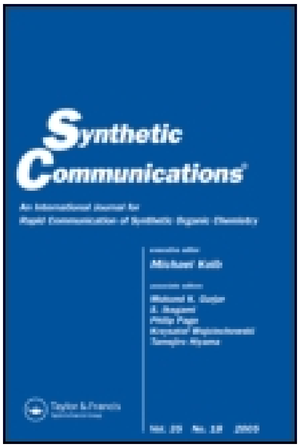


Synthetic Communications: An International Journal for Rapid Communication of Synthetic Organic Chemistry

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/lsyc20

# Synthesis of Bis(indolyl)methanes using a Catalytic Amount of ZnO under Solvent-Free Conditions

Mona Hosseini-Sarvari [a]

[a] Department of Chemistry, College of Science, Shiraz University, Shiraz, Iran

Version of record first published: 22 Feb 2008.

To cite this article: Mona Hosseini-Sarvari (2008): Synthesis of Bis(indolyl)methanes using a Catalytic Amount of ZnO under Solvent-Free Conditions, Synthetic Communications: An International Journal for Rapid Communication of Synthetic Organic Chemistry, 38:6, 832-840

To link to this article: http://dx.doi.org/10.1080/00397910701845274

*Synthetic Communications*®, 38: 832–840, 2008
Copyright © Taylor & Francis Group, LLC
ISSN 0039-7911 print/1532-2432 online
DOI: 10.1080/00397910701845274

# Synthesis of Bis(indolyl)methanes using a Catalytic Amount of ZnO under Solvent-Free Conditions

**Mona Hosseini-Sarvari**

Department of Chemistry, College of Science, Shiraz University,
Shiraz, Iran

**Abstract:** Efficient electrophilic substitution reactions of indoles with various aromatic aldehydes were carried out using a catalytic amount of ZnO under solvent-free conditions to afford the corresponding bis(indolyl)methanes in excellent yields. Among the various methods published for the synthesis of bis(indolyl)methane, ZnO is a very cheap, environmentally friendly, and reusable catalyst that can be used for synthesis of a new range of bis(indolyl)methane derivatives.

**Keywords:** aldehyde, bis(indolyl)methane, indole, solvent-free conditions, ZnO

## INTRODUCTION

With the development of industrialization, organic chemists have been confronted with a new challenge of finding novel methods in organic synthesis that can reduce and finally eliminate the impact of volatile organic solvents and hazardous toxic chemicals on the environment. So, use of nontoxic, environmentally friendly, and inexpensive solid catalysts under solvent-free conditions to perform organic reactions has attracted considerable interest recently. Undoubtedly, one of the most important solid catalysts is zinc oxide (ZnO). ZnO is a versatile material. It is a dry, nonvolatile, nonhydroscopic, odorless, and white crystalline solid with outstanding physical

Received in Poland May 30, 2007

Address correspondence to Mona Hosseini-Sarvari, Department of Chemistry, College of Science, Shiraz University, Shiraz 71454, Iran. E-mail: hossaini@.susc.ac.ir

properties and stability. It is a commercially available, very inexpensive chemical that has key applications as a catalyst[1] and in sensors, piezoelectric transducers,[2] transparent conductors,[3] surface acoustic wave devices,[4] and so on.

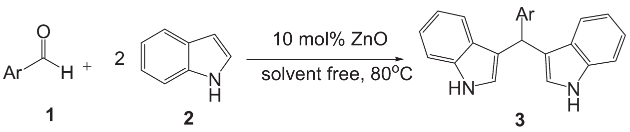
Indoles and their derivatives are important intermediates in organic synthesis because of their pharmacological activities.[5,6] Bis(indolyl)alkanes and their derivatives have received more attention because of their presence in bioactive metabolites and marine materials.[7] Hence, the synthesis of these moieties has become interesting to synthetic organic chemists and biologists. The simple method for the synthesis of this class of compounds involves the electrophilic substitution of indoles with carbonyl compounds in the presence of protic[8] or Lewis acids.[9,10] Recently many methods have been published in the literature for the synthesis of this class of compounds.[11] However, many of these reagents are expensive, need longer reaction time, and are not environmentally friendly, which warrants the development of a new, practical, economical, and environmentally friendly protocol for the synthesis of bis(indolyl)methanes.

