Abstract: Transparent conducting oxides (TCOs) are electrical conductive materials with comparably low absorption of electromagnetic waves within the visible region of the spectrum. They are usually prepared with thin film technologies and used in opto-electrical apparatus such as solar cells, displays, opto-electrical interfaces and circuitries. Here, based on a modern database-system, aspects of up-to-date material selections and applications for transparent conducting oxides are sketched, and references for detailed information are given. As n-type TCOs are of special importance for thin film solar cell production, indium-tin oxide (ITO) and the reasonably priced aluminum-doped zinc oxide (ZnO:Al), are discussed with view on preparation, characterization and special occurrences. For completion, the recently frequently mentioned typical p-type delafossite TCOs are described as well, providing a variety of references, as a detailed discussion is not reasonable within an overview publication.

Keywords: transparent conducting oxide; oxide; TCO; ITO; ZnO:Al; delafossite

1. Introduction

Transparent conducting oxides (TCOs) are electrical conductive materials with a comparably low absorption of light. They are usually prepared with thin film technologies and used in opto-electrical devices such as solar cells, displays, opto-electrical interfaces and circuitries. Glass fibers are nearly lossless conductors of light, but electrical insulators; silicon and compound semiconductors are wavelength dependent optical resistors (generating mobile electrons), but dopant dependent electrical conductors. Transparent conducting oxides are highly flexible intermediate states with both these characteristics. Their conductivity can be tuned from insulating via semiconducting to conducting as
well as their transparency adjusted. As they can be produced as n-type and p-type conductives, they open a wide range of power saving opto-electrical circuitries and technological applications.

A still valuable overview of transparent conductive oxides is given in [1], basics to material physics of TCOs are discussed in [2], some structural investigation of TCOs was made e.g., in [3], preparation of TCOs was discussed in [4] and substitutes for the most popular transparent conducting oxide, namely ITO (indium-tin oxide), are listed in [5]. Here, based on a modern database-system, aspects of up-to-date material selections and applications for transparent conducting oxides are sketched, and references for detailed information are given. As n-type TCOs are of special importance for thin film solar cell production, ITO and the reasonably priced aluminum-doped zinc oxide (ZnO:Al) are discussed with view on preparation, characterization and special occurrences. For completion, the recently frequently mentioned typical p-type delafossite TCOs are described as well, providing a variety of references, as a detailed discussion is not reasonable within an overview publication.

As transparent conducting oxides are usually compound semiconductors—where the nonmetal part is oxygen—they are discussed along their metal elements. Metals were used as compound materials or dopants (with just a few percent content).

2. Transparent Conducting Oxides (TCOs)

2.1. TCOs in General

In transparent conducting oxides (TCOs), the nonmetal part, B, consists of oxygen. In combination with different metals or metal-combinations, A, they lead to compound semiconductors, $A_yB_z$, with different opto-electrical characteristics. These opto-electrical characteristics can be changed by doping, $A_yB_z:D$ ($D = $ dopant), with metals, metalloids or nonmetals. Hence, metals can be part of the compound semiconductor itself, A, or can be a dopant, D. Scanning the periodic table of elements, with a view on the utilization of metals for TCOs, results in Table 1 (regarding just the 2nd and 3rd period, exclusively aluminum).

| Period of the PE | Compound semiconductor | Dopant | Preparation | Characterization | Reference |
|-----------------|------------------------|--------|-------------|------------------|-----------|
| 2               | NiO                    | Li     | Pulsed Laser Deposition (different Li-concentr.) | ? | [6] |
|                 |                        |        | No TCO-Layers with Be |                |           |
| 3               | ZnO                    | Na, Al | Sol-gel, Annealing | SEM, Photoluminescence | [7–9] |
|                 | Cr$_2$O$_3$            | Mg, N  | Spray Pyrolysis | ? | [10] |
|                 | CuCrO$_2$ (Delafossite) | Mg     | Sol-gel Technique | ? | [11] |
Table 1. Cont.

| Period of the PE | Compound semiconductor | Dopant | Preparation | Characterization | Reference |
|------------------|------------------------|--------|-------------|------------------|-----------|
| Mg_{1-x}ZnxO     | In                     | Pulsed Laser Deposition (different substrates) | X-ray diffraction, HRTEM | [12]       |
| Mg_{1-x}ZnxO     | Al                     | Magnetron Sputtering (different substrates)   | ?                     | [13]       |
| Mg_{12}Al_{14}O_{33} ("Mayenite") | Al | ? | ? | [14] |

Outstanding good optical characteristics have been provided by tin-, indium- and zinc oxides (A = tin, indium, zinc). Well known is, for example, indium tin oxide (ITO), and the doping of zinc oxide with less than 5% aluminum (ZnO:Al). Moreover, doped delafossite and mayenite compounds are of upcoming interest (see Table 1). A variety of preparation and characterization methods was applied to investigate their different chemical structures and physical characteristics. These shall be briefly discussed.

2.2. Indium Tin Oxide (ITO)

Indium tin oxide (ITO) is a solid solution of indium(III) oxide (In$_2$O$_3$) and tin(IV) oxide (SnO$_2$), with typically 90%$_{wt}$ In$_2$O$_3$, 10%$_{wt}$ SnO$_2$. It is transparent and colorless as a thin film and yellowish to grey as bulk material. Indium tin oxide is the most widely used transparent conducting oxide (TCO [15]) because of its two key properties, its electrical conductivity and optical transparency. ITO thin films are still deposited with ion assisted plasma evaporation [16], (low temperature) electron beam evaporation [17–19], direct current (DC), pulsed DC (PDC), high power pulsed magnetron sputtering (HPPMS), radio frequency (RF) magnetron sputtering [20–25], thermal evaporation [25] or pulsed laser deposition (PLD) [26–29]. Post process thermal annealing steps are discussed for the example in [17–20], oxygen-plasma treatments in [30] and the influence of acids and bases on ITO thin films in [31]. Investigations were made on electrical [16–28,30,31], optical [16–26,28,31,32] and structural [17,21,22,26,28,29,32,33] properties of this ternary compound semiconductor. According to structural investigations, the focus was set on the border between amorphous and crystal phases [17] and the growth mechanisms (Volmer-Weber, Frank-van der Merwe) [29]. Band structure and work function are analyzed in [34–36].

2.3. Aluminum Doped Zinc Oxide (ZnO:Al)

Transparent conducting, aluminum doped zinc oxide thin films (Al$_x$Zn$_{y}$O$_z$, ZnO:Al) [37,38] contain about 2%$_{wt}$ aluminum and can be produced with spray pyrolysis [39–44], sol gel technology [45–51], electro deposition [52,53], vapor phase deposition [54,55], magnetron DC sputtering [56–60], magnetron RF sputtering [61–64] or a combination of both the sputter deposition methods [65–82]. Moreover, high quality deposition methods using thermal plasmas [83,84], (low pressure (LP), metal organic (MO), plasma enhanced (PE)) chemical vapor deposition (CVD) [85,86], electron beam evaporation [87], pulsed laser deposition [88–93] and atomic layer deposition [94] can be applied.
The underlying substrate—crystalline, amorphous or organic—may have an influence on the grown structure and the opto-electronic properties of the thin film [95–99], independent of the used deposition method. For example, in the case of solar cell production, an ultra-thin CdS buffer layer is usually the basis for ZnO:Al deposition [100,101]. Even if the substrate is identical, the layer thickness (deposition time, position upon the substrate) itself influences the physical values of the deposited thin film [102]. A variation of the physical values from the grown thin films can also be reached by changing process parameters, as temperature [103] or pressure [104,105], or by additions to the process gas, as oxygen [106] or hydrogen [107].

Commonly, pure zinc oxides [108,109] are n-doped with aluminum [110,111]. Alternatively, n-doping can be done with metals such as copper, Cu, silver, Ag, gallium, Ga, magnesium, Mg, cadmium, Cd, indium, In, tin, Sn, scandium, Sc, yttrium, Y, cobalt, Co, manganese, Mn, chrome, Cr, and boron, B [88,112–120]. p-Doping of ZnO is technologically difficult, but apart from nitrogen, N, phosphorus, P, seems to be an adequate dopant [121–128].

The opto-electronic properties [129] of these TCO thin films can be changed by post process thermal annealing in an inert gas or reactive gas atmosphere [38,130–132]. Especially surface and interface states can be influenced [133,134]. The deterioration of ZnO:Al thin films is discussed in [135].

2.4. Delafossite and Mayenite Type Transparent Conducting Oxides

Commonly, ITO- and ZnO-based TCO thin films are n-doped, as p-doping has been shown to be technologically more difficult. Fortunately, for delafossite compound semiconductors this is vice versa. They typically show TCO properties with semiconducting p-type characteristics. Delafossites, CuₙA₂O₂, are commonly ternary material combinations of copper, Cu, one (or more) further metal(s), A, (aboriginal iron, A = Fe) and oxygen, O.

Copper may be replaced by silver [136–141], palladium [139] or platinum [142]. As further metal, A, iron [143–145], cobalt [138] or chrome [146–150] (without doping hardly transparent) may be used as well as elements of the 2nd group of the periodic table of the elements—strontium [151–154], barium [155]—or the 3rd group—aluminum [149,156–169], gallium [168,169], indium [170], scandium [171,172], yttrium [173–176], lanthanum [175,176]. Moreover, other lanthanides such as praseodymium, neodymium samarium and europium have been applied [175–177], in order to get ternary semiconductor compounds.

Quaternary semiconductors as for example the Sb-based Cu₂₋₃Sb₁/₃O₂ (A = Mn, Co, Ni, Zn, Mg), respectively Ag₂₋₃Sb₁/₃O₂ (A = Ni, Zn) [138,140] or the Cr-based CuCr₁₋ₓAₓO₂ (A = Mg, Ca, Al) delafossites have been investigated [147,178].

Ag-Cu and Rh-Mg replacements were for example studied in the quaternary structure Cu₁₋ₓAgₓRh₁₋ₓMgₓO₂ [179].

Oxygen off-stoichiometry, CuₙA₂O₂₋ₓ, has been examined [175,180]. Oxy-sulphide delafossite type TCOs, CuₙA₂O₂Sₓ, were sputtered (CuLaₓOS:Srx, x = 0%–5% [181]) or already existing delafossite-oxide films, Cu₂In₂O₄, sulfurized to CulnS₂, by annealing in H₂S [182].

