METAL BASED THIN FILMS FOR ELECTRONICS pdf

1: Conference Program and Schedule â€“ International Thin-Film Transistor Conference

This up-to-date handbook covers the main topics of preparation, characterization and properties of complex metal-based layer systems. The authors -- an outstanding group of researchers -- discuss advanced methods for structure, chemical and electronic state characterization with reference to the.

Flexible and transparent electronics have been studied intensively during the last few decades. The technique establishes the possibility of fabricating innovative products, from flexible displays to radio-frequency identification tags. Typically, large-area polymeric substrates such as polypropylene PP or polyethylene terephthalate PET are used, which produces new requirements for the integration processes. A key element for flexible and transparent electronics is the thin-film transistor TFT , as it is responsible for the driving current in memory cells, digital circuits or organic light-emitting devices OLEDs. In this paper, we discuss some fundamental concepts of TFT technology. Additionally, we present a comparison between the use of the semiconducting organic small-molecule pentacene and inorganic nanoparticle semiconductors in order to integrate TFTs suitable for flexible electronics. Moreover, a technique for integration with a submicron resolution suitable for glass and foil substrates is presented. Introduction Nowadays, transparent and flexible electronics are one of the technologies with the widest range for innovative products, so they are the focus of several research groups and enterprises. One reason for this interest is the chance to integrate identification tags, smart cards or flexible displays using almost the same integration processes. Moreover, the cost of these devices is kept low due to the innovative use of newly created or adapted processes for large-area and flexible substrates. Thin-film transistors TFT are an essential element of this technology. They are responsible for the driving current in memory cells, digital circuits or for light-emitting diodes LEDs. Another characteristic of this technology is the opportunity to introduce new materials, which improve the electrical performance, simplify the integration process or even add new mechanical properties to the final product. Organic and inorganic semiconductors have been used to integrate TFTs for more than 20 years [1 , 2]. They exhibit better characteristics in comparison to amorphous silicon-based transistors due to the achieved performance and low production cost. Nevertheless, when pursuing a cost-efficient production with a high reliability and restrained mechanical characteristics, there are new requirements. Most of them are related to the fact that flexible substrates can only be handled at low temperatures, due to their flexibility, i. For instance, the use of non-malleable metal connections or dielectrics may induce a failure after bending the substrate. For this sake, all components materials and integration processes have to be selected carefully to fulfill these requirements. In this review paper, we concisely address the fundamental concept, electrical analysis and limitations of the flexible electronic technology. Additionally, we present a comparison between organic and inorganic based TFTs, as well as an integration routine in order to fabricate submicron structures on foil at reduced costs. Thin-Film Transistor Fundamentals Thin-film transistors basically consist of three elements: As a voltage is applied to the gate electrode, the majority charge carriers are attracted by the electric field and form a conducting channel accumulation mode. In general, the electrical connections consist of thermally evaporated or sputtered metal layers. Considering the metal-semiconductor interface, a Schottky barrier will be formed Figure 1 , which has poor blocking properties in comparison to a pn-junction. As a voltage is applied between drain and source contacts, an off-current occurs due to the tunneling of charge carriers across the formed potential barrier Figure 1 b. The potential barrier width can be reduced by applying a voltage to the gate electrode and, as a result, the drain current increases Figure 1 c. Band diagram of the Schottky contacts to an n-type semiconductor with metal contacts: Reprinted, with permission, from [3]. Integration As discussed above, the three elements, i. The arrangement of these elements has a strong influence on both the device performance and the integration process itself. The devices are divided into two main groups, the staggered and the coplanar setup. The position of the gate electrode is also used to classify the setups as either bottom-gate Figure 2 a,b or top-gate devices Figure 2 c,d. Usually, bottom-gate devices are referred as an inverted structure. General thin-film transistor configurations: The contact resistances between the metal drain and source electrodes and the semiconductor reduce the maximum current that will flow through the device in the on-state. Nevertheless, as a Schottky barrier is formed at those contacts, the contact resistance during the transistor off-state should be high enough to prevent a high leakage current. For staggered structures, a major contribution to the contact resistance is related to access resistance. In the case of coplanar setups, the drain and source electrodes are already in contact with the formed accumulation layer, which results in a low access resistance. Moreover, the integration process has to be adapted for the different setups. The inverted coplanar layout permits the semiconducting layer to be deposited in the last step. For this reason, the semiconducting film will not suffer from chemical impacts and other integration process steps. For other layouts, the semiconductor has to withstand different processes, as for example lithography, etching or annealing steps. Deposition methods for metals, dielectrics, semiconductors