## RESULTS AND DISCUSSION

We herein report the design and development of a truly heterogeneous catalyst for the synthesis of a variety of biologically important bis(indolyl)methanes with good yields under solvent-free conditions (Scheme 1).

Initially the effects of different metal oxides as catalysts of the reaction of benzaldehyde (**1a**) with indole (**2**) were examined. Formation of bis(indolyl)-methane **3a** could be observed in all cases but the best value was achieved in the case of ZnO (Table 1). The solvent effect was also studied, and among those examined, under solvent-free conditions ZnO led to the best result.

The inexpensive and commercially available catalyst ZnO could be now applied under optimized conditions to variously substituted aromatic and heteroaromatic aldehydes (Table 2). The methodology is found to be general as the reactions of a variety of substituted aromatic aldehydes **1a–k** as well as alicyclic aldehydes **1l–o** with indole **2** have furnished the corresponding bis(indolyl)methanes in excellent yields. Many of the pharmacologically relevant substitution patterns on the aromatic ring could be introduced with high efficiency using this procedure. The electron deficiency and the nature of the substituents on the aromatic ring affect the conversion rate; aromatic aldehydes having electron-withdrawing groups on the aromatic ring



*Scheme 1.*

***Table 1.*** Screening of different metal oxides for the synthesis of **3a**

| Entry | Catalyst (%) | Solvent | Time | Yield (%)[a] |
|---|---|---|---|---|
| 1 | 20 ZnO | None | 45 min | 98 |
| 2 | 10 ZnO | None | 45 min | 98 |
| 3 | 5 ZnO | None | 1.5 h | 90 |
| 4 | 10 $TiO_2$ | None | 3 h | 95[15] |
| 5 | 10 MgO | None | 5 h | 87 |
| 6 | 10 $Fe_2O_3$ | None | 8 h | 62 |
| 7 | 10 $Al_2O_3$ | None | 3 h | 93 |
| 8 | 10 ZnO | $CH_3CN$ | 12 h | Trace |
| 9 | 10 ZnO | $CH_2Cl_2$ | 12 h | Trace |
| 10 | 10 ZnO | EtOAc | 12 h | Trace |
| 11 | 10 ZnO | EtOH | 12 h | Trace |

[a] Yields are the isolated compounds.

(i.e., $NO_2$) react faster than benzaldehyde, and an electron-donating substitutent (i.e., $CH_3$) remarkably deactivated aryl aldehydes.

Furthermore, the heterocyclic aldehydes such as furfural and **2**, and/or 3-thiophenecarboxaldehyde and 4-pyridylcaboxaldehyde also worked well without the formation of any side products. The reaction condition are mild

***Table 2.*** ZnO-catalyzed synthesis of bis(indolyl)methane[a] by condensation reaction of indole with aldehydes

| Entry | Ar | Product | Time (min) | Yield (%)[b] |
|---|---|---|---|---|
| 1 | ph | **3a** | 45 | 98 |
| 2 | 4-MePh | **3b** | 60 | 99 |
| 3 | 4-MeOPh | **3c** | 90 | 96 |
| 4 | 3-MeOPh | **3d** | 60 | 98 |
| 5 | 4-ClPh | **3e** | 30 | 95 |
| 6 | 3-ClPh | **3f** | 60 | 97 |
| 7 | 2-ClPh | **3g** | 45 | 95 |
| 8 | 4-BrPh | **3h** | 45 | 90 |
| 9 | 4-$NO_2$Ph | **3i** | 20 | 95 |
| 10 | 2-$NO_2$Ph | **3j** | 45 | 84 |
| 11 | 2-HOPh | **3k** | 120 | 93 |
| 12 | 2-Thiophene | **3l** | 120 | 80 |
| 13 | 3-Thiophene | **3m** | 90 | 81 |
| 14 | 4-Pyridine | **3n** | 120 | 75 |
| 15 | 2-Furyl | **3o** | 90 | 63 |

[a] IR and $^1$H NMR spectra were found to be identical with the one described in Refs. [11–13].