Delafossites have been grown from a melt by a slow cooling-method in air [166,183]. They were deposited using low temperature hydro/solvothermal processes [159,168,184], the sol-gel technology [146,147,149,153,185] and the spray pyrolysis technique [148,158]. Moreover, advanced
methods such as (direct current (DC), radio frequency (RF)) magnetron sputter of prefabricated targets [143,144,156,157,162,164,167,173,181,186], with varying temperature, pressure, oxygen flow or sputter energies [144,161,165], pulsed laser deposition [136,152,163,169,187,188], with varying temperature and pressure [187], thermal evaporation [174], e-beam evaporation technique [154], and low-pressure (LP), metal-organic (MO) chemical vapor deposition (CVD) [150] were applied.

Annealing in N₂, O₂, air [157,161,162,165] or argon [149] was examined, showing for example a reduction in CuO resp. spinel CuCr₂O₄ fraction and formation of highly crystalline films with single-phase delafossite CuCrO₂ structure [148,164].

The Cu₃O₂ group shows increasing band gap from A = Al, Ga, to In. The largest gap CuInO₂ can be doped both n- and p-type but not the smaller gaps CuAlO₂ and CuGaO₂ [189]. Therefore, doping CuInO₂ with Ca results in p-type, doping with Sn in n-type semiconducting TCO thin films [188,190]. Bidirectional doping is possible for CuFeO₂, too (p-type: Mg, n-type: Sn [191]). In addition, the electronic structure of Cu₃O₂ (A = Al, Ga, Y) was discussed in [192–196] and its luminescent properties in [197]. Defect analyses have been made with the screened-hybrid density functional theory [160].

Additional p-doping is usually performed with Ca, Mg or occasionally with K, in order to increase the conductivity resulting in e.g., CuIn₂O₅:Ca [151,187], Cu₂In₂O₅:Ca [187], CuYO₂:Ca [173,174], CuCrO₂:Mg [138,148,198], CuScO₂:Mg [138,172] or Cu₃SrO₂:K [152]. N-type doping of delafossite TCO thin films is normally done with Sn, e.g., CuIn₂O₅:Sn [188,190] or AgInO₂:Sn [136]. Further discussion on doping of delafossite TCOs is shown in [199].

Because of the structural anisotropy of the CuAlO₂-crystal, anisotropic electrical conductivity was detected in [200]. Ohmic contacts between CuInO₂ and Cu are reported in [170].

The crystal structures and chemistries are by far the best investigated topics in delafossite (semi)conductor research and systematically discussed in [201,193]; the according temperature dependency is shown in [202].

3. Further Aspects to Technological Advances of Transparent Conducting Oxides

Reasons for technical advances in transparent conducting oxides are manifold— influencing aspects are: The investigation of adequate novel materials and material-combinations, as for example the first delafossites by Charles Friedel in 1873 (named after the French mineralogist and crystallographer Gabriel Delafosse); an increasing financial support for research according to political decisions, as for example the increased financial support of solar cell investigations and therefore of TCOs by the present nuclear power phase-out in Germany; the publication of new results, as research groups in industrial companies often reserve important information; and the efficiency of modern literature data-bases, as only included literature can be found and selected.

Therefore, technical advances in transparent conducting oxides may be illustrated researching the web of knowledge (Thomson Reuters). Applying e.g., the search item “TCO < name of element > oxide” leads to the carefully selected citation statistics, shown in Table 2. Again, the already discussed elements aluminum (Al), zinc (Zn), indium (In) and tin (Sn) show the by far highest nominal citation impacts. In order to demonstrate the technical advances in transparent conducting oxides, the gradient of citations over the years 2007 until 2011 shall be printed for these four elements in Figure 1. This indicates, that the focus of investigation was preferably set on ITO and that A tcro rises until 2010 by
about 100 a year. Until 2011, the number of citations per year decreases—not only because this literature research was done in November 2011.

\[
A_{\text{TCO}} = \frac{\text{citation}}{\text{year}}
\]  

(1)

**Table 2.** Carefully selected citation report results for TCO-materials, containing metallic elements from the 2nd to the 7th period of the periodic table of the elements (PE)—researched with the web of knowledge using “TCO < name of element > oxide”.

| Topic          | Citation report | Av. Citations/Year |
|----------------|-----------------|--------------------|
|                | 2007 2008 2009 2010 2011 Total |                   |
| 2nd Period     |                 |                    |
| TCO Li oxide   | 4 0 3 7 5 19    | 3.17               |
| TCO Be oxide   | x x x x x     |                    |
| 3rd Period     |                 |                    |
| TCO Na oxide   | 0 0 0 0 3 3 3 | 3                  |
| TCO Mg oxide   | 8 7 8 8 9 40 8 | 8                  |
| TCO Al oxide   | 196 306 394 500 434 2122 | 192.91             |
| 4th Period     |                 |                    |
| TCO K oxide    | 1 2 5 3 1 12   | 2.4                |
| TCO Ca oxide   | 5 11 5 8 5 47  | 5.88               |
| Subgroup       |                 |                    |
| TCO Sc oxide   | x x x x x x    |                    |
| TCO Ti oxide   | 1 5 14 50 38 114 | 14.25              |
| TCO V oxide    | 0 1 9 1 3 18   | 2                  |
| TCO Cr oxide   | 3 2 2 1 12 28  | 3.5                |
| TCO Mn oxide   | 0 0 3 1 1 5    | 1.25               |
| TCO Fe oxide   | x x x x x x    |                    |
| TCO Co oxide   | 0 12 23 23 17 75 | 18.75              |
| TCO Ni oxide   | 0 0 0 2 5 7    | 3.5                |
| TCO Cu oxide   | 18 40 44 73 76 268 | 33.5               |
| TCO Zn oxide   | 275 415 487 723 612 3142 | 184.82             |
| TCO Ga oxide   | 0 1 15 54 37 107 | 26.75              |
| 5th Period     |                 |                    |
| TCO Rb oxide   | x x x x x x    |                    |
| TCO Sr oxide   | 2 7 3 6 1 22   | 3.14               |
| Subgroup       |                 |                    |
| TCO Y oxide    | 0 0 2 1 1 4    | 1                  |
| TCO Zr oxide   | 0 0 0 1 4 5    | 2.5                |
| TCO Nb oxide   | 2 4 8 4 45 103 | 20.6               |
| TCO Mo oxide   | 1 17 24 35 21 98 | 19.6               |
| TCO Tc oxide   | radioactive! |                    |
| TCO Ru oxide   | 3 8 13 8 1 36  | 6                  |
| TCO Rh oxide   | x x x x x x    |                    |
Table 2. Cont.

| Topic       | 2007 | 2008 | 2009 | 2010 | 2011 | Total | Av. Citations/Year |
|-------------|------|------|------|------|------|-------|---------------------|
| TCO Pd oxide| x    | x    | x    | x    | x    | x     | x                   |
| TCO Ag oxide| 16   | 43   | 57   | 95   | 67   | 328   | 18.22               |
| TCO Cd oxide| 37   | 48   | 54   | 119  | 59   | 509   | 36.36               |
| TCO In oxide| 247  | 328  | 397  | 546  | 388  | 2511  | 156.94              |
| TCO Sn oxide| 346  | 406  | 493  | 641  | 519  | 3755  | 197.63              |
| 6th Period  |      |      |      |      |      |       |                     |
| TCO Cs oxide| x    | x    | x    | x    | x    | x     | x                   |
| TCO Ba oxide| x    | x    | x    | x    | x    | x     | x                   |
| Subgroup    |      |      |      |      |      |       |                     |
| TCO Hf oxide| x    | x    | x    | x    | x    | x     | x                   |
| TCO Ta oxide| 7    | 8    | 9    | 19   | 10   | 60    | 8.57                |
| TCO W oxide | 3    | 5    | 5    | 10   | 8    | 34    | 5.67                |
| TCO Re oxide| x    | x    | x    | x    | x    | x     | x                   |
| TCO Os oxide| x    | x    | x    | x    | x    | x     | x                   |
| TCO Ir oxide| x    | x    | x    | x    | x    | x     | x                   |
| TCO Pt oxide| 1    | 0    | 0    | 1    | 2    | 0.4   |                     |
| TCO Au oxide| x    | x    | x    | x    | x    | x     | x                   |
| TCO Hg oxide| 3    | 4    | 9    | 5    | 3    | 24    | 4.8                 |
| TCO Tl oxide| x    | x    | x    | x    | x    | x     | x                   |
| TCO Pb oxide| x    | x    | x    | x    | x    | x     | x                   |
| TCO Bi oxide| x    | x    | x    | x    | x    | x     | x                   |
| Lanthanide Series |      |      |      |      |      |       |                     |
| TCO La oxide| 0    | 0    | 2    | 0    | 1    | 3     | 1                   |
| TCO Ce oxide| 0    | 0    | 1    | 1    | 0    | 39    | 2.17                |
| TCO Pr oxide| x    | x    | x    | x    | x    | x     | x                   |
| TCO Nd oxide| x    | x    | x    | x    | x    | x     | x                   |
| TCO Pm oxide| x    | x    | x    | x    | x    | x     | x                   |
| TCO Sm oxide| 0    | 0    | 1    | 10   | 8    | 19    | 6.33                |
| TCO Eu oxide| 0    | 0    | 1    | 8    | 5    | 14    | 4.67                |
| TCO Gd oxide| 0    | 0    | 0    | 1    | 4    | 5     | 2.5                 |
| TCO Tb oxide| x    | x    | x    | x    | x    | x     | x                   |
| TCO Dy oxide| 0    | 0    | 0    | 9    | 6    | 15    | 7.5                 |
| TCO Ho oxide| x    | x    | x    | x    | x    | x     | x                   |
| TCO Er oxide| x    | x    | x    | x    | x    | x     | x                   |
| TCO Tm oxide| x    | x    | x    | x    | x    | x     | x                   |
| TCO Yb oxide| x    | x    | x    | x    | x    | x     | x                   |
| TCO Lu oxide| x    | x    | x    | x    | x    | x     | x                   |
| 7th Period  |      |      |      |      |      |       |                     |
| TCO Fr oxide| x    | x    | x    | x    | x    | x     | x                   |
| TCO Ra oxide| x    | x    | x    | x    | x    | x     | x                   |
| Actinide Series |      |      |      |      |      |       |                     |
| TCO Ac oxide| x    | x    | x    | x    | x    | x     | x                   |
Despite these four elements, let us regard the next five metals, which exhibit the most average citations per year in TCO-related publications, see Table 2, Figure 2. Hence, Cadmium (Cd) is discussed as CdO:D (D = Ga, Sn, Sm, Eu, Gd, or Dy), CdIn$_2$O$_4$ or Cd$_2$SnO$_4$, where H$_2$-annealing is frequently applied to widen the energy gap [203–205].

