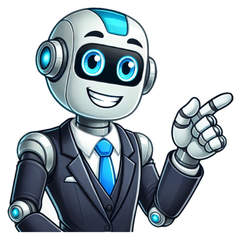
I'm not a robot



The bulk material is loaded into the basket. The amount depends on the shape of the parts and the bulk density of the component determines the capacity in the basket. Then the basket is immersed in the dip tank. The paint wets the entire surface of the parts. A mechanical movement by slowly rotating the basket improves the wetting process by removing bubbles and changing the contact surfaces. After the dipping process, the basket is lifted out of the dipping bath and quickly turned or centrifuged, so that the coated parts are thrown against the outer wall of the basket. The centrifugal force drips the excess paint through the holes of the basket back into the dip tank. The process of dip-spinning is influenced by several parameters. The most important are: immersion time, basket size, spin speed, spin time and load, and viscosity of the paint. There are also other parameters that affect this process. These depend on the coating technique, such as pivoting the spinner unit and / or directional change, which can lead to quality improvement. Share copy and redistribute the material in any medium or format for any purpose, even commercially. Adapt remix, transform, and build upon the material for any purpose, even commercially. The licensor cannot revoke these freedoms as long as you follow the license terms. Attribution You must give appropriate credit , provide a link to the license, and indicate if changes were made . You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use. ShareAlike If you remix, transform, or build upon the material, you must distribute your contributions under the same license as the original. No additional restrictions You may not apply legal terms or technological measures that legally restrict others from doing anything the license permits. You do not have to comply with the license for elements of the material in the public domain or where your use is permitted by an applicable exception or limitation . No warranties are given. The license may not give you all of the permissions necessary for your intended use. For example, other rights such as publicity, privacy, or moral rights may limit how you use the material. After a surface preparation adapted to the parts to be coated, these are immersed in a bath containing a liquid paint. They are then centrifugated at high speed in order to leave on their surface only a thin and homogeneous wet film of paint. The applied layer is thin and uniform. This film is then dried and then polymerized at low temperature.A second coating is usually applied afterwards as required. The parts are therefore cooled so that a new layer is produced. As a result, this process allows the production of multifunctional coatings by stacking layers of different materials.Polymerization at low temperature: below 250COver 100 coatings availableRates of up to 2 tons of coated parts per hourWe specialize in the application of industrial coatings for a wide range of industries and products. One popular selection for companies that manufacture parts is dip-spin coating. This method quickly and efficiently applies a durable coating to parts of many sizes, helping your parts to last longer in many types of environments.Keep reading our complete guide to discover more about dip-spin coating. Were happy to help in any way we can.What Is Dip-Spin Coating?Dip-spin coating refers to an industrial process that applies coatings evenly on objects, especially those with complex geometries that arent easily coated otherwise. The goal is to coat every surface of the part, even the small crevices, with a thin, uniform layer. It works best for industries that need corrosion protection.The process follows four basic steps:Our team thoroughly cleans the parts to remove contaminants that could interfere with the coating process.We dip the parts into the coating solution in a single, small batch, depending on the part sizes.We spin the parts in a special hopper, between 1,000 and 3,000 RPM, to remove excess coating and leave a thin, even coat.The parts are cured, typically in an oven, to dry the coating.Advantages of Dip-Spin CoatingDip-spin coating offers numerous advantages, making it a preferred method for applying protective and decorative finishes to small parts.Uniformity Over Complex ShapesDip-spin coating has the ability to coat complex shapes and intricate designs effectively. Fasteners, springs, and other small components with tight spaces receive uniform coverage, ensuring comprehensive protection without gaps or inconsistencies that could lead to premature defects.Minimal WasteThe process minimizes material waste, enhancing sustainability and cost-efficiency. During the spinning phase, excess coating returns to the system for reuse, which lowers our costs (and yours).If your company has sustainability in mind, this is a relevant coating technique. Even better, we can discuss coating your objects with Rilsan, an eco-friendly option made from castor beans.Control Over ThicknessDip-spin coating delivers exceptional consistency across large batches of small parts. By immersing and spinning components under controlled conditions, the process ensures uniform thickness and adhesion depending on the viscosity of the coating and the substrate. Consistency and reliability enhance product performance and reduce the likelihood of defects.Versatility & CustomizationAnother benefit lies in its versatility with various coatings, including anti-corrosion treatments, lubricants, and decorative finishes. Our technicians can tailor the coating solution to meet specific requirements, making the method adaptable across diverse applications. From protecting metal fasteners against rust to adding aesthetic appeal, dip-spin coating addresses multiple needs effectively.Efficiency of Dip-Spin CoatingsDo you need your batch of parts coated quickly? Dip-spin coating offers significant time savings in high-volume production. Simultaneously coating and spinning multiple components streamlines the application process without sacrificing quality. You might find shorter lead times and increased output when you need items coated quickly.Materials That Can Be Dip-Spin CoatedDip-spin coating can be applied to a wide variety of substrates.MetalsMetals, particularly steel, aluminum, and brass, benefit significantly from this process. If your metal parts can benefit from enhanced corrosion resistance and durability, especially in demanding environments, dip-spin coating can work for you.PlasticsPlastics can also undergo dip-spin coating, provided they possess