

# Study of Sol-Gel Chemical Process for the Creation of ZnO Thin Films

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## ABSTRACT

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ZnO-focused research goes back so several decades, when doped with transition metals, the renewed interest is fuelled by the availability of high quality substrates and reports of ferromagnetic and p-type conduction behaviour. For the ZnO nanomaterials synthesis, various techniques such as spray pyrolysis, sol-gel, wet chemical processes, thermal evaporation, etc are used. The interest growing in this material arose from the advancement of growing technologies for the manufacture of high-quality epitaxial layers and single crystal, which enable the realization of optoelectronic and nanoelectronic devices based on ZnO. This paper focus on study of Sol-Gel chemical process for the creation of ZNO thin films.

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## 1. Introduction

In 1965, Gordon Moore discovered that silicon transistors underwent a continuous downward scaling cycle, an observation that was further codified as Moore's law. Since its transistor observation the minimum size of the feature has fallen from 10 micrometers to 28-22 nm in 2011. The field of nanoelectronics aims to support this law to be continuously implemented through the use of new methods and materials to build electronic devices with feature sizes on the nanoscale.

The volume of an object reduces as its linear dimensions become the third power, its surface area just reduces as the second power drops. There are enormous ramifications to this rather subtle and inevitable principle. For example, the drill strength (or any other machine) is directly proportionate to the length, whereas the drill's bearings and gears are frictional to their surface area. The tool's power is sufficient for a standard-sized drill to handily resolve any frictions. For example, by scaling down its length by a factor of 1000, its power decreases by 1000<sup>3</sup> (a factor of one billion) while reducing friction by only 1000<sup>2</sup> (a factor of only one million). It has a power 1000 times less per unit of friction than the original drill. If, say, the original friction-to-power ratio was 1 percent, which implies the smaller drill would be 10 times as frictional as powerful; the drill is useless.

For this reason, while super-miniature electronically integrated circuits are fully functional, it is not possible to use the same technology to render functioning mechanical devices beyond the scales where frictional forces begin to surpass available power. So while you may see microphotographs of delicately engraved silicone gears, at current these instruments are nothing more than curiosities with minimal real-world uses, for example in rotating shutters and mirrors. Surface stress increases in almost the same way, so the tendency for very small objects to stay together is increased. This could theoretically render some sort of "small factory" impractical: although robotics hands and arms may be dropped, any of it those who pick up would seem to be hard to finish. Above it has resulted in functioning cilia, muscle fibers, flagella and rotary motors in aqueous ecosystems, all on the nanoscale. These devices take advantage of the higher friction force observed at micro or nanoscale level. Cilia produces motion from excessive

flip or laminar forces (frictional forces parallel to the surface) at micro and nano dimensions, but instead of a paddle or propeller that relies on ordinary frictional forces (friction force perpendicular to the surface) to achieve propulsion. The underlying forces must be considered for the construction of practical "machines" at the nanoscale. We are faced with the creation and design of machines that are intrinsically important, rather than simple macroscopic reproductions.

Therefore, all scaling issues need to be carefully analyzed when testing nanotechnology for realistic applications. Nanoelectronics holds the potential of making computer processors more efficient than traditional manufacturing methods for semiconductors would. A variety of methods are currently under study, along with modern approaches to nanolithography, including the use of nanomaterials such as nanowires or small molecules instead of conventional CMOS components. All semi-conductive carbon nanotubes and heterostructured semiconductor nanotubes (SiNWs) were used to make field effect transistors.

In 1999, at the Electronics and Information Technology Laboratory in Grenoble, France, the CMOS transistor checked the limit of 18 nm diameter MOSFET transistor concepts (about 70 atoms positioned side by side). That was almost one tenth of the smallest commercial transistor in 2003 (130 nm in 2003, 90 nm in 2004, 65 nm in 2005 and 45 nm in 2007).

In the past, electronic memory designs used to rely largely on transistor formation. Research into crossbar switch-based electronics has, however, offered an alternative, to build high-density memories, utilizing reconfigurable interconnections among horizontal and vertical cable arrays. Two pioneers in this field are Nantero who developed a carbon nanotube-based crossbar memory named Hewlett-Packard and Nano-RAM which proposed using memristor material as a future Flash memory replacement.