Copper (Cu) represents the group of doped and undoped CuO$_2$ and delafossites, see above.

Gallium (Ga) on the one hand is used as dopant, D (about 2\%at), for ZnO and CdO. On the other hand Ga is the metallic part, A, of Ga$_2$O$_3$. Based on this, gallium zinc oxide (GZO: ZnGa$_2$O$_4$) is produced with 90\%wt of Ga$_2$O$_3$ and 10\%wt of ZnO. Moreover, aluminum gallium zinc oxide (AGZO) is a combination of aluminum zinc oxide (AZO) and GZO, respectively indium gallium zinc oxide (IGZO) a combination of IZO and GZO [206,207].

Niobium (Nb) is exclusively used as dopant, with an atomic concentration of about 3\%-6\%at, primarily for TiO$_2$:Nb but also for SnO$_2$:Nb [208,209].

Molybdenum (Mo) is usually used in comparatively high conductive TCOs. Mo is a dopant for ZnO (MZO) or In$_2$O$_3$ (IMO). MoO is also applied in layer stacks with silver, Ag [210–212].

The upcoming importance of transparent conductive materials for thin film solar cells, opto-electrical interfaces, displays and opto-electrical circuitry widens the area of investigation. So, exotic dopants, such as sodium (Na) [213] and manganese (Mn) [214] for zinc oxides (ZnO), zirconium (Zr) [215],

---

**Table 2. Cont.**

| Topic         | Citation report | Av. Citations/Year |
|---------------|-----------------|--------------------|
| TCO Th oxide  | x               | x                  |
| TCO Pa oxide  | x               | x                  |
| TCO U oxide   | radioactive!    | radioactive!       |
| ...           |                 |                    |

**Figure 1.** Demonstration of the technical advances in transparent conducting oxides, using the gradient of citations of publications over the years 2007 until November 2011.
platinum (Pt) and tungsten (W) [216] for indium oxide (In₂O₃), ITO and IGZO or lanthanum (La) [217] for strontium stannate LaₓSr₁₋ₓSnO₃ have been discussed in the last few years.

Finally, ultra-thin metals without any oxygen content (except natural oxidation in air at room temperature)—as for example nickel (Ni)—have been applied as optical transparent conducting materials [218].

**Figure 2.** Demonstration of the technical advances in transparent conducting oxides, using the gradient of citations of publications over the years 2007 until November 2011.

4. Conclusions

Based on a modern database-system, aspects of up-to-date material selections and applications for transparent conducting oxides have been sketched; references for detailed information have been given for the interested reader. As n-type TCOs are of special importance for thin film solar cell production, indium-tin oxide (ITO) and the reasonably priced aluminum-doped zinc oxide (ZnO:Al) have been discussed with view on preparation, characterization and special occurrences. For completion, typical p-type delafossite TCOs have been described the same way, providing a variety of references, as a detailed discussion is not reasonable within an overview-publication. Moreover, absolutely unusual, novel TCO materials have been discussed and their presence and development in the world of science pointed out. Trends have been shown.

As transparent conducting oxides are usually compound semiconductors—where the nonmetal part is oxygen—they have been discussed along their metal elements. Metals were used as compound materials or dopants (with just a few percent content).

**Acknowledgments**

The author acknowledges the support of the Christian Doppler Research Society, Austria.
References

1. Chopra, K.L.; Major, S.; Pandya, D.K. Transparent conductors—A status review. Thin Solid Films 1983, 102, 1–46.
2. Edwards, P.P.; Porch, A.; Jones, M.O.; Morgan, D.V.; Perks, R.M. Basic materials physics of transparent conducting oxides. Dalton Trans. 2004, 19, 2995–3002.
3. Kawazoe, H.; Ueda, K. Transparent conducting oxides based on the spinel structure. J. Am. Ceram. Soc. 1999, 82, 3330–3336.
4. Jarzebski, Z.M. Preparation and physical properties of transparent conducting oxide films. Phys. Stat. Sol. 1982, 71, 13–41.
5. Minami, T. Present status of transparent conducting oxide thin-film development for Indium-Tin-Oxide (ITO) substitutes. Thin Solid Films 2008, 516, 5822–5828.
6. Joshi, U.S.; Matsumoto, Y.; Itaka, K.; Sumiya, M.; Koinuma, H. Combinatorial synthesis of Li-doped NiO thin films and their transparent conducting properties. Appl. Surf. Sci. 2006, 252, 2524–2528.
7. Wang, T.; Liu, Y.; Fang, Q.; Wu, M.; Sun, X.; Lu, F. Low temperature synthesis wide optical band gap Al and (Al, Na) co-doped ZnO thin films. Appl. Surf. Sci. 2011, 257, 2341–2345.
8. Wang, M. Comment on “low temperature synthesis wide optical band gap Al and (Al, Na) co-doped ZnO thin films”. Appl. Surf. Sci. 2011, 257, 8752–8753.
9. Wang, T.; Liu, Y. Response to the comment on “low temperature synthesis wide optical band gap Al and (Al, Na) co-doped ZnO thin films”. Appl. Surf. Sci. 2011, 257, p. 8754.
10. Arca, E.; Fleischer, K.; Shvets, I.V. Magnesium, nitrogen codoped Cr2O3: A p-type transparent conducting oxide. Appl. Phys. Lett. 2011, 99, 111910.
11. Götzendörfer, S.; Löbmann, P. Influence of single layer thickness on the performance of undoped and Mg-doped CuCrO2 thin films by sol–gel processing. J. Sol-Gel Sci. Technol. 2011, 57, 157–163.
12. Lau, C.H.; Zhuang, L.; Wong, K.H. In-doped transparent and conducting cubic magnesium zinc oxide thin films grown by pulsed laser deposition. Phys. Stat. Sol. B 2007, 244, 1533–1537.
13. Ellmer, K.; Vollweiler, G. Electrical transport parameters of heavily-doped zinc oxide and zinc magnesium oxide single and multilayer films heteroepitaxially grown on oxide single crystals. Thin Solid Films 2006, 496, 104–111.
14. Ingram, B.J.; Bertoni, M.I.; Poeppelmeier, K.R.; Mason, K.R. Point defects and transport mechanisms in transparent conducting oxides of intermediate conductivity. Thin Solid Films 2005, 486, 86–93.
15. Hartnagel, H.L. Semiconducting Transparent Thin Films; Institute of Physics Publishing: Bristol, UK, 1995, ISBN 978–0750303224.
16. Laux, S.; Kaiser, N.; Zöller, A.; Götzelmann, R.; Lauth, H.; Bernitzki, H. Room-temperature deposition of indium tin oxide thin films with plasma ion-assisted evaporation. Thin Solid Films 1998, 335, 1–5.
17. Paine, D.C.; Whitson, T.; Janiac, D.; Beresford, R.; Yang, C.O.; Lewis, B. A study of low temperature crystallization of amorphous thin film indium-tin-oxide. J. Appl. Phys. 1999, 85, 8445–8450.
18. Chen, C.H.; Chang, S.J.; Su, Y.K.; Chi, G.C.; Chi, J.Y.; Chang, C.A.; Sheu, J.K.; Chen, J.F. GaN metal-semiconductor-metal ultraviolet photodetectors with transparent indium-tin-oxide Schottky contacts. *IEEE Photonics Technol. Lett.* **2001**, *13*, 848–850.
19. Sheu, J.K.; Su, Y.K.; Chi, G.C.; Jou, M.J.; Chang, C.M. Effects of thermal annealing on the indium tin oxide Schottky contacts of n-GaN. *Appl. Phys. Lett.* **1998**, *72*, 3317–3319.
20. Karasawa, T.; Miyata, Y. Electrical and optical properties of indium tin oxide thin films deposited on unheated substrates by d.c. reactive sputtering. *Thin Solid Films* **1993**, 223, 135–139.
21. Kim, S.T.; Lee, J.H.; Yang, J.Y.; Ryu, S.W.; Hong, J.S.; Hong, W.P.; Kim, J.J.; Kim, H.M.; Yang, J.M.; Park, S.H. The Electronic and optical properties of IZO thin films prepared by pulsed dc magnetron sputtering. *J. Korean Phys. Soc.* **2007**, *50*, 662–665.
22. Sittinger, V.; Ruske, F.; Werner, W.; Jacobs, C.; Szyszka, B.; Christie, D.J. High power pulsed magnetron sputtering of transparent conducting oxides. *Thin Solid Films* **2008**, *516*, 5847–5859.
23. Park, S.K.; Jeong, I.H.; Kim, W.K.; Kwak, M.G. Deposition of indium-tin-oxide films on polymer substrates for application in plastic-based flat panel displays. *Thin Solid Films* **2001**, 397, 49–55.
24. Meng, L.-J.; dos Santos, M.P. Properties of indium tin oxide films prepared by RF reactive magnetron sputtering at different substrate temperature. *Thin Solid Films* **1998**, *322*, 56–62.
25. Horng, R.-H.; Wuu, D.-S.; Lien, Y.-C.; Lan, W.-H. Low-resistance and high-transparency Ni/indium tin oxide ohmic contacts to p-type GaN. *Appl. Phys. Lett.* **2001**, *79*, 2925:1–2925:3.
26. Kim, H.; Piqué, A.; Horwitz, J.S.; Mattoussi, H.; Murata, H.; Kafafi, Z.H.; Chrisey, D.B. Indium tin oxide thin films for organic light-emitting devices. *Appl. Phys. Lett.* **1999**, *74*, 3444:1–3444:3.
27. Ohta, H.; Orita, M.; Hirano, M.; Tanji, H.; Kawazoe, H.; Hosono, H. Highly electrically conductive indium-tin-oxide thin films epitaxially grown on yttria-stabilized zirconia (100) by pulsed-laser deposition. *Appl. Phys. Lett.* **2000**, *76*, 2740:1–2740:3.
28. Kim, H.; Gilmore, C.M.; Piqué, A.; Horwitz, J.S.; Mattoussi, H.; Murata, H.; Kafafi, Z.H.; Chrisey, D.B. Electrical, optical, and structural properties of indium–tin–oxide thin films for organic light-emitting devices. *J. Appl. Phys.* **1999**, *86*, 6451–6461.
29. Sun, X.W.; Huang, H.C.; Kwok, H.S. On the initial growth of indium tin oxide on glass. *Appl. Phys. Lett.* **1996**, *68*, 2663:1–2663:3.
30. Milliron, D.J.; Hill, I.G.; Shen, C.; Kahn, A.; Schwartz, J. Surface oxidation activates indium tin oxide for hole injection. *J. Appl. Phys.* **2000**, *87*, 572–576.
31. Nüesch, F.; Rothberg, L.J.; Forsythe, E.W.; Le, Q.T.; Gao, Y.L. A photoelectron spectroscopy study on the indium tin oxide treatment by acids and bases. *Appl. Phys. Lett.* **1999**, *74*, 880:1–880:3.
32. Synowicki, R.A. Spectroscopic ellipsometry characterization of indium tin oxide film microstructure and optical constants. *Thin Solid Films* **1998**, *313*, 394–397.
33. Ishida, T.; Kobayashi, H.; Nakato, Y. Structures and properties of electron-beam-evaporated indium tin oxide films as studied by X-ray photoelectron spectroscopy and work-function measurements. *J. Appl. Phys.* **1993**, *73*, 4344–4350.
34. Mryasov, O.N.; Freeman, A.J. Electronic band structure of indium tin oxide and criteria for transparent conducting behavior. *Phys. Rev. B* **2001**, *64*, 233111–233113.
35. Sugiyama, K.; Ishii, H.; Ouchi, Y.; Seki, K. Dependence of indium–tin–oxide work function on surface cleaning method as studied by ultraviolet and x-ray photoemission spectroscopies. *J. Appl. Phys.* **2000**, *87*, 295: 1–295: 4.
36. Park, Y.; Choong, V.; Gao, Y.; Hsieh, B. R.; Tang, C.W. Work function of indium tin oxide transparent conductor measured by photoelectron spectroscopy. *Appl. Phys. Lett.* **1996**, *68*, 2699–2701.
37. Jagadish, C. *Zinc Oxide Bulk, Thin Films and Nanostructures, Processing, Properties and Applications*; Jagadish, C., Pearton, S., Eds.; Elsevier: Oxford, UK, 2006.
38. *Transparent Conductive Zinc Oxide: Basics and Application in Thin Film Solar Cells*, 2nd ed.; Ellmer, K., Klein, A., Rech, B., Eds.; Springer-Verlag: Berlin, Germany, 2008.
39. Seeber, W.T.; Abou-Helal, M.O.; Barth, S.; Beil, D.; Höche, T.; Afify, H.H.; Demian, S.E. Transparent semiconducting ZnO:Al thin films prepared by spray pyrolysis. *Mater. Sci. Semicond. Process.* **1999**, *2*, 45–55.
40. Nunes, P.; Malik, A.; Fernandes, B.; Fortunato, E.; Vilarinho, P.; Martins, R. Influence of the doping and annealing atmosphere on zinc oxide thin films deposited by spray pyrolysis. *Vacuum* **1999**, *52*, 45–49.
41. Nunes, P.; Fernandes, B.; Fortunatoa, E.; Vilarinhob, P.; Martinsa, R. Performances presented by zinc oxide thinfilms deposited by spray pyrolysis. *Thin Solid Films* **1999**, *337*, 176–179.
42. Lokhande, B.J.; Uplane, M.D. Structural, optical and electrical studies on spray deposited highly oriented ZnO films. *Appl. Surf. Sci.* **2000**, *167*, 243–246.
43. Monragnón-Suárez, H.; Reyes, A.; Castanedo-Pérez, R.; Torres-Delgado, G.; Asomoza, R. ZnO:Al thin films obtained by chemical spray: effect of the Al concentration. *Appl. Surf. Sci.* **2002**, *193*, 52–59.
44. Gümű, C.; Ozkendir, O.M.; Kavak, H.; Ufuktepe, Y. Structural and optical properties of zinc oxide thin films prepared by spray pyrolysis methode. *J. Optoelectron. Adv. Mater.* **2006**, *8*, 299–303.
45. Jiménez-González, A.E. Urueta, J.A.S.; Suárez-Parra, R. Optical and electrical characteristics of aluminum-doped ZnO thin films prepared by solgel technique. *J. Cryst. Growth* **1998**, *192*, 430–438.
46. Schuler, T.; Aegerter, M.A. Optical, electrical and structural properties of sol gel ZnO:Al coatings. *Thin Solid Films* **1999**, *351*, 125–131.
47. Natsume, Y.; Sakata, H. Zinc oxide films prepared by sol-gel spin-coating. *Thin Solid Films* **2000**, *372*, 30–36.
48. Musat, V.; Teixeira, B.; Fortunato, E.; Monteiro, R.C.C.; Vilarinho, P. Al-doped ZnO thin films by sol–gel method. *Surf. Coat. Tech.* **2004**, *180*, 659–662.
49. Valle, G.G.; Hammer, P.; Pulcinelli, S.H.; Santilli, C.V. Transparent and conductive ZnO:Al thin films prepared by sol-gel dip-coating. *J. Eur. Ceram. Soc.* **2004**, *24*, 1009–1013.
50. Maity, R.; Kundoo, S.; Chattopadhyay, K.K. Electrical characterization and Poole-Frenkel effect in sol-gel derived ZnO:Al thin films. *Sol. Energ. Mat. Sol. C* **2005**, *86*, 217–227.
51. Li, L.J.; Deng, H.; Dai, L.P.; Chen, J.J.; Yuan, Q.L.; Li, Y. Properties of Al heavy-doped ZnO thin films by RF magnetron sputtering. *Mater. Res. Bull.* **2006**, *41*, 354–358.