sufficient heat resistance to undergo the curing process. Manufacturers frequently use this technique to apply decorative or functional layers, such as anti-friction coatings or primers, to plastic components. Careful temperature control during the curing stage ensures that the process does not compromise the integrity of these lightweight materials.CeramicsCeramics represent another category that adapts well to dip-spin coating. Engineers often coat ceramic substrates with protective layers to improve surface properties like wear resistance or thermal stability. This capability proves valuable in applications such as electronics or high-temperature environments, where high-tech ceramics play a crucial role.CompositesComposites can also benefit from dip-spin coating. Fiber-reinforced polymers, for instance, gain enhanced functionality when coated, such as improved UV resistance or a smoother finish for aesthetic purposes. The flexibility of dip-spin coating allows for precise application without damaging the composite structure.Exotic Metal AlloysFasteners and small components made from exotic alloys, including titanium or nickel-based materials, benefit greatly from this technique. These materials, often used in aerospace or medical industries, require specialized coatings to meet strict performance standards.Dip-spin coating ensures consistent coverage, even on intricate geometries like hexagonal or octagonal shapes, while ensuring an even coat among the threads of nuts, bolts, and screws, such as for construction or automotive parts.The Dip-Spin Coating ProcessThe dip-spin coating process is designed to be efficient. A cleaning solution removes any dirt, grime, dust, or other contaminants that may interfere with the application of the coating or reduce its effectiveness. This usually happens in batches because the smaller parts fit easily into hoppers.Then, we immerse the parts into the industrial coating. During this step, the liquid flows into every surface area, including hard-to-reach spots, which other types of coating processes might not accomplish.Careful timing ensures consistent thickness while preventing over-saturation. Temperature control also plays a critical role so that the coating maintains optimal viscosity when adhering to the parts.How the Spinning Process Ensures an Even FinishNext, our technicians spin the object rapidly to remove excess liquid. Centrifugal force directs the surplus coating outward, preventing drips or uneven coatings. This spinning action also reduces the drying time and eliminates the possibility of puddles forming on flat surfaces. The result is smooth and even finishes over the entire batch.The final stage involves curing or drying the coated objects, either through air-drying or baking in a precise and controlled environment. Heat solidifies the coating, locking it onto the substrate. Proper curing ensures durability, chemical resistance, and aesthetic appeal.Size Considerations for Dip-Spin CoatingThe main limitations of dip-spin coating come from the size, dimensions, and weight of the parts. Typical dip-spin machines operate with baskets measuring 24 inches in diameter and up to 18 inches deep while handling up to 12,000 pounds per hour with 350-pound loads per batch.Part SizeThe method excels at handling small to medium-sized components, making it ideal for parts like bolts, screws, nuts, and washers. These items fit easily into standard dip-spin equipment, allowing for efficient and consistent coverage across multiple pieces.Batch SizeBatch size plays a crucial role in the efficiency of dip-spin coating operations, and there are weight limits depending on what is being coated. Manufacturers can process hundreds of small parts simultaneously, provided the equipment can handle the total volume without overcrowding.Proper spacing ensures each item receives even coating, while excessive loading risks uneven finishes or defects. Our technicians will adjust the batch size to balance throughput and quality.Part DimensionsIndividual part dimensions affect the feasibility of using dip-spin coating. Items with intricate geometries, such as springs or threaded fasteners, benefit significantly from the technique, as the liquid coating flows into hard-to-reach areas.However, extremely large or flat components may not suit this method, as achieving uniform coverage could prove challenging. Alternatives like spray or brush applications, or even powder coating, may work better for oversized parts.Batch WeightsWeight considerations impact both handling and equipment capacity. Heavier items require specialized equipment designed to support their mass during the dipping and spinning stages.Overloading machines can lead to mechanical strain or uneven rotation, compromising the quality of the coating. Lightweight components, on the other hand, rotate more easily and allow for higher batch quantities, increasing overall efficiency.Strengthen Your Products With a Professional Coating CompanyCoating Systems, located in Greater Cincinnati, Ohio, can handle your dip-spin coating needs to strengthen the outer layers of your products.Talk to us by calling 503-367-5600 or contacting us online.The history of spin coat technology can be traced back to the middle of the 20th century. Spin coating was originally developed for the semiconductor industry, where the need for ultra-thin, uniform coatings on silicon wafers was critical. Over the years, advances in technology and materials science have refined the process, making it more versatile and efficient.In the 1960s, spin coating became the standard method for manufacturing integrated circuits, contributing greatly to the miniaturization and performance of electronic devices. By the 1980s, spin coating had expanded into other fields such as optics and nanotechnology, proving its adaptability and effectiveness.Today, spin coating continues to evolve, incorporating new materials and innovative techniques to meet the growing demands of advanced manufacturing processes. From creating anti-reflective coatings on lenses to depositing photoresist layers in micromachining, the applications of spin coating are varied and essential.Advantages and Limitations of Spin Coating. Magni Industries, Inc.NOF Metal Coatings North AmericaNorthern Coatings and Chemical Company, Inc. Applying plastic coatings is a time-tested way to add durability and functionality, and to provide added safety, vibration dampening, impact protection, and other improvements to coated parts and products. Dip coating and spray coating are the two most common ways these coatings are applied, but