[b] Isolated yield.

enough not to damage moieties such as methoxy (**1c**, **d**) and acid sensitives such as furfural (**1o**), which often undergoes cleavage under strong acidic reaction conditions. In the absence of ZnO, the reaction did not yield any product even after a long reaction time. The efficacy of various Lewis acids was tested for this conversion, and the results are shown in Table 3. Among these catalysts, ZnO was found to be superior in term of yield and reaction rate, a result of the very mild Lewic acidity of zinc ion, which activates the carbonyl group to promote the reaction.

This reaction was further explored for the synthesis of tetraindolyl compound **3p** by the condensation of terephtalaldehyde **1p** with 4 equivalents of indole under similar conditions in excellent yields (Scheme 2). Also, to show the generality and novelty of the present protocol, the reaction of a new aldehyde **1q** was shown to have good results without any significant influence of structure on the product yields, such this compound **3q**. This may be applied as a key step in a total synthesis of some natural or other biologically important compound(s) (Scheme 2).

Structurally, the ZnO crystal is described schematically as a number of alternating planes composed of four-fold coordinated $O^{2-}$ and $Zn^{+2}$ ions. We think that ZnO catalyzes the reaction as a mild Lewis acid even under solvent free conditions.[14] In Scheme 3, we give the likely mechanism for the reaction. First, ZnO activates the carbonyl group of the aromatic aldehydes with its Lewis acid site $Zn^{2+}$ to give intermediate **I** and is followed by indole attack to **I** to give **II** and loss of $H_2O$ from **II** to afford **III**, which is activated by ZnO. The other indole is added to **III** in the following step to give the product **IV** and ZnO.

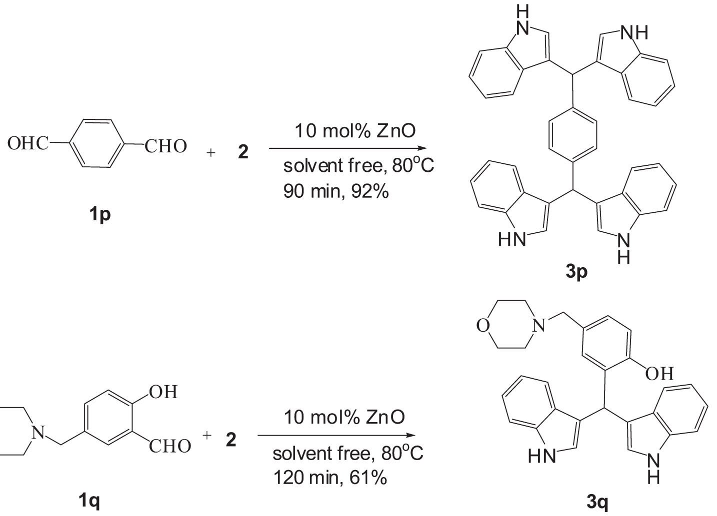
To check the reusability of the catalyst, ethyl acetate was added and the catalyst was filtered off when the reaction of indole with benzaldehyde was over and the product had formed. It was washed with water repeatedly, dried, and reused for the reaction of indole with the same or different aldehydes. The catalyst can be recycled for at least five cycles without any changes in activity.