52. Gal, D.; Hodes, G.; Lincot, D.; Schock, H.-W. Electrochemical deposition of zinc oxide films from non-aqueous solution: A new buffer/window process for thin film solar cells. *Thin Solid Films* **2000**, *361*, 79–83.

53. Jia, S. Polyelectrolyte Assisted Preparation and Characterization of Nanostructured ZnO Thin Films, Ph.D. Thesis; Universität Stuttgart: Stuttgart, Germany, 2005.

54. Ma, J.; Ji, F.; Ma, H.-L.; Li, S.-Y. Electrical and optical properties of ZnO: Al films prepared by an evaporation method. *Thin Solid Films* **1996**, *279*, 213–215.

55. Ma, J.; Ji, F.; Zhang, D.-H.; Ma, H.-L.; Li S.-Y. Optical and electronic properties of transparent conducting ZnO and ZnO:Al films prepared by evaporating method. *Thin Solid Films* **1999**, *357*, 98–101.

56. Chen, M.; Pei, Z.L.; Sun, C.; Wen, L.S.; Wang, X. Formation of Al-doped ZnO films by dc magnetron reactive sputtering. *Mater. Lett.* **2001**, *48*, 194–198.

57. Ting, J.-M.; Tsai, B.S. DC reactive sputter deposition of ZnO:Al thin film on glass. *Mater. Chem. Phys.* **2001**, *72*, 273–277.

58. Fang, G.J.; Li, D.J.; Yao, B.-L. Fabrication and characterization of transparent conductive ZnO:Al thin films prepared by direct current magnetron sputtering with highly conductive ZnO(ZnAl2O4) ceramic target. *J. Cryst. Growth* **2003**, *247*, 393–400.

59. Herrmann, D.; Oertel, M.; Menner, R.; Powalla, M. Analysis of relevant plasma parameters for ZnO:Al film deposition based on data from reactive and non-reactive DC magnetron sputtering. *Surf. Coat. Tech.* **2003**, *174*, 229–234.

60. Wang, W.W.; Diao, X.G.; Wang, Z.; Yang, M.; Wang, T.M.; Wu, Z. Preparation and characterization of high-performance direct current magnetron sputtered ZnO:Al films. *Thin Solid Films* **2005**, *491*, 54–60.

61. Dimova-Malinovska, D.; Tzenov, N.; Tzolov, M.; Vassilev, L. Optical and electrical properties of R.F. magnetron sputtered ZnO:Al thin films. *Mater. Sci. Eng.* **1998**, *B52*, 59–62.

62. Chang, J.F.; Wang, H.L.; Hon, M.H. Studying of transparent conductive ZnO:Al thin films by RF reactive magnetron sputtering. *J. Cryst. Growth* **2000**, *211*, 93–97.

63. Chang, J.F.; Shen, C.C.; Hon, M.H. Growth characteristics and residual stress of RF magnetron sputtered ZnO:Al films. *Ceram. Int.* **2003**, *29*, 245–250.

64. Yoo, J.S.; Lee, J.; Kim, S.; Yoon, K.; Park, I.J.; Dhungel, S.K.; Karunagaran, B.; Mangalaraj, D.; Yi, J.S. High transmittance and low resistive ZnO:Al films for thinfilm solar cells. *Thin Solid Films* **2005**, *480*, 213–217.

65. Sieber, I.; Wanderka, N.; Urban, I.; Dörfel, I.; Schierhorn, E.; Fenske, F.; Fuhs, W. Electron microscopic characterization of reactively sputtered ZnO films with different Al-doping levels. *Thin Solid Films* **1998**, *330*, 108–113.

66. Ellmer, K.; Cebulla, R.; Wendt, R. Transparent and conducting ZnO(:Al) films deposited by simultaneous RF- and DC-excitation of a magnetron. *Thin Solid Films* **1998**, *317*, 413–416.

67. Tominaga, K.; Umezuru, N.; Mori, I.; Ushiro, T.; Morita, T.; Nakabayashi, I. Transparent conductive ZnO film preparation by alternating sputtering of ZnO:Al and Zn or Al targets. *Thin Solid Films* **1998**, *334*, 35–39.
68. Fenske, F.; Fuhs, W.; Nebauer, E.; Schöpke, A.; Selle, B.; Sieber, I. Transparent conductive ZnO:Al films by reactive co-sputtering from separate metallic Zn and Al targets. *Thin Solid Films* **1999**, *343*, 130–133.