in some instances, spin coating, also called dip-spin coating, may be a more appropriate choice. Here are some guidelines to help you choose between them. What Is Dip Coating? Dip coating is a fairly straightforward process where the item to be coated is heated and then dipped into liquid plastic. After the plastic sets, the coated piece is heated again to cure the plastic coating. What Is Spin Coating? To perform spin coating, the parts to be coated are loaded into a porous basket. The basket full of parts is dipped into the liquid plastic to coat them. Then, the filled basket is put into a device to spin it at high speeds so that the excess coating will fly off, leaving just the coated parts. Additional layers can be added as needed, and then they are then heat cured in the same fashion that dip coated parts are set. Best Candidates for Spin Coating Spin coating is clearly limited to the size of the basket your facility can spin, and the size of parts which can fit into that basket. It is generally a great solution for coating small parts such as fasteners and other hardware components. Best Candidates for Dip Coating Dip coating is an excellent solution for countless applications. Some smaller parts that would seem to be good candidates for spin coating can produce poor results with that process and do better with dip coating. These include small parts that could interlock or nest during the spinning process or those which have deep or complicated openings that would prevent an even coating.At Precision Dip Coating, we have the expertise to help you choose the best plastic coating technique to achieve the results you need. Contact us today to learn more about our capabilities. < Older Post Newer Post > Spin coating is a common technique for applying thin films to substrates. When a solution of a material and a solvent is spun at high speeds using a spin coater, the centripetal force and the surface tension of the liquid together create an even covering. After any remaining solvent has evaporated, spin coating results in a thin film ranging from a few nanometres to a few microns in thickness.Spin coating is used in a wide variety of industries and technology sectors. Its primary advantage of spin coating over other methods is its ability to quickly and easily produce very uniform films.The use of spin coating in organic electronics and nanotechnology is widespread and has built upon many of the techniques used in other semiconductor industries. The relatively thin films and high uniformity required for effective device preparation, as well as the need for self-assembly and organisation to occur during the casting process, do however necessitate some differences in method.This guide aims to introduce general spin coating concepts, cover spin coating equations and theory, and describe some of the specific techniques useful in organic electronics and nanotechnology. Introduction to Spin Coating Spin coating generally involves the application of a thin film (a few nm to a few um) evenly across the surface of a substrate by coating (casting) a solution of the desired material in a solvent (an "ink") while it is rotating. Put simply, a liquid solution is deposited onto a spinning substrate in order to produce a thin film of solid material, such as a polymer.The rotation of the substrate at high speed (usually >10 rotations per second = 600 rpm) means that the centripetal force combined with the surface tension of the solution pulls the liquid coating into an even covering. During this time the solvent then evaporates to leave the desired material on the substrate in an even covering.This process can be broadly divided into 4 main steps:DepositionSpin up.Spin offEvaporationIn the initial step, the solution is cast onto the substrate, typically using a pipette. Whether the substrate is already spinning (dynamic spin coating) or is spun after deposition (static spin coating), the centrifugal motion will spread the solution across the substrate.The substrate then reaches the desired rotation speed either immediately or following a lower-speed spreading step. At this stage, most of the solution is expelled from the substrate. Initially, the fluid may be spinning at a different rate than the substrate, but eventually the rotation speeds will match up when drag balances rotational accelerations leading to the fluid becoming level.The fluid now begins to thin, as it is dominated by viscous forces. As the fluid is flung off, often the film will change colour due to interference effects (see video below). When the colour stops changing, this will indicate that the film is mostly dry. Edge effects are sometimes seen because the fluid must form droplets at the edge to be thrown off.Finally, fluid outflow stops and thinning is dominated by evaporation of the solvent. The rate of solvent evaporation will depend the solvent volatility, vapour pressure, and ambient conditions. Non-uniformities in evaporation rate, such at the edge of a substrate, will cause corresponding non-uniformities in the film.Your browser does not support the video tag.Example of spin coating a small molecule in solution using a static dispense. First the substrate is coated in the ink containing the molecules dissolved in a solvent (1). Then the substrate is rotated at high speed and the majority of the ink is flung off the side (2). Airflow then dries the majority of the solvent, leaving a plasticised film (3) - before the film fully dries to just leave the molecules on the surface (4). Interference effects, when films change color as fluid is thrown off and thickness changes, seen during the spin off stage of spin coating Spin coating is extremely widely used and has a varied range of applications. The technique can be used to coat anything from small substrates measuring only a few millimetres squared, up to flat panel displays which might be a metre or more in diameter. It is used for coating substrates with everything from photoresistors, insulators, organic semiconductors, synthetic metals, nanomaterials, metal and metal oxide precursors, transparent conductive oxides and many more materials. In short, spin coating is ubiquitous throughout the semiconductor and nanotechnology R&D and industrial sectors.Advantages and Disadvantages of Spin CoatingThe main advantages of spin coating are:The simplicity and relative ease with which a process can be set up coupled with the thin and uniform coating that can be achieved at various thicknesses makes it ideal for both research and rapid prototyping.The ability to have high spin speeds leads to fast drying times (due