***Table 3.*** Effect of different Lewis acids on the reaction of indole with benzaldehyde[a]

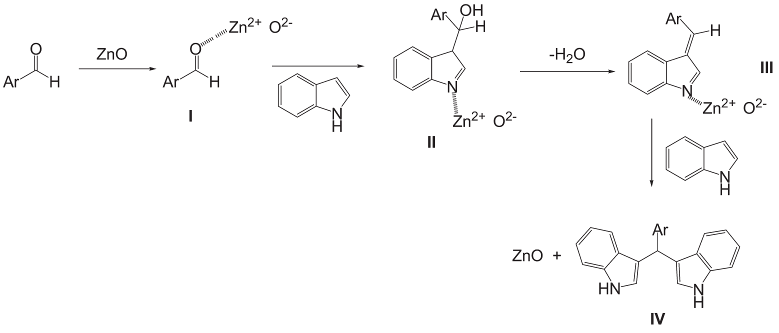
| Entry | Catalyst | Time | Yield (%)[b] |
|---|---|---|---|
| 1 | None | 24 h | 0 |
| 2 | $ZnCl_2$ | 10 h | 25 |
| 3 | $FeCl_3$ | 10 h | 45 |
| 4 | $AlCl_3$ | 4 h | 83 |
| 5 | $CuCl_2$ | 2 h | 84 |
| 6 | ZnO | 45 min | 98 |

[a] The reaction was carried out according to the typical experimental procedure.

[b] Yields are the isolated compounds.



*Scheme 2.*



*Scheme 3.*

In conclusion, we have developed an efficient electrophilic substitution reaction of indoles with various aromatic aldehydes using ZnO as a recyclable catalyst. The method offers several advantages including high yields, short reaction times, simple experimental workup procedure, solvent-free conditions, and use of a very inexpensive and commercially available catalyst; hence, it is a useful addition to the existing methods.

## EXPERIMENTAL

Starting materials were obtained from Fluka Company. Melting points were determined by Buchi 510 apparatus and are uncorrected. IR spectra recorded on Perkin-Elmer spectrometer. Proton NMR spectra were recorded on Bruker Advance DPX FT 250-MHz instrument.

## General Procedure for Synthesis of Bis(indolyl)methanes

A mixture of ZnO (0.008 g, 0.1 mmol), benzaldehyde (1 mmol), and indole (0.4 g, 2 mmol) was added to a test tube and heated in an oil bath at 80°C with stirring. The progress of the reaction was monitored by thin-layer chromatography (TLC) eluent: hexane–EtOAc, 80:20). After the reaction was completed, the catalyst was filtered off, following by washing with ethyl acetate (3 × 30 ml). The filtrate was concentrated under reduced pressure, and the product was purified by column chromatography. The following compounds were obtained:

3,3′-Bisindolylphenylmethane (**3a**): $^1$H NMR ($CDCl_3$): 7.82 (br s, 2H), 7.13–7.57 (m, 13H), 6.56 (s, 2H), 6.02 (s, 1H); $^{13}$C NMR ($CDCl_3$): (40.3, 102.3, 111.4, 119.4, 120.0, 121.9, 123.9, 124.5, 126.3, 128.4, 128.9, 136.8, 144.4.

3,3′-Bisindolyl-4-methylphenylmethane (**3b**): $^1$H NMR ($CDCl_3$): 7.68 (br s, 2H), 7.12–7.55 (m, 12H), 6.56 (s, 2H), 5.97 (s, 1H), 2.45 (s, 3H); $^{13}$C NMR ($CDCl_3$): (22.0, 39.9, 102.4, 111.3, 119.8, 121.9, 123.8, 127.1, 129.1, 135.6, 136.7, 141.2.

3,3′-Bisindolyl-4-methoxyphenylmethane (**3c**): $^1$H NMR ($CDCl_3$): 7.93 (br s, 2H), 6.92–7.91 (m, 12H), 6.42 (s, 2H), 5.99 (s, 1H), 3.95 (s, 3H); $^{13}$C NMR ($CDCl_3$): (39.5, 55.5, 102.3, 111.4, 119.8, 121.9, 123.9, 127.2, 129.8, 135.9, 136.8, 157.9.

3,3′-Bisindolyl-2-methoxyphenylmethane (**3d**): $^1$H NMR ($CDCl_3$): 7.84 (br s, 2H), 6.81–7.40 (m, 12H), 6.64 (s, 2H), 6.35 (s, 1H), 3.82 (s, 3H); $^{13}$C NMR ($CDCl_3$): (32.3, 56.0, 110.8, 111.1, 119.2, 119.8, 120.2, 120.6, 121.9, 123.7, 127.3, 129.9, 132.5, 136.9, 157.1.