69. Kluth, O.; Recha, B.; Houbena, L.; Wiedera, S.; Schöpea, G.; Benekinga, C.; Wagnera, H.; Löflfb, A.; Schockb, H.W. Texture etched ZnO:Al coated glass substrates for silicon based thin film solar cells. *Thin Solid Films* **1999**, *351*, 247–253.

70. Szyszka, B. Transparent and conductive aluminum doped zinc oxide films prepared by mid-frequency reactive magnetron sputtering. *Thin Solid Films* **1999**, *351*, 130–133.

71. Stadler, A. Analyzing UV/Vis/NIR spectra—Part II: Correct and efficient parameter extraction. *IEEE Sens. J.* **2011**, 11, 897–904.

72. Zhang, D.H.; Yang, T.L.; Wang, Q.P.; Zhang, D.J. Electrical and optical properties of Al-doped transparent conducting ZnO films deposited on organic substrate by RF sputtering. *Mater. Chem. Phys.* **2001**, 68, 233–238.

73. Müller, J.; Kluth, O.; Wieder, S.; Siekmann, H.; Schöpe, G.; Reetz, W.; Vetterl, O.; Lundszen, D.; Lambertz, A.; Finger, F.; et al. Development of highly efficient thin film silicon solar cells on texture-etched zinc oxide-coated glass substrates. *Sol. Energ. Mat. Sol. C* **2001**, 66, 275–281.

74. Müller, J.; Schöpe, G.; Kluth, O.; Rech, B.; Ruske, M.; Trube, J.; Szyszka, B.; Jiang, X.; Bräuer, G. Upscaling of texture-etched zinc oxide substrates for silicon thin film solar cells. *Thin Solid Films* **2001**, 392, 327–333.

75. Tzolov, M.; Tzenov, N.; Dimova-Malinovska, D.; Kalitzova, M.; Pizzuto, C.; Vitali, G.; Zollo, G.; Ivanov, I. Modification of the structure of ZnO:Al films by control of the plasma parameters. *Thin Solid Films* **2001**, 396, 274–279.

76. Hong, R.J.; Jiang, X.; Heide, G.; Szyszka, B.; Süttinger, V.; Werner, W. Growth behaviours and properties of the ZnO:Al films prepared by reactive mid-frequency magnetron sputtering. *J. Cryst. Growth* **2003**, 249, 461–469.

77. Müller, J.; Schöpe, G.; Kluth, O.; Rech, B.; Süttinger, V.; Szyszka, B.; Geyer, R.; Lechner, P.; Schade, H.; Ruske, M.; et al. State-of-the-art mid-frequency sputtered ZnO films for thin film silicon solar cells and modules. *Thin Solid Films* **2003**, 442, 158–162.

78. Hong, R.J.; Jiang, X.; Szyszka, B.; Süttinger, V.; Pflug, A. Studies on ZnO:Al thin films deposited by in-line reactive mid-frequency magnetron sputtering. *Appl. Surf. Sci.* **2003**, 207, 341–350.

79. Szyszka, B.; Süttinger, V.; Jiang, X.; Hong, R.J.; Werner, W.; Pflug, A.; Ruske, M.; Lopp, A. Transparent and conductive ZnO:Al films deposited by large area reactive magnetron sputtering. *Thin Solid Films* **2003**, 442, 179–183.

80. Fu, E.G.; Zhuang, D.M.; Zhang, G.; Zhao, M.; Yang, W.F. Properties of transparent conductive ZnO:Al thin films prepared by magnetron sputtering. *Microelec. J.* **2004**, 35, 383–387.

81. Oh, B.-Y.; Jeong, M.-C.; Lee, W.; Myoung, J.-M. Properties of transparent conductive ZnO:Al films prepared by co-sputtering. *J. Cryst. Growth* **2005**, 274, 453–457.

82. Lin, S.-S.; Huang, J.-L.; Saigalik, P. Effects of substrate temperature on the properties of heavily Al-doped ZnO films by simultaneous r.f. and d.c. magnetron sputtering. *Surf. Coat. Tech.* **2005**, 190, 39–47.
83. Groenen, R.; Linden, J.L.; van Lierop, H.R.M.; Schram, D.C.; Kuypers, A.D.; van de Sanden, M.C.M. An expanding thermal plasma for deposition of surface textured ZnO:Al with focus on thin film solar cell applications. *Appl. Surf. Sci.* **2001**, *173*, 40–43.

84. Lee, H.W.; Lau, S.P.; Wang, Y.G.; Tse, K.Y.; Hng, H.H.; Tay, B.K. Structural, electrical and optical properties of Al-doped ZnO thin films prepared by filtered cathodic vacuum arc technique. *J. Cryst. Growth* **2004**, *268*, 596–601.

85. Kim, Y.-J.; Kim, H.-J. Trapped oxygen in the grain boundaries of ZnO polycrystalline thin films prepared by plasma-enhanced chemical vapor deposition. *Mater. Lett.* **1999**, *41*, 159–163.

86. Groenen, R.; Löffler, J.; Sommeling, P.M.; Linden, J.L.; Hamers, E.A.G.; Schropp, R.E.I.; van de Sanden, M.C.M. Surface textured ZnO films for thin film solar cell applications by expanding thermal plasma CVD. *Thin Solid Films* **2001**, *392*, 226–230.

87. Aghamalyan, N.R.; Gambaryan, I.A.; Goulanian, E.K.; Hovsepyan, R.K.; Kostanyan, R.B.; Petrosyan, S.I.; Vardanyan, A.; Zerrouk, A.F. Influence of thermal annealing on optical and electrical properties of ZnO films prepared by electron beam evaporation. *Semicond. Sci. Technol.* **2003**, *18*, 525–529.

88. Ning, Z.Y.; Cheng, S.H.; Ge, S.B; Chao, Y.; Gang, Z.Q.; Zhang, Y.X.; Liu, Z.G. Preparation and characterization of ZnO:Al films by pulsed laser deposition. *Thin Solid Films* **1997**, *307*, 50–53.

89. Sun, X.W.; Kwok, H.S. Optical properties of epitaxially grown zinc oxide films on sapphire by pulsed laser deposition. *J. Appl. Phys.* **1999**, *86*, 408–411.

90. Kim, H; Piqué, A.; Horwitz, J.S.; Murata, H.; Kafafi, Z.H.; Gilmore, C.M.; Chrisey, D.B. Effect of aluminum doping on zinc oxide thin films grown by pulsed laser deposition for organic light-emitting. *Thin Solid Films* **2000**, *377*, 798–802.

91. Dolbec, R.; Khakani, M.A.E; Serventi, A.M.; Trudeau, M.; Saint-Jacques, R.G. Microstructure and physical properties of nanostructured tin oxide thin films grown by means of pulsed laser. *Thin Solid Films* **2002**, *419*, 230–236.

92. Matsubara, K.; Fons, P.; Iwata, K.; Yamada, A.; Sakurai, K.; Tampo, H.; Niki, S. Transparent conducting films deposited by pulsed laser deposition for solar cell applications. *Thin Solid Films* **2003**, *431*, 369–372.

93. Vincze, A.; Kováč, J.; Novotný, I.; Bruncko, J.; Haško, D.; Šatka, A.; Shtereva, K. Preparation and properties of ZnO layers grown by various methods. *Appl. Surf. Sci.* **2008**, *255*, 1419–1422.

94. Elam, J.W.; George, S.M. Growth of ZnO/Al2O3 alloy films using atomic layer deposition techniques. *Chem. Mater.* **2003**, *15*, 1020–1028.

95. Yang, T.L.; Zhang, D.H.; Ma, J.; Ma, H.L.; Chen, Y. Transparent conducting ZnO:Al films deposited on organic substrates deposited by RF magnetron-sputtering. *Thin Solid Films* **1998**, *326*, 60–62.

96. Yoshino, Y.; Inoue, K.; Takeuchi, M.; Makino, T.; Katayama, Y.; Hata, T. Effect of substrate surface morphology and interface microstructure in ZnO thin films formed on various substrates. *Vacuum* **2000**, *59*, 403–410.

97. Zhang, D.H.; Yang, T.L.; Ma, J.; Wang, Q.P.; Gao, R.W.; Ma, H.L. Preparation of transparent conducting ZnO:Al films on polymer substrates by RF magnetron sputtering. *Appl. Surf. Sci.* **2000**, *158*, 43–48.
98. Hao, X.T.; Ma, J.; Zhang, D.H.; Yang, T.L.; Ma, H.L.; Yang, Y.G.; Cheng, C.F.; Huang, J. Thickness dependence of structural, optical and electrical properties of ZnO:Al films prepared on flexible substrates. *Appl. Surf. Sci.* 2001, *183*, 137–142.

99. Zhang, D.H.; Yang, T.L.; Wang, Q.P.; Zhang D.J. Electrical and optical properties of Al-doped transparent conducting ZnO films deposited on organic substrate by RF sputtering. *Mater. Chem. Phys.* 2001, *68*, 233–238.

100. Durrani, S.M.A.; Al-Shukri, A.M.; Ilob, A.; Khawaja, E.E. Optical constants of zinc sulfide films determined from transmittance measurements. *Thin Solid Films* 2000, *379*, 199–202.

101. Gunasekaran, M.; Ramasamy, P.; Ichimura, M. Preparation of ternary Cd$_{1-x}$Zn$_x$S alloy by photochemical deposition (PCD) and its application to photovoltaic devices. *Phys. Status. Solidi C* 2006, *3*, 2656–2660.

102. Lin, S.-S.; Huang, J.-L. The effect of thickness on the properties of heavily Al-doped ZnO films by simultaneous rf and dc magnetron sputtering. *Ceram. Int.* 2004, *30*, 497–501.

103. Chang, J.F.; Hon, M.H. The effect of deposition temperature on the properties of Al-doped zinc oxide thin films. *Thin Solid Films* 2001, *386*, 79–86.

104. Igasaki, Y.; Kanma, H. Argon gas pressure dependence of the properties of transparent conducting ZnO:Al films deposited on glass substrates. *Appl. Surf. Sci.* 2001, *169*, 508–511.