to the high airflow) which in turn results in high consistency at both macroscopic and nano length scales, and often removes the need for post-deposition heat treatment.Spin coating is a very low cost way to batch process individual substrates compared to other methods, many of which require more expensive equipment and high energy processes.The primary disadvantage of spin coating is that it is an inherently batch (single substrate) process and therefore has a relatively low throughput compared to roll-to-roll processes like slot die coating. The actual material usage in a spin coating process is also typically very low (at around 10% or less), with the rest being flung off the side and wasted. This is not usually an issue for research environments, but is clearly wasteful for large-scale manufacturing.The fast drying times can also lead to lower performance for some particular nano-technologies (small molecule OFETs for example) which require time to self-assemble and/or crystallise. Despite these drawbacks, however, spin coating is usually the starting point and benchmark for most academic and industrial processes that require a thin and uniform coating.Quickstart Video Guide The video below shows in brief how to get started with the Ossila Spin Coater. Vacuum-free spin coaters like the Ossila Spin Coater reduce the possibility of substrate warping, help to improve film quality, and require far less space in a lab and glove box than vacuum spin coaters. The Ossila Spin Coater is powerful and versatile, with speed ranging from 100 rpm to 6000 rpm and 100 programs each with up to 100 steps.Spin Coating Theory Due to the relative simplicity of the spin coating technique, it is possible to produce high quality films even without a deep understanding of the background physics involved. Having a deeper understanding of the mechanisms at work, however, will give you better insight into how solution properties can affect deposited films.This section covers the theory of spin coating and the various physical factors that are important for eventual film thickness.Spin Coating Thickness EquationIn general, the thickness of a spin coated film is proportional to the inverse of the square root of spin speed as in the below equation where is angular velocity/spin speed and hf is final film thickness.Equation 1: Spin coating thickness equationThis means that a film that is spun at four times the speed will be half as thick. A spin curve can also be calculated from this equation such as shown below.Example spin curve for a solutionThe exact thickness of a film will depend upon the material concentration and solvent evaporation rate (which in turn depends upon the solvent viscosity, vapour pressure, temperature and local humidity) and so for this reason spin thickness curves for new inks are most commonly determined empirically. Typically a test film is spin coated and the thickness measured either by ellipsometry or surface profilometry (Dektak). From this one or more data points, the spin thickness curve can be calculated - usually with a good degree of accuracy. The spin speed can then be adjusted to give the desired film thickness. Emslie, Bonner, and Peck ModelMany researchers will use a simple proportionality rule (related to spin speed) to describe the final film thickness from spin coating, as expressed in Equation 1 (above).However, this rule does not always apply and does not allow for predictions of film thickness without experimental data. There have also been several attempts to describe the process in a more rigorous manner. The earliest (and simplest) of these was by Emslie, Bonner, and Peck in 1958.1 This analysis made several approximations, including ignoring the effects of evaporation (the validity of which will depend on how volatile the solvent is) and ignoring the possibility of non-Newtonian behaviour. This means it is assumed that the viscosity of the fluid used will not be changed by stress. For a non-volatile, viscous fluid on an infinite rotating disk, Emslies model can be seen in Equation 2.Equation 2: Emslie, Bonner, and Pecks model for fluid dynamics during spin coatingWhere t is time since the start of the process, is angular velocity, r is the distance from the centre of rotation, is the density, is the viscosity and h is thickness of the fluid layer, (rather than the dry thin film). Here, h/t represents the rate of change of thickness, and h/r the rate of spreading.The approximation of a rotating disk used by Emslie, Bonner and Peck, where the rotational plane is horizontalIf the film is considered initially uniform, this leads to a description of the fluid film thickness as seen in Equation 3.Equation 3: Emslie, Bonner and Pecks equation for final fluid film thicknessHere h0 represents the uniform thickness of the film at the start of the process (i.e. t=0). As this model does not account for evaporation, it cannot be used to calculate the exact thickness of the final dry film. An approximate dry thickness can be calculated from fluid film thickness by using the concentration of solute and solution density. To get an accurate value, including the impact of solvent viscosity and surface tension, a more detailed model is needed.Meyerhofer ModelThe first attempt to include evaporation effects was published by Meyerhofer in 1978,2 who modified the equations of Emslie, Bonner, and Peck (seen earlier in Equation 2) with the inclusion of a solvent evaporation rate:Equation 4: Meyerhofers equation for fluid dynamics during spin coatingHere E is the uniform solvent evaporation rate, in units of solvent volume evaporated per unit area per unit time.Meyerhofer proposed that early in the spin coating process, flow dominates the thinning process of the film (spin off); whereas later in the process (when the film is thinner and flow is slow), thinning is mainly due to evaporation. Meyerhofer also established that if the transition from fluid thinning to evaporation thinning is abrupt, then the film thickness can be estimated analytically where it is assumed that the film is thin enough to ensure solvent concentration remains uniform through the depth of the film. This transition point will clearly be the point at which thinning by flow is equal to thinning by evaporation:Equation 5: The transition point between fluid thinning to evaporative thinningWhere C is the volume fraction of solute in the film and h0 is the film thickness at the transition between the two film-thinning regimes.A representation of the different thinning regimes in spin coating, as used by MeyerhoferThis gives the final film thickness