3,3′-Bisindolyl-4-chlorophenylmethane (**3e**): $^1$H NMR ($CDCl_3$): 7.73 (br s, 2H), 7.29 (d, 2H, $J = 7.8$), 7.03–7.13 (m, 8H), 6.88–6.95 (m, 2H), 6.34 (s, 2H), 5.73 (s, 1H); $^{13}$C NMR ($CDCl_3$): (44.5, 111.0, 112.1, 119.0, 120.5, 121.7, 122.8, 128.8, 130.8, 131.6, 135.8, 136.5.

3,3′-Bisindolyl-3-chlorophenylmethane (**3f**): $^1$H NMR ($CDCl_3$): 7.81 (br s, 2H), 6.92–7.41 (m, 12H), 6.45 (s, 2H), 5.85 (s, 1H); $^{13}$C NMR ($CDCl_3$): $\delta$ 40.0, 11.4, 118.4, 119.4, 119.8, 120.3, 122.1, 126.5, 127.1, 129.4, 130.5, 134.1, 136.8, 146.5.

3,3′-Bisindolyl-2-chlorophenylmethane (**3g**): $^1$H NMR ($CDCl_3$): 7.89 (br s, 2H), 7.07–7.51 (m, 12H), 6.53 (s, 2H), 6.36 (s, 1H); $^{13}$C NMR ($CDCl_3$): (36.9, 110.1, 111.3, 119.3, 119.8, 122.0, 124.0, 126.7, 127.0, 128.3, 130.4, 130.7, 135.3, 136.7, 141.5.

3,3′-Bisindolyl-4-bromophenylmethane (**3h**): $^1$H NMR ($CDCl_3$): 7.58 (br s, 2H), 6.86–7.25 (m, 12H), 6.37 (s, 2H), 5.68 (s, 1H); $^{13}$C NMR ($CDCl_3$): (39.6, 111.2, 118.9, 119.4, 119.8, 119.9, 122.1, 123.7, 126.8, 130.5, 131.3, 136.6, 143.1.

3,3′-Bisindolyl-4-nitrophenylmethane (**3i**): $^1$H NMR ($CDCl_3$): 8.17 (d, 2H, $J = 7.81$), 7.74 (br s, 2H), 7.45–7.62 (m, 10H), 7.03 (s, 2H), 6.01 (s, 1H); $^{13}$C NMR ($CDCl_3$): $\delta$ 44.5, 110.0, 112.1, 119.6, 119.8, 120.9, 121.3, 121.9, 130.2, 133.8, 136.2, 143.1, 145.2.

3,3′-Bisindolyl-2-nitrophenylmethane (**3j**): $^1$H NMR ($CDCl_3$): 8.36 (br s, 2H), 7.10–7.87 (m, 12H), 6.55 (s, 2H), 5.24 (s, 1H); $^{13}$C NMR ($CDCl_3$): $\delta$ 34.9, 111.5, 111.6, 119.5, 120.7, 121.9, 122.2, 124.3, 126.8, 129.6, 131.2, 132.6, 134.2, 136.8, 149.7.

3,3′-Bisindolyl-2-hydroxyphenylmethane (**3k**): $^1$H NMR (DMSO): 7.58 (br s, 2H), 6.69–7.24 (m, 13H), 6.67 (s, 2H), 5.85 (s, 1H); $^{13}$C NMR (DMSO): $\delta$ 35.5, 111.2, 111.4, 116.5, 119.9, 120.0, 120.8, 121.9, 122.2, 124.4, 126.8, 129.4, 130.1, 154.4.