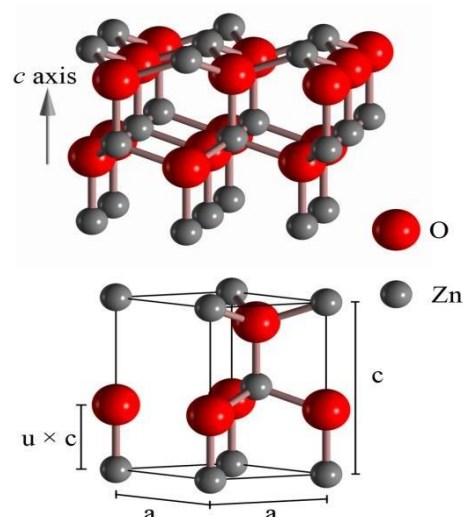
Spintronics is one such example of novel devices. Dependence of a material's resistance (because of the electrons spin) on an external field known as magnetoresistance. For nanosized objects, this effect can be significantly amplified (GMR-Giant Magneto-Resistance), for example when two ferromagnetic layers are spilted by a non-magnetic layer that is several nanometers thick (e.g. Co-Cu-Co

.The GMR effect has contributed to a dramatic rise in the density of hard disk data storage and made the number of gigabytes possible. The so-called tunneling magnetoresistance (TMR) is much related to GMR and is based on the spin-dependent electron tunneling via adjacent ferromagnetic layers. Both TMR and GMR effects, including so-called magnetic random-access memory, can be used to construct a non-volatile main memory.

Nanoscale electronic device development has recent times become one of emerging research areas in the physical sciences. Enlargement of the surface without raising the product dimension results in more efficient devices based on surface-controlled phenomena that increase the surface area to volume ratio alters the thermal, mechanical and catalytic properties of materials. Growth of the zinc oxide nanostructure is currently under heavy research. Among all the materials known the substance is likely to have the Nanostructures of the greatest variety (and their related properties). The hexagonal lattice can easily match catalyst lattice structure and promote regulated growth patterns. Positive zinc and negative oxygen surfaces create electric dipoles which promote the growth of polarization in some directions and planes under temperature and applied voltage. For the ZnO nanomaterials synthesis, various techniques such as spray pyrolysis, sol-gel, wet chemical processes, thermal evaporation, etc are used. The interest growing in this material arose from the advancement of growing technologies for the manufacture of high-quality epitaxial layers and single crystal, which enable the realization of optoelectronic and nanoelectronic devices based on ZnO. The integration of optical and magnetic properties offers significant applications for the composite materials in biomedical fields such as bioseparation, drug targeting and diagnostic analysis. Comparison to other semiconductor materials, ZnO has a wide band gap, abundance in nature, lack of toxicity and higher exciton binding energy (60 meV), is more radiation resistant, and is multifunctional with use in the areas as piezoelectric, ferroelectric and ferromagnetic. The incorporation on a single chip is also encouraging for ZnO-based semiconductors and nanomaterial devices. It is a low-cost, n-type semiconductor [Chopra *et al.*, 1983].

## 2. Importance of ZnO

A multifunctional material is Nanostructured zinc oxide (ZnO) which can be produced as ferromagnetic, piezoelectric, and transparent and performed by proper doping or alloy. Because of their Wide range of practical applications in photonic crystals, the semiconductor ZnO has gained considerable interest in the research in this field [Scharrer *et al.*, 2005], varistor [Leite *et al.*, 1992], photodetectors [Nidhal. N. Jandow *et al.*, 2010], surface acoustic devices [Wen-Ching Shih *et al.*, 2010], sensors [Oleg Lupan *et al.*, 2008] and solar-cells [Alex B. F. Martinson *et al.*, 2007]. In addition, electro-optical devices such as diode lasers and light emitting diodes(LED) are very essential for low-voltage and short wavelengths. Zinc oxide (ZnO) is a electrical optic, piezoelectric and a semiconductor with a 3.37 eV bandwidth gap[Atul Gupta *et al.*, 2006]. ZnO's most special property is its high binding exciton capacity (60 meV) [Vladimir A *et al.*, 2004] which is much greater than that of ZnS (36meV) [Urbaszek *et al.*2001], GaN (24.7meV) [Martínez-Criado *et al.*, 2001] and ZnSe (21meV) [Zhu *et al.* 2011].



**Fig 1 Top:** A part of a wurtzite ZnO crystal lattice. **Bottom:** The parameters of the unit cell lattice for the ZnO wurtzite.

This higher binding exciton energy could tend to lead to lasting action based on a recombination of excitons which is above room temperature. ZnO holds a hexagonal crystal structure (wurtzite) including lattice parameters 'a' and 'c' in a ratio of  $c/a = 1.633$  [Fouzri *et al.*, 2011]. The Zn atoms are coupled tetrahedrally to four O atoms, in which the Zn s-electrons hybridize towards the O p-electrons.

ZnO crystallizes at ambient pressure and temperature in wurtzite structure, as shown in Fig 1. This has a hexagonal lattice and is comprised of two interconnecting  $Zn^{2+}$  and  $O^{2-}$  sublattices, like each Zn ion is accompanied by oxygen tetrahedron and vice versa.