and all materials used in the integration process should be also entirely suitable for flexible electronics. However, there are variations, either in the quality of the material, temperature or production costs. For the deposition of the semiconductor, commonly vacuum techniques produce a denser film with higher charge carrier mobilities [6 , 7]. During the last few decades, pentacene seems to be the most promising candidate for organic semiconductor applications. Furthermore, deposition under low vacuum conditions assisted by an inert gas stream is possible [8]. Nowadays, new materials promising good environmental stability and higher mobilities have been synthesized. Various research groups focus on materials such as dinaphtho 2,3-b: For inorganic semiconducting films, the highest mobilities and denser films are commonly achieved using sputtering techniques [2 , 18]. In , Hoffman et al. Using RF magnetron sputtering, Fortunato et al. The transistor performance can be further improved by using a GIZO target [24] or co-sputtering techniques [25]. Additionally, adjusting the pressure in the chamber and the power during the process, the defect concentration as well as the film density can be controlled [26 , 27]. When oxygen is added, a reactive process occurs and the amount of oxygen in the film can be adjusted [28 , 29]. Atomic layer deposition ALD is another method to achieve high-density layers as demonstrated by [30 , 31]. Nevertheless, these films are deposited under vacuum conditions, increasing the production cost. Conjointly, when large area substrates are used, the equipment size will limit the template size. For this reason, methods using solutions have greater potential to fulfill the requirements imposed for large-area and flexible substrates. They can be divided into two main groups, i. For molecular precursors, the temperature in which the semiconductor film will be synthesized depends on the type of precursor [32]. Commonly nitrate precursors require lower annealing temperatures than acetate or chloride precursors, and greater performance is achieved [33]. In the case of nanoparticle suspensions, the semiconductor is already synthesized in the form of nanoparticles being dispersed in a solution, either water or other solvents, like ethanol, isopropanol and buthyl acetate. That means it is possible to fabricate high-quality nanoparticles in mass production, using high temperature and vacuum processes. It maintains an attractive cost base and has almost no influence on the transistor integration process. After the nanoparticle deposition, an annealing process removes the solvent [34 , 35 , 36]. One of the main advantages of using a solution based process is the variety in coating methods. Most of the literature refers to spin-coating methods; however, methods like inkjet printing, spray coating, doctor blade and Meyer rods have attracted the interest of research groups, due to the opportunity to integrate low-cost devices on large area and flexible substrates either using organic or inorganic semiconductors [17 , 37 , 38 , 39 , 40]. Submicron Structures Suitable for Foil Substrates To investigate and integrate thin-film transistors at submicron scales, a suitable process is required. In general, nanostructures are established using expensive equipment, like high-resolution lithography [41] or electron beam lithography [42]. Nonetheless, these methods are not entirely suitable for large area and flexible substrates. The side-wall deposition and etch-back SWEB technique is a cheap method to fabricate nanostructures applying only conventional lithography. The SWEB technique can be used to integrate nanoscaled field-effect transistors in bulk silicon. Figure 3 depicts the schematic integration process of this method on silicon. The main advantage of the SWEB technique is that the transistor size is not defined by the lithography itself, but by the deposition of a sacrificial layer in combination with an etching process. After the thermal oxidation of the wafer or the deposition of SiO_2 by plasma-enhanced chemical vapor deposition PECVD , the position of the nanostructure is defined by a standard photolithography step and a subsequent anisotropic etching Figure 3 aâ€”c. As a result, a rectangular edge, perpendicular to the wafer surface, is formed in the oxide film. Subsequently, the Si_3N_4 is etched back by a directional dry etching process. After removing of SiO_2 by selective wet etching, a Si_3N_4 spacer stays on the surface, as shown in Figure 3 d,e. As the structure size is defined by the thickness of the deposited silicon nitride film, it is possible to achieve nanostructures using standard lithography. Applying the spacers as a mask, the structure can be transferred to the underneath layer Figure 3 f. Additional information and discussion about this technique can be found in [43]. Schematic process of the side wall deposition and etch-back technique. Reprinted, with permission, from [43]. In the MOSFET technology, the creation of a nanoline acting as the gate electrode is sufficient as the source and drain contact areas are defined subsequent to the ion implantation. In contrast, to integrate nanoscaled TFTs on glass and flexible substrates an additional step is required to define the channel length of the transistor by a nanogap. Figure 5 shows the adaptation of the SWEB technique to avail the process to flexible substrates. First, the position of the structure is defined by conventional photolithography, where the sacrificial layer is the photoresist itself Figure 5 a. After the photoresist removal, the nanostructure nanoline stays back Figure 5 d. In order to achieve a nanogap from a nanoline, a metal is evaporated anisotropically Figure 5 e. Nevertheless, when the technique is performed over the gate dielectric, the anisotropic etching of the PECVD-SiO_2 can damage the dielectric layer, if the etching time is not defined carefully. Process flow for integrating nanoscaled gaps on glass or foils.