as:Equation 6: Meyerhofers equation for final dry film thickness from evaporation rateWhere C0 is the initial concentration of solute, and 0 equates to (C0). The concentration of solute is assumed to remain at C0 until the transition of evaporation-driven thinning begins. Final spin coating film thickness can also be calculated without the solvent evaporation rate. This can be done by making several assumptions, including the assumption that air flow remains laminar during the process. This gives an overall equation as:Equation 7: Meyerhofers equation for final dry film thickness without evaporation rateWhere k is a constant specific to the coating solvent and for typical spin coating solvents k 1(-5)cm/s(-1/2). Readers will then recognise that this can be expressed as hf (-1/2) which is equivalent to Equation 1, showing that the proportionality constant is a product of several other terms, including solution density, viscosity and concentration, and the properties of the solvent.Despite what is shown in Equation 7, final film thickness from spin coating is not always proportional to (-1/2).This equation is dependent on numerous assumptions, and where these are not correct, the dependency will fail.An example of this is when the transition between the two thinning regimes is not abrupt. This has occurred in some cases in research,3 where the spin coating process is terminated early. This means the cross-over to evaporative thinning doesnt occur, and thickness and spin speed have a different relationship. If a longer spin time was used in these cases, it is possible that Equation 7 would have proven correct. Systems may also deviate from expected behaviour where non-Newtonian fluids do not cross over to a Newtonian flow before being immobilised by evaporative thinning. This mostly occurs in colloidal solutions or solutions close to the gelation point.In many cases, it is most straightforward to establish the relationship for a given solution by using a spin curve. This can be done by spin coating a solution at varying spin speeds and then measuring the film thickness. In literature, there has also been success using semi-empirical models, as a combination of Meyerhofers equation and experimental data.4Spin SpeedThe range of spin speeds available is important as it defines the range of thicknesses that can be achieved from a given solution. In general, spin coating can produce uniform films relatively easily from about 1000 rpm upwards, but with care and attention good film quality can be achieved down to around 500 or 600 rpm in most cases (and even lower in some cases). Most common spin coaters will also reach a maximum speed of 6000 to 8000 rpm (although specialist coaters may go to 12000 rpm or higher). As such, a normal range of working spin coating rpm might span a factor of ten (from say 600 rpm to 6000 rpm) which in turn means a maximum variation in film thickness of around a factor (10)=3.2.For example, a solution which gives a film thickness of 10 nm at 6000 rpm will give a thickness of around 32 nm at 600 rpm and if a thicker film is required then the solution concentration would need to be adjusted. In the reverse scenario, if a solution gives a thickness of 100 nm at 600 rpm then the minimum thickness that can be achieved without diluting the solution will be 31.25 nm (100 / 3.2).This dependence upon the square root of spin speed is both an advantage and a disadvantage. The disadvantage is that it means that the range of thicknesses that can be achieved from a given solution spans a relatively narrow range (around a factor of 3-4). On the other hand the advantage is that it allows precise control of film thickness within this range.The maximum thickness that can be produced from a given material/solvent combination also depends upon the maximum concentration that the material can be dissolved in the solvent. For high solubility materials (100 mg/ml or higher), thicknesses of >1 m can be achieved. Meanwhile for some low solubility conjugated polymers (a few mg/ml) the maximum thickness might be limited to 20 nm or so.At low concentrations the thickness of a film is approximately linearly dependent upon the concentration of the material in the ink, however as concentrations increase this will affect the viscosity of the ink and thus a non-linear relationship will develop.Spin Coating DurationFor most standard spin coating techniques the objective is to keep the substrate spinning until the film is fully dry. As such this will mainly depend upon the boiling point and vapour pressure of the solvent that is used but also on the ambient conditions (temperature and humidity) that the spin coating is performed in. For most solvents (such as the list below) a spin coating duration of 30 seconds is usually more than adequate and is therefore recommended as a starting point for most processes.Table 1: Common solvents for which 30 seconds spin duration is usually adequate and those for which longer durations are required30 seconds usually adequateLonger spin speeds requiredWaterDichlorobenzeneIPATrichlorobenzeneEthanolDiiodooctaneMethanolOctanedithiolAcetoneGlycerolButanoneTolueneXyleneChloroformChlorobenzeneFor higher boiling point (and/or lower vapour pressure) solvents, drying may take considerably longer (up to ten minutes in some cases) and therefore these solvents are most commonly used either as additives or with additional drying steps (covered in later sections).Choosing a Spin Coating Method In general, a dynamic dispense is preferred as it is a more controlled process that gives better substrate-to-substrate variation. This is because the solvent has less time to evaporate before the start of spinning and the ramp speed and dispense time is less critical (so long as the substrate has been allowed time to reach the desired rpm). A dynamic dispense also uses less ink in general although this does depend upon the wetting properties of the surface.The disadvantage of a dynamic dispense is that it becomes increasingly difficult to get compete substrate coverage when using either low spin speeds below 1000 rpm or very viscous solutions. This is because there is insufficient centrifugal force to pull the liquid across the surface, and the lower rotation speed also means that there is increased chance that the ink will be dispensed before the substrate has completed a full rotation (at 600 rpm the substrate is rotating once every 0.1 seconds, commensurate with a fast pipette drop). As such, Ossila generally recommend using a static dispense at 500 rpm or below and with either technique a possibility in the region between 