3,3′-Bisindolyl-2-thienylmethane (**3l**): $^1$H NMR ($CDCl_3$): 7.79 (br s, 2H), 7.62 (d, 2H, $J = 7.80$), 7.14–7.33 (m, 10H), 6.65 (s, 2H), 6.09 (s, 1H); $^{13}$C NMR ($CDCl_3$): $\delta$ 35.9, 110.3, 111.5, 119.3, 120.0, 121.8, 122.6, 123.5, 125.3, 126.3, 128.9, 136.7, 145.5.

3,3′-Bisindolyl-3-thienylmethane (**3m**): $^1$H NMR ($CDCl_3$): 7.85 (br s, 2H), 7.75 (d, 2H, $J = 7.80$), 7.08–7.56 (m, 10H), 6.74 (s, 2H), 6.22 (s, 1H); $^{13}$C NMR ($CDCl_3$): $\delta$ 35.3, 111.2, 111.4, 119.8, 120.7, 121.5, 122.0, 122.5, 126.5, 128.4, 135.4, 136.7, 148.9.

3,3′-Bisindolyl-4-pyridylmethane (**3n**): $^1$H NMR ($CDCl_3$): 7.43 (br s, 2H), 6.78–7.22 (m, 12H), 6.44 (s, 2H), 5.71 (s, 1H); $^{13}$C NMR ($CDCl_3$): $\delta$ 39.7, 111.1, 111.4, 119.7, 120.6, 121.8, 122.4, 124.3, 126.7, 136.7, 149.1, 154.0.

3,3′-Bisindolyl-2-furylmethane (**3o**): $^1$H NMR ($CDCl_3$): 7.74 (br s, 2H), 7.32–7.63 (m, 9H), 7.09 (s, 2H), 6.35 (d, 1H, $J = 3.21$), 6.21 (d, 1H, $J = 4.10$), 5.82 (s, 1H); $^{13}$C NMR ($CDCl_3$): $\delta$ 41.2, 102.1, 110.3, 111.8, 112.6, 119.4, 120.3, 121.5, 122.6, 131.0, 136.4, 141.2, 152.0.

3,3′,3″,3‴-Tetraindolyl(terephthalyl)dimethane (**3p**): $^1$H NMR ($CDCl_3$): 8.12 (br s, 4H), 6.95–7.84 (m, 24H), 6.98 (s, 4H), 5.89 (s, 2H); $^{13}$C NMR ($CDCl_3$): $\delta$ 34.9, 111.3, 112.8, 119.8, 120.3, 121.0, 122.2, 124.5, 129.8, 131.3, 134.7, 142.5.

2-[Di(*1H*indol-3-yl)methyl]-4-(morphonilomethyl)phenol (**3q**): $^1$H NMR (DMSO-$d_6$): 1.94 (s, 4H, 2× -N-$CH_2$-), 2.98 (s, 2H, -$CH_2$-), 3.28 (s, 4H, 2× -O-$CH_2$-), 5.99 (s, 1H, -CH-), 6.53 (s, 2H, 2 × NH), 6.60–7.33 (m, 13H, Ar-H), 10.42 (br s, 1H, OH); $^{13}$C NMR (DMSO-$d_6$): $\delta$ 31.8, 52.3, 59.7, 66.1, 111.2, 118.7, 119.2, 120.6, 120.8, 123.5, 124.8, 126.8, 127.3, 130.1, 130.4, 136.6, 152.2, 153.3. GC-Ms/EI: m/z (%) 437 ($M^+$, 100%). Anal. calcd. for $C_{28}H_{27}N_3O_2$: C, 76.86; H, 6.22; N, 9.60. Found: C, 76.95; H, 6.30; N, 9.72.

## ACKNOWLEDGMENTS

We gratefully acknowledge the support of this work by Shiraz University. We are also grateful to Prof. H. Sharghi for synthesis of aldehyde **1q** and his helpful cooperation.