2: Metal Based Thin Films for Electronics - [PDF Document]

Metal Based Thin Films for Electronics 2nd Edition by Klaus Wetzig (Editor), Claus M. Schneider (Editor) Be the first to review this item.

Above this level, the conduction type in the material switches from semiconductor to metallic. Polymer photovoltaic cell using transparent conducting polymers. Conductive polymers were reported in the mid the 20th century as derivatives of polyaniline. By manipulating the band structure, polythiophenes have been modified to achieve a HOMO-LUMO separation bandgap that is large enough to make them transparent to visible light. Applications[edit] Transparent conductive polymers are used as electrodes on light emitting diodes and photovoltaic devices. However, because transparent conductive polymers do absorb some of the visible spectrum and significant amounts of the mid to near IR, they lower the efficiency of photovoltaic devices. This makes them useful in the development of flexible electronics where traditional transparent conductors will fail. Substituents can also be electron-accepting or donating which will modify the electronic character and thus modify the bandgap. This allows for the formation of a wide bandgap conductor which is transparent to the visible spectrum. The oxidizing agent acts as an initiator for polymerization. PSS compound has become the industry leader in transparent conductive polymers. PSS is water-soluble, making processing easier. This aqueous solution is then spin coated and dried to make a film. When doped with iodine, a conductivity of 0. However, the iodine has a tendency to diffuse out in air, making the iodine-doped poly 4,4-dioctyl cyclopentadithiophene unstable. However, DDQ-doped poly 4,4-dioctyl cyclopentadithiophene also tends to decrease its conductivity in air. PSS, which need to be improved for realistic applications. Poly 4,4-dioctyl cyclopentadithiophene is solution polymerized by combining monomer with iron III chloride. Once the polymerization is complete the doping is done by exposing the polymer to iodine vapor or DDQ solution. However, these thin films are usually fragile and such problems as lattice mismatch and stress-strain constraints lead to restrictions in possible uses for TCFs. ITO has been shown to degrade with time when subject to mechanical stresses. Recent increases in cost are also forcing many to look to carbon nanotube films as a potential alternative. Preparation of CNT thin films[edit] Figure 3. CNTs of various diameters separated within a centrifuge tube. Each distinct diameter results in a different color. Nanotubes can be grown using laser ablation , electric-arc discharge, or different forms of chemical vapor deposition such as PECVD. However, nanotubes are grown en-masse, with nanotubes of different chiralities stuck together due to van der Waals attraction. Density gradient ultracentrifugation DGU has recently been used to get rid of this problem. Because DGU allows for separation by density, tubes with similar optical properties due to similar diameters were selected and used to make CNT conductive films of different colors. In order to separate the grown tubes, the CNTs are mixed with surfactant and water and sonicated until satisfactory separation occurs. This solution is then sprayed onto the desired substrate in order to create a CNT thin film. The film is then rinsed in water in order to get rid of excess surfactant. Due to the ultrasonic vibration of the nozzle itself, this method also provides an additional level of sonification during the spray process for added separation of agglomerated CNTs. PV devices made with these TCOs attained energy-conversion efficiencies of These photovoltaic devices had much higher efficiencies compared to the devices made with CNT thin films: This paves the way for new applications, indicating that CNT thin films can be used as heat dissipaters in solar cells because of this high transmittance. As stated previously, nanotube chirality is important in helping determine its potential aid to these devices. Before mass production can occur, more research is needed in exploring the significance of tube diameter and chirality for transparent conducting films in photovoltaic applications. Ordering these tubes should also increase conductivity, as it will minimise scattering losses and improve contact between the nanotubes. Conducting nanowire networks and metal mesh as flexible transparent electrodes[edit] Figure 4. Schematic of metal network based Transparent Conducting Electrodes. Electrical transport is through the percolating metal network, while optical transmittance is through the voids. Randomly conducting networks of wires or metal meshes obtained from templates are new generation transparent electrodes. In these electrodes, nanowire or metal mesh network is charge collector, while the voids between them are transparent to light.