Zinc oxide (ZnO) is one of the most potential materials for the next generation of UV optoelectronic devices and TCO optical or display devices. The transmission of light in the visible region suggests the wide band gap features of the transparent conducting materials which make them appropriate for use in various types of optoelectronic devices. One of the TCOs is zinc oxide (ZnO). Because of high optical transmittance and electrical conductivity, such films are helpful in conversion of LEDs and solar energy. Doped zinc oxide films, deposited using different techniques, show high transmittance in the visible region, high reflectivity in the IR region and moderately better metallic conductivity [Rozati, 2006]. The LED's emit mostly in light range blue and UV. Inherently n-type ZnO and various semiconductors of the p-type allow the manufacture of light emitting p – n heterojunctions. Gallium nitride (GaN) in particular is regarded to be one of the more appropriate semiconductors for the construction of LED heterojunctions due to its compatibility with ZnO in the lattice parameter and lattice structure [Hong *et al.*, 2001]. As a result, both ZnO / GaN heterostructures and LED systems have been investigated for sensing [Jha *et al.*, 2010]. Simple nano-manufacturing processes and superior properties, particularly primarily high crystalline nanomaterial consistency, large band gap and lasting effect, make ZnO a suitable nano-optoelectronic material and short wavelength applications [Huang *et al.*, 2002, Wang *et al.*, 2004]. Theoretically, and experimentally proven [Pan *et al.*, 2007] [He *et al.*, 2008, Stephen J. Pearton *et al.* That zinc oxide is a high curie temperature (TC) distilled magnetic semiconducting material (DMS) even when doped with transition metals (TM) or rare earth metals. All of those zinc oxide

properties can be obtained by doping, which manipulates ZnO's behaviour.

The thin films of pure ZnO are typically n-type semiconductors that have the electrical conductivity due to either the oxygen vacancy or interstitial Zn that occurs at ZnO lattice locations. The energy level of the intrinsic defects is around 0.05 eV down the conduction band.

### 3. Benefits of Sol-Gel Process

ZnO films are strongly dependent on their physical properties on deposition methods. Different methods have been used to accumulate high-quality ZnO thin films and nanoparticulated films such as dc sputtering [r.f [Xu et al., 2010 or Czernastek, 2004] ], chemical vapor deposition (CVD) [Stefan Lautenschlaeger *et al.*, 2009], pulsed laser deposition (PLD) [Suchea *et al.*, 2005], spray pyrolysis [Erki Kärber *et al.*, 2011], thermal evaporation [Calestani *et al.*, 2011], and molecular beam epitaxy (MBE) [Heo *et al.*, 2003]. Another chemical process for the creation of ZnO thin films is sol-gel, which is commonly used in the ZnO nano crystals synthesis. The sol-gel method [Mingsong Wang et al., 2008] is simple, cheap in manufacturing, producing a large sample size, simpler composition control and accurately measured high solubility, mole ratio, lower processing temperature, better homogeneity, and has a general advantage for wide area film thickness and film deposition. In fact, dopants are simpler to integrate in this technique.

Sol-gel processing offers many benefits. Quite pure products are produced by either crystallization, distillation or electrolysis simply purifying the precursors [Alain C.Pierre, 1998]. In addition, from the first steps, the chemical processes are always conducted at low temperatures.. This significantly minimizes the chemical interactions between both the material and the container walls as compared to conventional high-temperature synthesis of conventional ceramics. The sol-gel processing has many, more key benefits. The kinetics of the different chemical reactions, for example, can be easily

controlled by the low processing temperatures and by the often-diluted conditions. Nucleation may also be controlled and growth of the main colloidal particles to deliver particles with a given distribution of size, shape and size. Sol-gel processing provides the more significant benefits for a mixed oxide method in which the homogeneity of chemical of different elements can be regulated down to the atomic level.

### 4. Conclusion

Sol-gel method preparations are suitable for exploratory studies for which a huge number of candidate materials, compositions, or preparatory conditions are required. Normally alcoholic solvents such as methoxyethanol or propanol / ethanol [Yuonesi et al., 2008, Anubha Jain et al., 2006] are often used in the preparation of doped and undoped c-axis oriented ZnO in a simplified way to solve. These solvents perform the role of reagents and never participate in the reaction from zinc acetate that forms ZnO. The existence of a permanent dipole moment is also the explanation for a strong relative dielectric constant. Such molecules have good ionizing properties and are able to dissolve other polar solutions. So, the solvents above are used [Alain C.Pierre, 1998]. To increase the solubility of zinc acetate in alcohols, the heating cycle is applied when the mixture is stirred from around 40 to 100 C [Srinivasan et al., 2007]. Ingredients such as mono, di, or triethanolamine are used to enhance the efficacy and solution homogeneity, preventing uncontrolled hydrolysis and ZnO precipitation.

In study using basic technique of sol gel spin coating, thin films of doped and undoped ZnO are of significance. ZnO is a semiconductor of n-type; its physical properties including structural, optical and magnetic properties can be modified by doping cationically or anionically. To utilize the undoped and doped ZnO for different spintronic and electrooptical applications, its properties of structural, magnetic and optical must also be thoroughly and appropriately studied.

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