chemistry, Delhi University, Delhi; Principal and Head of Department, M. S. J. College, Bharatpur for providing laboratory facilities and helping in carrying out the analytical and spectral studies. We are also grateful to Dr. Narendra Bhojak, Dungar College, Bikaner for biological studies and also Deptt. of Chemistry, Raj. University, Jaipur for helping in spectral and analytical studies.

## REFERENCES

1. M. Gupta, P. Mathur and R. J. Butcher, Inorg. Chem., **40,** 878 (2001).
2. K. P. Ross and E. I. Solomon, J. Am. Chem. Soc., **113,** 3246 (1991).
3. T. Klabunde, C. Eicken, J. Sacchettini and B. Krebs, Nat. Struct. Biol., **5**, 1084 (1998).
4. I. Sanyal, M. M. Tahir, M. S. Nasir, P. Ghosh, B. I. Cohen, T. Gultneh, R. W. Cruse, A. Farooq, K. D. Karlin, S. Liu and J. Zubieta, Inorg. Chem., **31**, 4322 (1992).
5. D. Ghosh and R. Mukherjee, Inorg. Chem., **37**, 6597 (1998).
6. M. Singla, P. Mathur, M. Gupta and M. S. Hundal, Trans. Met. Chem., **33**, 175 (2008).

7. L. Casella, O. Carugo, M. Gullioti, S. Doldi and M. Frassoni, Inorg. Chem., **35,** 1101 (1996).

8. K. Chen, M. Costas, J. Kim, A. K. Tipton and L. Que Jr., J. Am. Chem. Soc., **124**, 3020 (2002).

9. M. Costas, K. Chen and L. Que Jr., Coord. Chem. Rev., **200**, 517 (2002).

10. E. I. Solomon, T. C. Brunoid, M. I. Devis, J. M. Kemsley, S. K. Lee, N. Lehnert, F. Neese, A. J. Skulan, Y. S. Yang and J. Zhou, Chem. Rev., **100**, 235 (2000).

11. E. Monzani, L. Quintinii, A. Peroti, L. Casella, M. Gullioti, L. Ranadccio, S. Gearmia, G. Nardin, P. Faleschini and G. Tabbi, Inorg. Chem., **37**, 553 (1998).

12. H. Liu, H. Wang, F. Gao, D. Niu and Z. Lu, J. Coord. Chem., **60(24)**, 2671 (2007).

13. P. Mathur, M. Crowder and G. C. Dismukes, J. Am. Chem. Soc., **109**, 5227 (1987).

14. S. Menge and L. Que. Jr., Inorg. Chem., **29**, 4293 (1990).

15. D. P. Singh, R. Kumar, V. Malik and P. Tyagi, Trans. Met. Chem., **32**, 1051 (2007).

*Accepted : 20.11.2011*