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These are obtained from the deposition of silver or copper nanowires, or by depositing metals in templates such as hierarchical patterns of random cracks, leaves venation and grain boundaries etc. These metal networks can be made on flexible substrates and can act as flexible transparent electrodes. For better performance of these conducting network based electrodes, optimised density of nanowires has to be used as excess density, leads to shadowing losses in solar cells, while the lower density of the wires, leads to higher sheet resistance and more recombination losses of charge carriers generated in solar cells. S; Hu; Irvin, G. Semiconductor Science and Technology.

3: Thin films of a lead-free piezoelectric finally match the performance of the lead-bearing standard

The microstructure and the magnetic and magnetotransport properties have been investigated depending on the types of the magnetic and nonmagnetic materials, composition, nanostructure, and regimes.

Deposition[edit] The act of applying a thin film to a surface is thin-film deposition â€" any technique for depositing a thin film of material onto a substrate or onto previously deposited layers. Molecular beam epitaxy , Langmuir-Blodgett method and atomic layer deposition allow a single layer of atoms or molecules to be deposited at a time. It is useful in the manufacture of optics for reflective , anti-reflective coatings or self-cleaning glass , for instance , electronics layers of insulators , semiconductors , and conductors form integrated circuits , packaging i. Similar processes are sometimes used where thickness is not important: Deposition techniques fall into two broad categories, depending on whether the process is primarily chemical or physical. An everyday example is the formation of soot on a cool object when it is placed inside a flame. Since the fluid surrounds the solid object, deposition happens on every surface, with little regard to direction; thin films from chemical deposition techniques tend to be conformal , rather than directional. Chemical deposition is further categorized by the phase of the precursor: Plating relies on liquid precursors, often a solution of water with a salt of the metal to be deposited. Some plating processes are driven entirely by reagents in the solution usually for noble metals , but by far the most commercially important process is electroplating. It was not commonly used in semiconductor processing for many years, but has seen a resurgence with more widespread use of chemical-mechanical polishing techniques. Chemical solution deposition CSD or chemical bath deposition CBD uses a liquid precursor, usually a solution of organometallic powders dissolved in an organic solvent. This is a relatively inexpensive, simple thin-film process that produces stoichiometrically accurate crystalline phases. Langmuir-Blodgett method uses molecules floating on top of an aqueous subphase. The packing density of molecules is controlled, and the packed monolayer is transferred on a solid substrate by controlled withdrawal of the solid substrate from the subphase. This allows creating thin films of various molecules such as nanoparticles, polymers and lipids with controlled particle packing density and layer thickness. The speed at which the solution is spun and the viscosity of the sol determine the ultimate thickness of the deposited film. Repeated depositions can be carried out to increase the thickness of films as desired. Thermal treatment is often carried out in order to crystallize the amorphous spin coated film. Such crystalline films can exhibit certain preferred orientations after crystallization on single crystal substrates. There are two evaporation regimes: Commercial techniques often use very low pressures of precursor gas. Unlike the soot example above, commercial PECVD relies on electromagnetic means electric current, microwave excitation , rather than a chemical-reaction, to produce a plasma. Atomic layer deposition ALD uses gaseous precursor to deposit conformal thin films one layer at a time. The process is split up into two half reactions, run in sequence and repeated for each layer, in order to ensure total layer saturation before beginning the next layer. Therefore, one reactant is deposited first, and then the second reactant is deposited, during which a chemical reaction occurs on the substrate, forming the desired composition. Physical deposition[edit] Physical deposition uses mechanical, electromechanical