500 - 1000 rpm.Dynamic Dispense Spin Coating TechniqueFor the majority of spin coating above 1000 rpm, a dynamic dispense should be used as standard unless there are any special circumstances or difficulties.A pipettor is normally used to dispense a known amount of solution each time - usually 20 l for most common substrates/inks on standard sized (20 x 15 mm) substrates or around 100 l for 50 x 50 mm substrates. However, if there is a problem with wetting then increasing the volume may help.In this example we demonstrate using AI 4083, a PEDOT:PSS formulation typically used as a hole transporting layer but the technique is commonly used with a large variety of inks and photoresists.Here the substrate is spun to 6000rpm and the solution (a quantity of 30-40l) is dynamically deposited (i.e. during the spinning process) but the process works well for spin coating speeds of around 500 RPM and upwards. Dynamic Dispense Spin Coating MethodIn order to get a high quality and consistent thin film the below points must be observed:The substrate should have reached it's desired rotational speed before the dispense happens (usually only a few seconds).The ink should be deposited as close to the centre of the substrate as possible otherwise you may end up with a gap in the middle.The ink should be deposited in one quick and smooth action.The ink should be deposited in one and only one drop in order to prevent multiple coats.There should not be any bubbles blown onto the surface from the pipette.The pipette tip should never touch the rotating substrate.It's also worth noting that for spin coating, best results can be achieved when using a pipettor in a non-standard way. Normally when pipetting a solution the pipette would be used to the second stop so that additional solution is sucked up into the tip and then discarded afterwards. However, this leads to a higher chance of additional drops or bubbles being cast onto the surface. As such, it is advisable to only use pipettors to the first stop when spin coating.The above points will help to provide the best possible film uniformity for a particular substrate. In a research environment, however, new users in particular (but also for experienced users) often find that the variation between substrates is usually greater than the variation across a substrate. While often this is a small effect it can be an important consideration - especially for statistical results.Example of statistical data in a typical lab environment for solar cells with multiple pixels on each substrate. In a research environment there are usually a few poor pixels but the typical variation in performance between pixels can be small compared to the variation between substrates.As such, to get the best possible consistency between substrates there is a critical "practise factor". This refers to the fact that once an action (or combination of actions) has been done many times it is committed to "muscle memory" which means that it is done automatically with little or no conscious effort. This generally means that the dispense happens more consistently and precisely which has a knock on effect for the film quality.Static Dispense Spin Coating TechniqueAs spin speeds decrease below 1000 rpm or with very viscous solutions it becomes increasingly difficult to get a high quality film. Therefore, if possible, it is generally recommended that the ink is reformulated (increased concentration or change in solvent) to allow spin coating above this speed. However, there are many situations in nanotechnology where this is either not desirable or not possible. For example, better crystallisation will happen at low speeds and some materials just do not have sufficient solubility to reach the desired thickness at 1000 rpm.A dynamic dispense can be achieved at speeds all the way down to around 500 rpm, however it becomes more difficult to get complete substrate coverage and so more ink is required (using a 50 l dispense rather than 20 l will help with coverage but at the expense of greater material wastage). As such, the cut-off point can be considered to be around 700 rpm, below which the static dispense spin coating method starts to give better film quality.When using a static dispense it is usual to coat the entire substrate (or at least all of the active part of the substrate) before starting the spin coating. However, this in itself can cause several issues. The first is that unless the substrate surface gives particularly good wetting for the ink (i.e. the ink likes to spread out across the surface) then it is usually necessary to use the pipette tip to "pull" the ink across the surface. However, it is of course especially important for the pipette tip to never touch the surface of the substrate in the active areas as this can change the surface properties and/or damage any other layers present.By carefully placing the pipette tip close to the surface such that it touches the edge of the ink droplet, it is possible to move the ink around the surface without touching it. Alternatively, if the edges of the substrate are not critical then the pipette tip can be moved around the edge of the substrate to pull the meniscus around. A third alternative is just to add more and more ink until the substrate is fully covered - however this is in general not recommended as it may take up to a ml of solution in extreme cases for this to happen. The below videos show all three of these techniques being used for static dispense spin coating. This video demonstrates the static dispense spin coating method without touching the edge of the substrate. This video demonstrates the static dispense spin coating method, including how to touch the substrate edges (inactive area) to spread the ink. This video demonstrates the static dispense spin coating method using a large volume of ink.Finally, in some cases it is desirable to statically dispense a viscous solution and ensure that it coats right to the very edge of the substrate (for example spin coating PMMA as a gate insulator for prefabricated ITO OFET substrates). In this case it is not easy to use the pipette tip to pull the meniscus to the edge without touching it due to the viscosity of the ink and the relatively low wettability.Instead, use a different spin coating method where the pipette tip is angled at 45 degrees to the substrate and moved along the far edge of the substrate. This creates an effective technique to coat the PMMA right to the very edge of the substrate without touching it. This video demonstrates the static dispense spin coating method using 45 degree angle to avoid touching