## REFERENCES

1. (a) Hosseini-Sarvari, M.; Sharghi, H. ZnO as a new catalyst for *N*-formylation of amines under solvent-free conditions. *J. Org. Chem.* **2006**, *71*, 6652–6654; (b) Hosseini-Sarvari, M.; Sharghi, H. Reactions on a solid surface: A simple, economical and efficient Friedel–Crafts acylation reaction over zinc oxide (ZnO) as a new catalyst. *J. Org. Chem.* **2004**, *20*, 6953–6956; (c) Hosseini-Sarvari, M. ZnO/$CH_3$COCL: A new and highly efficient catalyst for dehydration of aldoximes into nitriles under solvent-free conditions. *Synthesis* **2005**, *5*, 787–790; (d) Sharghi, H.; Hosseini-Sarvari, M. Solvent-free and one-step Beckmann rearrangement of ketones and aldehydes by zinc oxide. *Synthesis* **2002**, *8*, 1057–1060; (e) Hosseini-Sarvari, M.; Sharghi, H. ZnO as a new, highly efficient, and reusable catalyst for acylation of alcohols, phenols and amines under solvent-free conditions. *Tetrahedron* **2005**, *61*, 10903; (f) Kim, Y. J.; Varma, R. S. Microwave-assisted preparation of cyclic ureas from diamines in the presence of ZnO. *Tetrahedron Lett.* **2004**, *45*, 7205–7208.
2. Minne, S. C.; Manalis, S. R.; Quate, C. F. Parallel atomic force microscopy using cantilevers with integrated piezoresistive sensors and integrated piezoelectric actuators. *Appl. Phys. Lett.* **1995**, *67*, 3918–3920.
3. Jayaraj, M. K.; Antony, A.; Ramachandran, M. See the special issue on transparent conducting oxide. *MRS Bulletin Augustissue*. **2000**, *25*, 227–235.
4. Gorla, C. R.; Emanetoglu, N. W.; Liang, S.; Mayo, W. E.; Lu, Y.; Wraback, M.; Shen, H. Structural, optical, and surface acoustic wave properties of epitaxial ZnO films grown on ($01\bar{1}2$) sapphire by metalorganic chemical vapor deposition. *J. Appl. Phys.* **1999**, *85*, 2595–2902.
5. Sundberg, R. J. *The Chemistry of Indoles*; Academic Press: New York, 1970.
6. (a) Porter, J. K.; Bacon, C. W.; Robins, J. D.; Himmelsbach, D. S.; Higman, H. C. Indole alkaloids from *Balansia epichloe* (Weese). *J. Agric. Food Chem.* **1977**, *25*, 88–93; (b) Osawa, T.; Namiki, M. Structure elucidation of streptindole, a novel genotoxic metabolite isolated from intestinal bacteria. *Tetrahedron Lett.* **1983**, *24*, 4719–4722; (c) Fahy, E.; Potts, B. C.; Faulkner, D. J.; Smith, K. 6-Bromotryptamine derivatives from the Gulf of California tunicate *Didemnum candidum*. *J. Nat. Prod.* **1991**, *54*, 564–569; (d) Bifulco, G.; Bruno, I.; Riccio, R.; Lavayre, J.; Bourdy, G. Further brominated bis- and tris-indole alkaloids from the deep-water new caledonian marine sponge *Orina* sp. *J. Nat. Prod.* **1995**, *58*, 1254–1260; (e) Bell, R.; Carmell, S.; Sar, N.; Vibrindole, A. A metabolite of

the marine bacterium *Vibrio parahaemolyticus*, isolated from the toxic mucus of the boxfish *Ostracion cubicus*. *J. Nat. Prod.* **1994**, *57*, 1587–1590; (f) Garbe, T. R.; Kobayashi, M.; Shimizu, N.; Takesue, N.; Ozawa, M.; Yukawa, H. Indolyl carboxylic acids by condensation of indoles with $\alpha$-keto acids. *J. Nat. Prod.* **2000**, *63*, 596–598.