105. Song, D.Y.; Aberle, A.G.; Xia, J. Optimisation of ZnO:Al films by change of sputter gas pressure for solar cell application. *Appl. Surf. Sci.* 2001, *195*, 291–296.

106. Brehme, S.; Fenske, F.; Fuhs, W.; Nebauer, E.; Poschenrieder, M.; Selle, B.; Sieber, I. Free-carrier plasma resonance effects and electron transport in reactivity sputtered degenerate ZnO:Al films. *Thin Solid Films* 1999, *342*, 167–173.

107. Addonizio, M.L.; Antoniaia, A.; Cantele, G.; Privato, C. Transport mechanisms of RF sputtered Al-doped ZnO films by H$_2$ process gas dilution. *Thin Solid Films* 1999, *349*, 93–99.

108. Look, D.C. Recent advances in ZnO materials and devices. *Mater. Sci. Eng.* 2001, *B80*, 383–387.

109. Feddern, K. Synthese und Optische Eigenschaften von ZnO-Nanokristallen. Ph.D. Thesis, Universität Hamburg: Hamburg, Germany, 2002.

110. Reuß, F. Untersuchung des Dotierverhaltens und der mag. Eigenschaften von Epitaktischen ZnO-Heterostrukturen. Ph.D. Thesis, Universität Ulm: Ulm, Germany, 2005.

111. Wischmeier, L. ZnO-Nanodrähte: Optische Eigenschaften und Ladungsträgerdynamik. Ph.D. Thesis, Universität Bremen: Bremen, Germany, 2007.

112. Waugh, K.C. Comments on “The effect of ZnO in methanol synthesis catalysts on Cu dispersion and the specific activity” [by T. Fujitani and J. Nakamura]. *Catalysis Lett.* 1999, *58*, 163–165.

113. Reitz, T.L.; Ahmed, S.; Krumpelt, M.; Kumar, R.; Kung, H.H. Characterization of CuO/ZnO under oxidizing conditions for the oxidative methanol reforming reaction. *J. Mol. Catal. A Chem.* 2000, *162*, 275–285.

114. Choi, Y.; Futagami, K.; Fujitani, T.; Nakamura, J. The role of ZnO in Cu/ZnO methanol synthesis catalysts—Morphology effect or active site model? *Appl. Catal. A Gen.* 2001, *208*, 163–167.

115. Jeong, S.H.; Park, B.N.; Lee, S.B.; Boo, J.-H. Structural and optical properties of silver-doped zinc oxide sputtered films. *Surf. Coat. Tech.* 2005, *193*, 340–344.
116. Cheong, K.Y.; Muti, N.; Ramanan, S.R. Electrical and optical studies of ZnO:Ga thin films fabricated via the sol–gel technique. *Thin Solid Films* **2002**, *410*, 142–146.

117. Lorenz, M.; Kaidashev, E.M.; von Wencernst, H.; Riede, V.; Bundesmann, C.; Spemann, D.; Benndorf, G.; Hochmuth, H.; Rahm, A.; Semmelhack, H.-C.; *et al*. Optical and electrical properties of epitaxial (Mg, Cd)\textsubscript{x}Zn\textsubscript{1−x}O, ZnO, and ZnO:(Ga, Al) thin films on c-plane sapphire grown by pulsed laser deposition. *Solid State Electron.* **2003**, *47*, 2205–2209.

118. Lee, J.-H.; Park, B.-O. Transparent conducting ZnO:Al, In and Sn thin films deposited by the sol–gel method. *Thin Solid Films* **2003**, *426*, 94–99.

119. Matsubara, K.; Fons, P.; Iwata, K.; Yamada, A.; Sakurai, K.; Tampo, H.; Niki, S. ZnO transparent conducting films deposited by pulsed laser deposition for solar cell applications. *Thin Solid Films* **2003**, *431*, 369–372.

120. Tominaga, K.; Takao, T.; Fukushima, A.; Moriga, T.; Nakabayashi, I. Film properties of ZnO:Al films deposited by co-sputtering of ZnO:Al and contaminated Zn targets with Co, Mn and Cr. *Vacuum* **2002**, *66*, 511–515.

121. Yamamoto, T. Codoping for the fabrication of p-type ZnO. *Thin Solid Films* **2002**, *420*, 100–106.

122. Wang, L.G.; Zunger, A. Cluster-doping approach for wide-gap semiconductors: The case of p-type ZnO. *Phys. Rev. Lett.* **2003**, *90*, 256401.

123. Grundmann, M.; Europas erste bipolare ZnO-Diode. *MaterialsNews*, 15th August 2006. Available online: www.materials-gate.de (accessed on 19 April 2012).

124. Pan, M.; Nause, J.; Rengarajan, V.; Rondon, R.; Park, E.H.; Ferguson, I.T. Epitaxial growth and characterization of p-type ZnO. *J. Electron. Mater.* **2007**, *36*, 457–461.

125. Yang, L.L.; Ye, Z.Z.; Zhu, L.P.; Zeng, Y.J.; Lu, Y.F.; Zhao, B.H. Fabrication of p-type ZnO thin films via DC reactive magnetron sputtering by using Na as the Dopant source. *J. Electron. Mater.* **2007**, *36*, 498–501.

126. Xue, S.-W.; Zu, X.-T.; Shao, L.-X.; Yuan, Z.-L.; Xiang, X.; Deng, H. Preparation of p-type ZnO:(Al, N) by a combination of sol-gel and ion-implantation techniques. *Chin. Phys.* **2008**, *B17*, 2240–2244.

127. Grundmann, M.; Lorenz, M. Erfolgreiche Phosphor-Dotierung von ZnO-Nanodrähten. Available online: http://www.uni-protokolle.de/nachrichten/id/146856 (accessed on 24 February 2009).

128. Jin, H.-J.; Song, M.-J.; Park, C.-B. A novel phenomenon: p-Type ZnO:Al films deposited on n-Si substrate. *Physica B* **2009**, *404*, 1097–1101.

129. Qiao, Z.H.; Agashe, C.; Mergel, D. Dielectric modeling of transmittance spectra of thin ZnO:Al films. *Thin Solid Films* **2006**, *496*, 520–525.

130. Lin, S.-S.; Huang, J.-L.; Šajgalik, P. The properties of heavily Al-doped ZnO films before and after annealing in the different atmospheres. *Surf. Coat. Tech.* **2004**, *185*, 254–263.

131. Oh, B.-Y.; Jeong, M.-C.; Kim, D.-S.; Lee, W.; Myoung, J.-M. Post-annealing of Al-doped ZnO films in hydrogen atmosphere. *J. Cryst. Growth* **2005**, *281*, 475–480.

132. Kuo, S.Y.; Chen, W.C.; Lai, F.-I; Cheng, C.P.; Kuo, H.C.; Wang, S.C.; Hsieh, W.H. Effects of doping concentration and annealing temperature on properties of highly-oriented Al-doped ZnO films. *J. Cryst. Growth* **2006**, *287*, 78–84.
133. Martínez, M.A.; Gutiérrez, M.T.; Maffiotte, C. Chemical changes of ITO/p and ZnO/p interfaces as a function of deposition parameters. *Surf. Coat. Tech.* 1998, 110, 68–72.

134. Kluth, O.; Rech, B.; Houben, L.; Wieder, S.; Schöpe, G.; Beneking, C.; Wagner, H.; Löfl, A.; Schock, H.W. Texture etched ZnO:Al coated glass substrates for silicon based thin film solar cells. *Thin Solid Films* 1999, 351, 247–253.

135. Klenk, R.; Linke, M.; Angermann, H.; Kelch, C.; Kirsch, M.; Klaer, J.; Köble, Ch. Die Stabilität von ZnO bei beschleunigter Alterung. In *Proceedings of FVS Workshop (Session III)*, Berlin, Germany, 2005.

136. Ibuki, S.; Yanagi, H.; Ueda, K.; Kawazoe, H.; Hosono, H. Preparation of n-type conductive transparent thin films of AgInO2:Sn with delafossite-type structure by pulsed laser deposition. *J. Appl. Phys.* 2000, 88, 3067: 1–3067: 3.

137. Otabe, T.; Ueda, K.; Kudoh, A.; Hosono, H.; Kawazoe, H. n-Type electrical conduction in transparent thin films of delafossite-type AgInO2. *Appl. Phys. Lett.* 1998, 72, 1036: 1–1036: 3.

138. Tate, J.; Jayaraj, M.K.; Draeseke, A.D.; Ulbrich, T.; Sleight, A.W.; Vanaja, K.A.; Nagarajan, R.; Wager, J.F.; Hoffman, R.L. p-Type oxides for use in transparent diodes. *Thin Solid Films* 2002, 411, 119–124.

139. Doumerc, J.-P.; Wichainchai, A.; Ammar, A.; Pouchard, M.; Hagenmuller, P. On magnetic properties of some oxides with delafossite-type structure. *Mater. Res. Bull.* 1986, 21, 745–752.

140. Nagarajan, R.; Uma, S.; Jayaraj, M.K.; Tate, J.; Sleight, A.W. New CuM2/3Sb1/3O2 and AgM2/3Sb1/3O2 compounds with the delafossite structure. *Solid. State Sci.* 2002, 4, 787–792.

141. Sheets, W.C.; Stampler, E.S.; Bertoni, M.I.; Sasaki, M.; Marks, T.J.; Mason, T.O.; Poeppelmeier, K.R. Silver Delafossite Oxides. *Inorg. Chem.* 2008, 47, 2696–2705.

142. Marquardt, M.A.; Ashmore, N.A.; Cann, D.P. Crystal chemistry and electrical properties of the delafossite structure. *Thin Solid Films* 2006, 496, 146–156.

143. Barnabé, A.; Mugnier, E.; Presmanes, L.; Tailhades, Ph. Preparation of delafossite CuFeO2 thin films by rf-sputtering on conventional glass substrate. *Mater. Lett.* 2006, 60, 3468–3470.

144. Mugnier, E.; Barnabé, A.; Presmanes, L.; Tailhades, Ph. Thin films preparation by rf-sputtering of copper/iron ceramic targets with Cu/Fe = 1: From nanocomposites to delafossite compounds. *Thin Solid Films* 2008, 516, 1453–1456.

145. Singh, M.; Mehta, B.R. Effect of structural anisotropy on electronic conduction in delafossite tin doped copper indium oxide thin films. *Appl. Phys. Lett.* 2008, 93, 192104: 1–192104: 3.