the edge of the substrate whilst moving the ink.However, one of the main issues for a static dispense is that the solvent in the ink has some time to evaporate before the spin coating process begins. For low vapour pressure solvents such as water this is not too much of an issue, however for high vapour pressure solvents such as chloroform (around 10x higher than water) it can be critical and the time between depositing the solution and the start of spinning can make a big difference to both film thickness and film quality. This is the primary reason why a static dispense gives lower substrate-to-substrate film uniformity and why a dynamic dispense is recommended if possible.Practical Spin Coating Tips Special Requirements for Spin Coating NanoparticlesIn many areas of organic electronics and nanotechnology, the casting and drying stages of an ink are an integral part of the technology, and is where all the "action" happens. It is sometimes referred to as "the science of paint drying" and in all of the examples below, part or all of the key process happens during the drying of the ink:- stacking/crystallisation of a small molecule or polymersself-assembly of a block-copolymerphase separation of a polymer-fullerene blendaggregation/assembly of nanoparticles and colloidsControl of this process is critical. In practice, this means that when spin coating nanoparticles for OE/nano applications, the properties of the film don't just depend upon its physical characteristics (thickness, uniformity) but also very strongly upon the processing (drying time and conditions). By comparison, in many more general spin coating processes, such as applying a photoresist, the end result is broadly independent of the exact application route. For this reason, variations on the usual technique are often used in organic electronics and nanotech - especially in a research environment.In particular, for industrial processes spin coating would generally only be recommended at speeds of >1000 rpm to ensure the best uniformity. However, in OE/nanotech, spin speeds down to 200 rpm might be used to slow down the drying process and allow additional time for self assembly. An industrial process engineer might not consider this to be spin coating at all but this sort of "pseudo-spinning" can be a powerful tool to investigate order and self assembly.The figure below shows how drop casting slowly without rotation can be a good way to provide highly ordered films at the nanoscale at the expense of uniformity across the substrate.A small molecule in a solvent is dispensed across the substrate and as the solvent begins to evaporate this produces internal currents (1). The droplet shrinks in size with the internal currents depositing molecules at the receding edges (2). By slowing down the evaporation rate it is possible to have highly ordered films produced at the edges (3). However, the coating across the surface is usually high uneven with a typical "coffee staining" effect (4).By spin coating at very low speeds it is possible to get a combination of the high levels of nanoscale order produced by drop casting with the uniformity of spin coating.Other issues in research environments are the requirement to coat often very small substrates, the desire to use in difficult spaces such as laboratory glove boxes, and the wish to keep services (vacuum, compressed air or nitrogen) to a minimum. The ability to cope with chlorinated or aggressive solvents while being low-maintenance is also of beneficial for many applications. As such, this guide details a full range of spin coating techniques and issues that might be encountered in a typical research lab.For most applications the most important consideration is the thickness of the film that is produced during spin coating.Probably the most important aspect to consider is the spin coating method used to dispense the solution - either a static dispense or a dynamic dispense.In a static dispense the solution is placed upon the substrate while it is stationary and usually the entire substrate is covered in the solution before rotation begins. The spin coater is then started and brought up to the required speed as fast as possible.In a dynamic dispense, the substrate is first started spinning and allowed to reach the desired spin speed before the solution is dispensed onto the centre of the substrate. The centrifugal force then rapidly pulls the solution from the middle of the substrate across the entire area before it dries.Normally a pipette or pipettor of some description is used to dispense a known volume of liquid on the surface. This video demonstrates the spin coating of small and odd-shaped substrates (in this case silicon wafer fragments) that in many cases would be too small to coat using a standard spin coater due to the size of the vacuum chuck (and so would otherwise need mounting).The spin coater chucks can be custom designed to hold arbitrary shaped substrates and work well with under-sized wafer fragments. The only general requirement that in order to get good coverage when dynamically dispensing a solution the fragment should cover the centre of the chuck so that centrifugal forces will spread it over the entire fragment. However, when using a static dispense this doesn't matter.You can download the design to make your own chucks for the Ossila spin coater and even 3D print them if you wish. We can also design and make them for you. Automated DispensingFor certain situations manual dispensing of solutions during spin coating may not be appropriate, these include:Specific timing needed for the dispensing of solutions.Specific dispense rate of the solution during spin coating.Dispensing of multiple layers being too repetitive and time consuming.Time between multiple dispenses is too short to perform manually.In these situations the dispensing of the solution needs to be automated, this can be done through the use of aprogrammable syringe pump. Syringe pumps work by displacing a volume of liquid at a specified rate at a given time, these values can be controlled to extremely high degrees of accuracies. Rates of dispense can vary from as low as 0.1 nl/s to as high as 10 ml/s, while the timing of the dispense can be controlled to within 10 ms allowing for a level of control that is not possible with manual solution dispensing.Syringe pumps are especially effective when dealing with dispensing multiple solutions, some examples of situations where multiple solutions are required are:Multi-layered structures that require alternating multilayer coatings, such as distributed agg reflectors (D's), can be fabricated