7. (a) Roomi, M.; MacDonald, S. Reductive *C*-alkylation, II. *Can. J. Chem.* **1970**, *48*, 139–143; (b) Gregorovich, B.; Liang, K.; Clugston, D.; MacDonald, S. Reductive *C*-alkylation. *Can. J. Chem.* **1968**, *46*, 3291–3300.
8. Noland, W. E.; Venkiteswaren, M. R.; Richards, C. G. Cyclizative condensations, I: 2-Methylindole with acetone and methyl ethyl ketone. *J. Org. Chem.* **1961**, *26*, 4241–4248.
9. Chatterji, A.; Manna, S.; Banerji, J.; Pascard, C.; Prange, T.; Shoolery, J. Studies in decarboxylation. part 13: The incursion of a stepwise mechanism in the gas-phase decarboxylation of cyclopropylacetic acids. *J. Chem. Soc., Perkin. Trans. 1* **1980**, 553–556.
10. Yadav, J. S.; Subba Reddy, B. V.; Murthy, C. V. S. R.; Kumar, G. M. Lithium perchlorate–catalyzed reactions of indoles: An expeditious synthesis of bis(indolyl)-methanes. *Synthesis* **2001**, 783–787.
11. (a) Bandgar, B. P.; Shikh, K. A. Molecular iodine–catalyzed efficient and highly rapid synthesis of bis(indolyl)methanes under mild conditions. *Tetrahedron Lett.* **2003**, *44*, 1959–1961; (b) Vijender Reddy, A.; Ravinder, K.; Niranjan Reddy, V. L.; Venkateshwer Goud, T.; Ravikanth, V.; Venkateswarlu, V. Zeolite-catalyzed synthesis of *bis*(indolyl) methanes. *Synth. Commun.* **2003**, *33*, 3687–3694; (c) Nagarajan, R.; Permal, P. T. Potassium hydrogen sulfate–catalyzed reactions of indoles: A mild, expedient synthesis of bis-indolylmethanes. *Chem. Lett.* **2004**, *33*, 288–289; (d) Nagarajan, R.; Perumal, P. T. $InCl_3$ and $In(OTf)_3$-catalyzed reactions: synthesis of 3-acetylindoles, bis-indolylmethanes and indolylquinoline derivatives. *Tetrahedron* **2002**, *58*, 1229–1232; (e) Hagiwara, H.; Sekifuji, M.; Hoshi, T.; Qiao, K.; Yokoyama, C. Synthasis of bis(indolyl)methanes catalyzed by acidic ionic liquid immobilized on silica (ILIS). *Synlett* **2007**, *8*, 1320–1322; (f) Zhan-Hui, Z.; Liang, Y.; Yong-Mei, W. An efficient and practical process for the synthesis of bis(indolyl)methanes catalyzed by zirconium tetrachloride. *Synthesis* **2005**, *12*, 1949–1954; (g) Firouzabadi, H.; Iranpoor, N.; Jafarpour, M.; Ghaderi, A. $ZrOCl_2 \cdot 8H_2O$/silica gel as a new efficient and a highly water-tolerant catalyst system for facile condensation of indoles with carbonyl compounds under solvent-free conditions. *J. Mol. Catal. A: Chem.* **2006**, *253*, 249–251.
12. Pore, D. M.; Desai, U. V.; Thopate, T. S.; Wadganokar, P. P. A mild, expedient, solventless synthesis of bis(indolyl)alkanes using silica sulfuric acid as a reusable catalyst. *Arkivoc* **2006**, *1*, 75–80.
13. Bandgar, B. P.; Bettigeri, S. V.; Joshi, N. S. Hexamethylenetetraamine-bromine catalyzed rapid and efficient synthesis of bis(indolyl)methanes. *Monatshefte fur Chemie* **2006**, *135*, 1265–1273.
14. Kong, X. Y.; Wang, Z. L. Spontaneous polarization-induced nanohelixes, nanospring and nanorings of piezoelectric nanobelts. *Nano Lett.* **2003**, *3*, 1625–1631.
15. Hosseini-Sarvari, M. Titania ($TiO_2$)–catalyzed expedient, solventless and mild synthesis of bis(indolyl)methanes. *Acta. Chim. Slov.* **2007**, *54*, 354–359.