146. Götzendörfer, S.; Löbmann, P. Influence of single layer thickness on the performance of undoped and Mg-doped CuCrO2 thin films by sol–gel processing. *J. Sol-Gel Sci. Techn.* 2011, 57, 157–163.

147. Götzendörfer, S.; Bywalez, R.; Löbmann, P. Preparation of p-type conducting transparent CuCrO2 and CuAl0.5Cr0.5O2 thin films by sol–gel processing. *J. Sol-Gel Sci. Techn.* 2009, 52, 113–119.

148. Lim, S.H.; Desu, S.; Rastogi, A.C. Chemical spray pyrolysis deposition and characterization of p-type CuCr1–xMgxO2 transparent oxide semiconductor thin. *J. Phys. Chem. Sol.* 2008, 69, 2047–2056.

149. Götzendörfer, S.; Polenzky, C.; Ulrich, S.; Löbmann, P. Preparation of CuAlO2 and CuCrO2 thin films by sol–gel processing. *Thin Solid Films* 2009, 518, 1153–1156.
150. Mahapatra, S.; Shivashankar, S.A. Low-pressure metal–organic chemical vapor deposition of transparent and p-type conducting CuCrO$_2$ thin films with high conductivity. *Chem. Vapor Depos.* **2003**, *9*, 238–240.

151. Ginley, D.; Roy, B.; Ode, A.; Warmsingh, C.; Yoshida, Y.; Parilla, P.; Teplin, C.; Kaydanova, T.; Miedaner, A.; Curtis, C.; *et al.* Non-vacuum and PLD growth of next generation TCO materials. *Thin Solid Films* **2003**, *445*, 193–198.

152. Kudo, A.; Yanagi, H.; Hosono, H.; Kawazoe, H. SrCu$_2$O$_2$: A p-type conductive oxide with wide band gap. *Appl. Phys. Lett.* **1998**, *73*, 220–222.

153. Roy, B.; Perkins, J.D.; Kaydanova, T.; Young, D.L.; Taylor, M.; Miedaner, A.; Curtis, C.; Kleebe, H.-J.; Readey, D.W.; Ginley, D.S. Preparation and characterization of sol–gel derived copper–strontium–oxide thin films. *Thin Solid Films* **2008**, *516*, 4093–4101.

154. Bobeico, E.; Varsano, F.; Minalini, C.; Roca, F. P-type strontium–copper mixed oxide deposited by e-beam evaporation. *Thin Solid Films* **2003**, *444*, 70–74.

155. Park, S.; Keszler, D.A.; Valencia, M.M.; Hoffman, R.L.; Bender, J.P.; Wager, J.F. Transparent p-type conducting BaCu$_2$S$_2$ films. *Appl. Phys. Lett.* **2002**, *80*, 4393: 1–4393: 2.

156. Banerjee, A.N.; Chattopadhyay, K.K. Size-dependent optical properties of sputter-deposited nanocrystalline p-type transparent CuAlO$_2$ thin films. *J. Appl. Phys.* **2005**, *97*, 084308: 1–084308: 8.

157. Chen, H.Y.; Tsai, M.W. Delafossite-CuAlO$_2$ thin films prepared by thermal annealing. *J. Nano Res.* **2011**, *13*, 81–86.

158. Rima, J.Y.; Songa, S.A.; Parka, S.B. Preparation of copper aluminium oxide by spray pyrolysis. *Mater. Res. Soc. Symp. Proc.* **2002**, *703*, 255–258.

159. Sato, T.; Sue, K.; Tsumatorii, H.; Suzuki, M.; Tanaka, S.; Kawai-Nakamura, A.; Saitoh, K.; Aida, K.; Hiaki, T. Hydrothermal synthesis of CuAlO$_2$ with the delafossite structure in supercritical water. *J. Supercrit. Fluid.* **2008**, *46*, 173–177.

160. Scanlon, D.O.; Watson, G.W. Conductivity Limits in CuAlO$_2$ from Screened-Hybrid Density Functional Theory. *J. Phys. Chem. Lett.* **2010**, *1*, 3195–3199.

161. Stevens, B.L.; Hoe, C.A.; Swanborg, C.; Tang, Y.; Zhou, C.; Grayson, M.; Poeppelmeier, K.R.; Barnett, S.A. DC reactive magnetron sputtering, annealing, and characterization of CuAlO$_2$ thin films. *J. Vac. Sci. Technol. A* **2011**, *29*, 011018: 1–011018: 7.

162. Tsuboi, N.; Moriya, T.; Kobayashi, S.; Shimizu, H.; Kato, K.; Kaneko, F. Characterization of CuAlO$_2$ Thin Films Prepared on Sapphire Substrates by Reactive Sputtering and Annealing. *Jpn. J. Appl. Phys.* **2008**, *47*, 592–595.

163. Yanagi, H.; Hase, T.; Ibuki, S.; Ueda, K.; Hosono, H. Bipolarity in electrical conduction of transparent oxide semiconductor CuInO$_2$ with delafossite structure. *J. Appl. Phys.* **2000**, *88*, 4159: 1–4159: 3.

164. Chen, H.-Y.; Tsai, M.-W. Delafossite-CuAlO$_2$ films prepared by annealing of amorphous Cu-Al-O films at high temperature under controlled atmosphere. *Thin Solid Films* **2011**, *519*, 5966–5970.

165. Lu, Y.M.; He, Y.B.; Yang, B.; Polity, A.; Volbers, N.; Neumann, C.; Hasselkamp, D.; Meyer, B.K. RF reactive sputter deposition and characterization of transparent CuAlO$_2$ thin films. *Phys. Status. Solidi. C* **2006**, *3*, 2895–2898.
166. Pellicer-Porres, J.; Segura1, A.; Kim, D. Refractive index of the CuAlO2 delafossite. *Semicond. Sci. Technol.* **2009**, *24*, 015002.

167. Tsuboi, N.; Takahashi, Y.; Kobayashi, S.; Shimizu, H.; Kato, K.; Kaneko, F. Delafossite CuAlO2 films prepared by reactive sputtering using Cu and Al targets. *J. Phys. Chem. Solids* **2003**, *64*, 1671–1674.

168. Chavillon, B.; Cario, L.; Doussier-Brochard, C.; Srinivasan, R.; Le Pleux, L.; Pellegrin, Y.; Blart, E.; Odobel, F.; Jobic, S. Synthesis of light-coloured nanoparticles of wide band gap p-type semiconductors CuGaO2 and LaOCuS by low temperature hydro/solvothermal processes. *Phys. Status Solidi. A* **2010**, *207*, 1642–1646.

169. Ueda, K.; Hase, T.; Yanagi, H.; Kawazoe, H.; Hosono, H.; Ohta, H.; Orita, M.; Hirano. M. Epitaxial growth of transparent p-type conducting CuGaO2 thin films on sapphire (001) substrates by pulsed laser deposition. *J. Appl. Phys.* **2001**, *89*, 1790–1793.

170. Varandani, D.; Singh, B.; Mehta, B.R.; Singh, M.; Singh, V.N.; Gupta, D. Resistive switching mechanism in delafossite-transition metal oxide (CuInO2–CuO) bilayer structure. *J. Appl. Phys.* **2010**, *107*, 103703.

171. Duan, N.; Sleight, A.W.; Jayaraj, M. K.; Tate J. Transparent p-type conducting CuScO2+x films. *Appl. Phys. Lett.* **2000**, *77*, 1325–1328: 2.

172. Yanagi, H.; Park, S.; Draeseke, A.D.; Keszler, D.A.; Tate, J. p-Type conductivity in transparent oxides and sulfide fluorides. *J. Solid State Chem.* **2003**, *175*, 34–38.

173. Manoj, R.; Nisha, M.; Vanaja, K.A.; Jayaraj, M.K. Effect of oxygen intercalation on properties of sputtered CuYO2 for potential use as p-type transparent conducting films. *Bull. Mater. Sci.* **2008**, *31*, 49–53.

174. Jayaraj, M.K.; Draeseke, A.D.; Tatea, J.; Hoffmana, R.L. Wagera, J.F. Transparent p-n Heterojunction Thin Film Diodes. *Mater. Res. Soc. Symp. P* **2001**, *666*, F4.1.1–F4.1.9.

175. Isawa, K.; Yaegashi, Y.; Komatsu, M.; Nagano, M.; Sudo, S. Synthesis of delafossite-derived phases, R CuO2+δ with R = Y, La, Pr, Nd, Sm, and Eu, and observation of spin-gap-like behavior. *Phys. Rev. B* **1997**, *56*, 3457–3466.

176. Isawa, K.; Yaegashi, Y.; Ogota, S.; Nagano, M.; Sudo, S. Thermoelectric power of delafossite-derived compounds, R CuO2+δ (R = Y, La, Pr, Nd, Sm, and Eu). *Phys. Rev. B* **1998**, *57*, 7950–7954.

177. Attili, R.N.; Saxena, R.N.; Carbonari, A.W.; Filho, J.M. Delafossite oxides ABO2 (A = Ag, Cu; B = Al, Cr, Fe, In, Nd, Y) studied by perturbed-angular-correlation spectroscopy using a 111Ag(β-)111Cd probe. *Phys. Rev. B* **1998**, *58*, 2563–2569.

178. Okuda, T.; Beppu, Y.; Fujii, Y.; Onoe, T.; Terada, N.; Miyasaka, S. Specific heat of delafossite oxide CuCr1−xMgxO2 (0 ≤ x ≤ 0.03). *Phys. Rev. B* **2008**, *77*, 134423.

179. Shibasaki, S.; Kobayashi, W.; Terasaki, I. Transport properties of the delafossite Rh oxide Cu1−xAgxRh1−yMgyO2: Effect of Mg substitution on the resistivity and Hall coefficient. *Phys. Rev. B* **2006**, *74*, 235110.

180. Mugnier, E.; Barnabé, A.; Tailhades, P. Synthesis and characterization of CuFeO2+δ delafossite powders. *Solid State Ionics* **2006**, *177*, 607–612.