rapidly and reproducibly when using an automated dispenser.In situations that require the washing of the substrate with a solvent before the dispensing of the solution to improve the wetting on the substrate, timing the dispensing of the solution so that it occurs just as the solvent is evaporating can dramatically improve the wetting.When surface washing. The washing of the top surface of a deposited layer where the surface of a dry or a semi-dry film can be washed with a solvent in order to alter the properties of the upper surface and improve morphological structure. This can be done when depositing PEDOT:PSS, the post deposition washing with solvents such as methanol or DMSO can significantly improve the conductivity of the film.For quenching of deposited films. Quenching of films is done by flooding the drying film with an anti-solvent causing the material in solution to rapidly precipitate. Syringe pumps excel in these situations as you can not only time when the quenching occurs but also the rate at which it happens something that is impossible to do accurately during manual deposition.Ultra-low Spin Speeds and Covered DryingAs mentioned above, spin coating below around 1000 rpm, the uniformity of films begins to be affected and below about 500 rpm this can cause significant issues. However, it is still possible to process films at speeds even lower than this and still get good results - albeit at the expense of consistency.In some cases it may even be possible to spin films at speeds as low as 120 rpm. While this can not really be described as spin coating it does still provide a significant increase in uniformity over drop casting because there is still some centripetal force. It also ensures that there are no effects due to the substrates being on a slight slope (getting a substrate sufficiently flat that an ink droplet does not move and dries evenly over the course of 5-10 minutes is difficult without a goniometer).Film uniformity at 1000 rpm (left) and 300 rpm (right).However, when spinning at ultra low speeds it's also important to consider the edge bead removal which is described below.As described in previous sections, a slow drying film is often desirable to allow for self organisation to occur, but reducing the spin speed often results in non-uniform films. On the other hand the solvent is changed to something with a high boiling point, the end result is often a thinner film (the ink has more time to migrate to the edge of the substrate before drying) with poor surface wetting (higher boiling point generally means higher intermolecular interactions and therefore more surface tension).Spin Coating with Solvent BlendsA good way to optimise spin coating uniformity is to mix two solvents together; using a major component of something that evaporates relatively quickly and a minor component of something that is relatively slow to evaporate. By using this combination it is often possible to get the best of both worlds; during the spin coating process the major component evaporates quickly to give good coverage and a uniform thick film, and the remaining minor component still leaves enough plasticity for the molecules to self-organise before the film is completely dry.Solvent ASolvent BMixture of A + BExample of solvent blends.Solvent A: If a low boiling point solvent (high evaporation rate) is used then coating can be achieved more easily but an amorphous (disorganised) film is produced.Solvent B: If a high boiling point (slow evaporation rate) solvent is used then coating is harder because the ink has time to dewet and is flung off the edge of the substrate leaving no coating.Mixture of A & B: If a mixture of solvents is used with a majority of low boiling point (fast evaporation rate) with minority of high boiling point (slow evaporation rate) then coating can still be achieved because the fast evaporating solvent is removed quickly leaving a plasticised film that is less likely to dewet but also gives the molecules time to organise themselves.An example of this which works to good effect is the spin coating of P3HT for OFETs. Spin coating from pure chlorobenzene will give worse performance than spin coating from trichlorobenzene. However, spin coating from trichlorobenzene gives poor wetting and a very rough surface. By spin coating from a solution of 98% chlorobenzene and 2% trichlorobenzene the wetting is significantly improved and the performance remains almost as good.Visible Assessment of Drying and Film UniformityLearn to trust your eyes - they are the primary tool and first line of analysis for almost all device engineering.Microscopy by optical, electron, AFM or STM techniques will obviously give you a better and more quantitative assessment of nanostructure. Dektak or ellipsometry can provide better thickness and roughness calculations. However all of these techniques are slow, may damage the sample and/or introduce additional delays or variables to a process that can be critically dependent upon timings. They are not suitable for assessing every pixel on every substrate at every stage of a process - at least in an R&D environment.The eyes are a highly sensitive and very versatile optical recognition system capable of discerning small differences quickly and effectively. With training and the correct lighting you can quite easily spot a 5 nm variation in film thickness just by looking at the colour. As such, inspecting a substrate

crystallites over time, such as the below examples of P3HT films, PCBM crystallites and F8BT aggregates, all of which will form if an ink is left standing for long times (hours to days).PCBM crystallites under an optical microscopeP3HT aggregates in a thin film via AFMF8BT aggregation in a working OLED pixelSeveral weeks storage prior to spin coating90 minutes cooling prior to spin coatingAggregation during spin coating at low speed - filtered immediately prior to spinningAggregates of different materials and the approximate timescales required. In all cases the solutions were filtered prior to storage.In some cases it's possible to re-dissolve these particles by re-heating/stirring and often it's worth filtering a second time after the solution has cooled. However, in some cases, such as for PCBM, the energy of crystallisation is significant and therefore it's very difficult, if not impossible (depending on the solvent) to re-dissolve them, therefore fresh solutions should be used each time.However, before filtering any solution it is always worth considering the size of any solutes relative to the filter pore size; while polymers, PCBM, and small nanoparticles (