or thermodynamic means to produce a thin film of solid. An everyday example is the formation of frost. Since most engineering materials are held together by relatively high energies, and chemical reactions are not used to store these energies, commercial physical deposition systems tend to require a low-pressure vapor environment to function properly; most can be classified as physical vapor deposition PVD. The material to be deposited is placed in an energetic , entropic environment, so that particles of material escape its surface. Facing this source is a cooler surface which draws energy from these particles as they arrive, allowing them to form a solid layer. The whole system is kept in a vacuum deposition chamber, to allow the particles to travel as freely as possible. Since particles tend to follow a straight path, films deposited by physical means are commonly directional, rather than conformal. Examples of physical deposition include: A thermal evaporator that uses an electric resistance heater to melt the material and raise its vapor pressure to a useful range. This is done in a high vacuum, both to allow the vapor to reach the substrate without reacting with or scattering against other gas-phase atoms in the chamber, and reduce the incorporation of impurities from the residual gas in the vacuum chamber. Obviously, only materials with a much higher vapor pressure than the heating element can be deposited without contamination of the film. Molecular beam epitaxy is a particularly sophisticated form of thermal evaporation. An electron beam evaporator fires a high-energy beam from an electron gun to boil a small spot of material; since the heating is not uniform, lower vapor pressure materials can be deposited. Typical deposition rates for electron beam evaporation range from 1 to 10 nanometres per second. In molecular beam epitaxy MBE , slow streams of an element can be directed at the substrate, so that material deposits one atomic layer at a time. Compounds such as gallium arsenide are usually deposited by repeatedly applying a layer of one element i. The beam of material can be generated by either physical means that is, by a furnace or by a chemical reaction chemical beam epitaxy. Sputtering relies on a plasma usually a noble gas , such as argon to knock material from a "target" a few atoms at a time. The target can be kept at a relatively low temperature, since the process is not one of evaporation, making this one of the most flexible deposition techniques. It is especially useful for compounds or mixtures, where different components would otherwise tend to evaporate at different rates. It is also widely used in the optical media. It is a fast technique and also it provides a good thickness control. Presently, nitrogen and oxygen gases are also being used in sputtering. Pulsed laser deposition systems work by an ablation process. Pulses of focused laser light vaporize the surface of the target material and convert it to plasma; this plasma usually reverts to a gas before it reaches the substrate. If a reactive gas is introduced during the evaporation process, dissociation , ionization and excitation can occur during interaction with the ion flux and a compound film will be deposited. Electrohydrodynamic deposition electrospray deposition is a relatively new process of thin-film deposition. The liquid to be deposited, either in the form of nanoparticle solution or simply a solution, is fed to a small capillary nozzle usually metallic which is connected to a high voltage. The substrate on which the film has to be deposited is connected to ground. Through the influence of electric field, the liquid coming out of the nozzle takes a conical shape Taylor cone and at the apex of the cone a thin jet emanates which disintegrates into very fine and small positively charged droplets under the influence of Rayleigh charge limit. The droplets keep getting smaller and smaller and ultimately get deposited on the substrate as a uniform thin layer.

4: Transparent conducting film - Wikipedia

This up-to-date handbook covers the main topics of preparation, characterization and properties of complex metal-based layer systems. The authors -- an outstanding group of researchers -- discuss advanced methods for structure, chemical and electronic state characterization with reference to the properties of thin functional layers, such as metallization and barrier layers for microelectronics.

5: Thin film - Wikipedia

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