181. Ueda, K.; Inoue, S.; Hirose, S.; Kawazoe, H.; Hosono, H. Transparent p-type semiconductor: LaCuOS layered oxysulfide. *Appl. Phys. Lett.* **2000**, *77*, 2701: 1–2701: 3.
182. Wada, T.; Negami, T.; Nishitani, M. Preparation of CuInS₂ films by sulfurization of CuInO films. *Appl. Phys. Lett.* **1993**, *62*, 1943: 1–1943: 3.

183. Shannon, R.D.; Rogers, D.B.; Prewitt, C.T. Chemistry of noble metal oxides. I. Syntheses and properties of ABO₂ delafossite compounds. *Inorg. Chem.* **1971**, *10*, 713–718.

184. Sheets, W.C.; Mognier, E.; Barnabé, A.; Marks, T.J.; Poeppelmeier, K.R. Hydrothermal synthesis of delafossite-type oxides. *Chem. Mater.* **2006**, *18*, 7–20.

185. Wang, J.; Li, D.; Z.; Zhu, X.; Dong, W.; Fang X. Preparation of the delafossite structure p type transparent conducting oxide thin films by sol-gel process. *Prog. Chem.* **2009**, *21*, 128–133.

186. Singh, M.; Mehta, B.R. Effect of structural anisotropy on electronic conduction in delafossite tin doped copper indium oxide thin films. *Appl. Phys. Lett.* **2008**, *93*, 192104.

187. Teplin, C.W.; Kaydanova, T.; Young, D.L.; Perkins, J.D.; Ginley, D.S.; Ode, A.; Readey, D.W. A simple method for the preparation of transparent p-type Ca-doped CuInO₂ films: Pulsed-laser deposition from air-sintered Ca-doped Cu₂In₂O₅ targets. *Appl. Phys. Lett.* **2004**, *85*, 3789–3791.

188. Yanagi, H.; Hase, T.; Ibuki, S.; Ueda, K.; Hosono, H. Bipolarity in electrical conduction of transparent oxide semiconductor CuInO₂ with delafossite structure. *Appl. Phys. Lett.* **2001**, *78*, 1583: 1–1583: 3.

189. Nie, X.; Wei, S.-H.; Zhang, S. B. Bipolar Doping and Band-Gap Anomalies in Delafossite Transparent Conductive Oxides. *Phys. Rev. Lett.* **2002**, *88*, 066405.

190. Yanagi, H.; Ueda, K.; Ohta, H.; Orita, M.; Hirano, M.; Hosono, H. Fabrication of all oxide transparent p–n homojunction using bipolar CuInO₂ semiconducting oxide with delafossite structure. *Solid State Commun.* **2002**, *121*, 15–18.

191. Benko, F.A.; Koffyberg, F.P. Opto-electronic properties of p- and n-type delafossite, CuFeO₂. *J. Phys. Chem. Solids* **1987**, *48*, 431–434.

192. Pellicer-Porres, J.; Segura1, A.; Gilliland, A.S.; Muñoz, A.; Rodríguez-Hernández, P.; Kim, D.; Lee, M.S.; Kim, T.Y. On the band gap of CuAlO₂ delafossite. *Appl. Phys. Lett.* **2006**, *88*, 181904.

193. Buljan, A.; Alemany, P.; Ruiz, E. Electronic Structure and Bonding in CuMO₂ (M = Al, Ga, Y) Delafossite-Type Oxides: An Ab Initio Study. *J. Phys. Chem. B* **1999**, *103*, 8060–8066.

194. Katayama-Yoshida, H.; Koyanagi, T.; Funashima, H.; Harima, H.; Yanase, A. Engineering of nested Fermi surface and transparent conducting p-type Delafossite CuAlO₂: possible lattice instability or transparent superconductivity? *Solid State Commun.* **2003**, *126*, 135–139.

195. Koyanagi, T.; Harima, H.; Yanase, A.; Katayama-yoshida, H. Materials design of p-type transparent conducting oxides of delafossite CuAlO₂ by super-cell FLAPW method. *J. Phys. Chem. Solids* **2003**, *64*, 1443–1446.

196. Vidal, J.; Trani, F.; Bruneval, F.; Marques, M.A.L. Botti, S. Effects of Electronic and Lattice Polarization on the Band Structure of Delafossite Transparent Conductive Oxides. *Phys. Rev. Lett.* **2010**, *104*, 136401.

197. Jacob, A.; Parent, C.; Boutinaud, P.; Flem, G.L.; Doumerc, J.P.; Ammar, A.; Elazhari, M.; Elaatmani, M. Luminescent properties of delafossite-type oxides LaCuO₂ and YCuO₂. *Solid State Commun.* **1997**, *103*, 529–532.

198. Nagarajan, R.; Draeseke, A.D.; Sleight, A.W.; Tate, J. p-type conductivity in CuCrₓMgₓO₂ films and powders. *J. Appl. Phys.* **2001**, *89*, 8022–8025.
199. Nagarajan, R.; Duan, N.; Jayaraj, M.K.; Li, J.; Vanaja, K.A.; Yokochi, A.; Draeseke, A.; Tate, J.; Sleight, A.W. p-Type conductivity in the delafossite structure. *Int. J. Inorg. Mater.* **2001**, *3*, 265–270.

200. Lee, M.S.; Kim, T.Y.; Kim, D. Anisotropic electrical conductivity of delafossite-type CuAlO2 laminar crystal. *Appl. Phys. Lett.* **2001**, *79*, 2028: 1–2028: 3.

201. Marquardt, M.A.; Ashmore, N.A.; Cann, D.P. Crystal chemistry and electrical properties of the delafossite structure. *Thin Solid Films* **2006**, *496*, 146–156.

202. Li, J.; Sleight, A.W.; Jones, C.Y.; Toby, B.H. Trends in negative thermal expansion behavior for AMO2 (A = Cu or Ag; M = Al, Sc, In, or La) compounds with the delafossite structure. *J. Solid State Chem.* **2005**, *178*, 285–294.

203. Dakhel, A.A. Influence of dysprosium doping on the electrical and optical properties of CdO thin films. *Sol. Energy* **2009**, *83*, 934–939.

204. Coutts, T.J.; Young, D.L.; Li, X.; Mulligan, W.P.; Wu, X. Search for improved transparent conducting oxides: A fundamental investigation of CdO, Cd2SnO4, and Zn2SnO4. *J. Vac. Sci. Technol. A* **2000**, *18*, 2646–2660.

205. Dakhel, A.A. Influence of hydrogenation on the electrical and optical properties of CdO:Tl thin films. *Thin Solid Films* **2008**, *517*, 886–890.

206. Kim, S.; Seo, J.; Jang, H.W.; Bang, J.; Lee, W.; Lee, T.; Myoung, J.-M. Effects of H2 ambient annealing in fully 0 0 2-textured ZnO: Ga thin films grown on glass substrates using RF magnetron co-sputter deposition. *Appl. Surf. Sci.* **2009**, *255*, 4616–4622.

207. Kang, J.; Kim, H.W.; Lee, C. Electrical resistivity and transmittance properties of Al and Ga-codoped ZnO thin films. *J. Korean Phys. Soc.* **2010**, *56*, 576–579.

208. Hojo, M.; Okimura, K. Effect of Annealing with Ar Plasma Irradiation for Transparent Conductive Nb-Doped TiO2 Films on Glass Substrate. *Jpn. J. Appl. Phys.* **2009**, *48*, 08HK06: 1–08HK06: 6.

209. Wang, Y.; Brezesinski, T.; Antonietti, M.; Smarsly, B. Ordered mesoporous Sb-, Nb-, and Ta-doped SnO2 thin films with adjustable doping levels and high electrical conductivity. *ACS Nano* **2009**, *3*, 1373–1378.

210. Lin, Y.C.; Wang, B.L.; Yen, W.T.; Ha, C.T.; Peng, C. Effect of process conditions on the optoelectronic characteristics of ZnO:Mo thin films prepared by pulsed direct current magnetron sputtering. *Thin Solid Films* **2010**, *518*, 4928–4934.

211. Prathap, P.; Devi, G.G.; Subbaiah, Y.P.V.; Ganesan, V.; Reddy, K.T.R.; Yi, J. Preparation and characterization of sprayed In2O3:Mo films. *Phys. Status Solid. A* **2008**, *205*, 1947–1951.

212. Cattin, L.; Morsli, M.; Dahou, F.; Abe, S.Y.; Khelil, A.; Bernède, J.C. Investigation of low resistance transparent MoO3/Ag/MoO3 multilayer and application as anode in organic solar cells. *Thin Solid Films* **2010**, *518*, 4560–4563.

213. Wang, Y.; Li, H.; Ji, L.; Zhao, F.; Liu, X.; Kong, Q.; Wang, Y.; Quan, W.; Zhou, H.; Chen, J. The effect of duty cycle on the microstructure and properties of graphite-like amorphous carbon films prepared by unbalanced magnetron sputtering. *J. Phys. D Appl. Phys.* **2010**, *43*, 505401.

214. Wang, T.; Fang, Q.; Wu, M.; Sun, X.; Lu, F. Low temperature synthesis wide optical band gap Al and (Al, Na) co-doped ZnO thin films. *Appl. Surf. Sci.* **2011**, *257*, 2341–2345.
215. Kumar, S.R.S.; Malar, P.; Osipowicz, T.; Banerjee, S.S.; Kasiviswanathan, S. Ion beam studies on reactive DC sputtered manganese doped indium tin oxide thin films. *Nucl. Instrum. Meth. Phys. Res. B* **2008**, *266*, 1421–1424.

216. Gessert, T.; Yoshida, Y.; Fesenmaier, C.; Duenow, J.; Coutts, T. TCO thin films with permittivity control. Symposium on thin-film compound semiconductor photovoltaics. *Mater. Res. Soc.* **2009**, *1165*, 247–252.

217. Li, J.; Wang, X.; Shi, S.; Song, X.; Lv, J.; Cui, J.; Sun, Z. Optical and wetting properties of CuAlO$_2$ films prepared by radio frequency magnetron sputtering. *Proc. Asia Display* **2007**, 1799–1802.

218. Giurgola, S.; Rodriguez, A.; Martinez, L.; Vergani, P.; Lucchi, F.; Benchabane, S.; Pruneri, V. Ultra thin nickel transparent electrodes. *J. Mater. Sci.* **2009**, *20*, S181–S184.

© 2012 by the authors; licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution license (http://creativecommons.org/licenses/by/3.0/).