Motic
MORE THAN MICROSCOPY

Battery Analysis with Light Microscopy

Introduction

Battery technology, a cornerstone of modern innovation, has propelled advancements across industries by powering an array of devices, from portable electronics to renewable energy systems. Today's landscape is defined by the pursuit of more efficient, sustainable, and compact energy storage solutions. Among the latest trends, solid-state batteries utilizing innovative electrolyte materials promise heightened safety and performance, while lithium-air batteries, though grappling with technical obstacles, offer the allure of unprecedented energy density. However, the road to commercialization is marked by challenges ranging from manufacturing scalability and cost-effectiveness to intricate compatibility requirements for integration. Looking ahead, as research and development efforts persist, these cutting-edge technologies could potentially revolutionize energy storage, driving a future where electronics, transportation, and renewable energy systems are more powerful, durable, and environmentally friendly.

Battery Overview

Electrodes (Anodes and Cathodes):

Electrodes, encompassing both anodes and cathodes, constitute the heart of electrochemical energy storage devices. The anode, often composed of materials like graphite, silicon, or lithium metal, acts as the site of electrochemical oxidation during discharging. In lithium-ion batteries, for instance, lithium ions intercalate into the anode material during charging and then deintercalate during discharging, releasing electrons and allowing for ion movement. Cathodes, constructed from diverse compounds such as lithium metal oxides (e.g., $LiCoO_2$), layered transition metal oxides (e.g., $LiNiCoAlO_2$), or polyanionic compounds (e.g., $LiFePO_4$), facilitate electrochemical reduction during discharging. This results in lithium ions migrating into the cathode material, accompanied by electron transfer. The choice of electrode materials significantly influences the battery's voltage, capacity, cycle life, and safety. Furthermore, advancements like alloying anodes, high-capacity cathodes, and conversion materials continue to shape the field, aiming to enhance energy storage and promote sustainable energy systems.

Electrolytes:

Electrolytes are pivotal components that enable ion transport between the anode and cathode, serving as conduits for the electrochemical reactions underlying battery operation. In liquid electrolytes, a lithium salt dissolved in a solvent facilitates ionic mobility. Propylene carbonate, ethylene carbonate, and dimethyl carbonate are commonly employed solvents due to their compatibility with lithium ions. Solid electrolytes, heralded for their enhanced safety and potential for high-energy-density batteries, encompass a diverse range of materials like ceramics (e.g., lithium garnets), polymers (e.g., polyethylene oxide-based polymers), and composite systems. The electrolyte's ionic conductivity, transference number, electrochemical stability window, and interfacial compatibility with electrodes profoundly affect battery performance and safety. Ongoing research focuses on optimizing solid electrolytes for improved ion transport, mechanical properties, and compatibility with electrode materials, thereby steering the evolution of advanced battery designs.

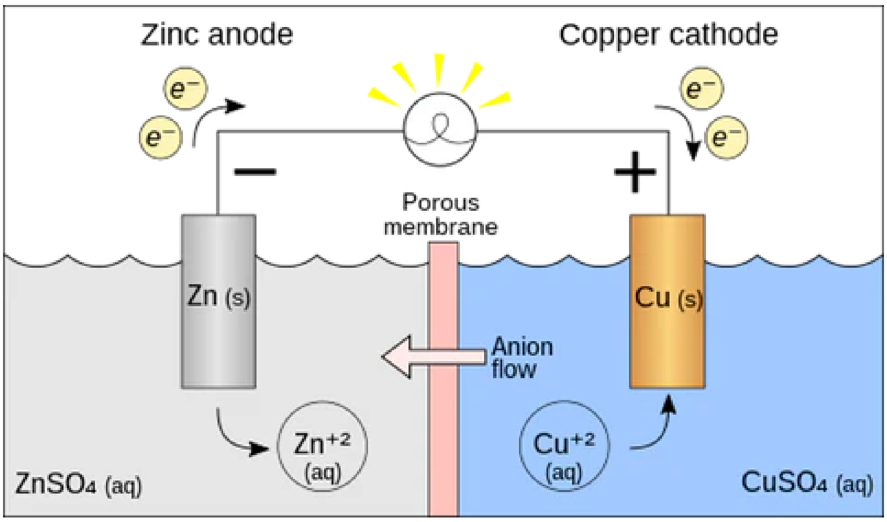


Figure 1: Generalized example of a battery, showing the electrodes, electrolyte, and porous separator.

Battery Overview

Separators:

Separators act as insulating barriers between the anode and cathode, ensuring efficient ion transport while preventing electrical contact and short circuits. Typically fabricated from porous materials like polyethylene or polypropylene, separators offer mechanical strength, thermal stability, and ion-permeable pathways. Their microstructure facilitates ion diffusion, promoting charge-discharge processes. Meanwhile, advancements have led to the exploration of advanced separators, particularly in the realm of solid-state batteries. Solid electrolytes inherently fulfill the separator function, negating the need for traditional separator materials. However, the design of solid-state electrolytes demands careful consideration of factors like ionic conductivity, mechanical flexibility, and interfacial stability. Innovations in separator technology are pivotal for enhancing battery safety, thermal management, and overall performance, especially as new chemistries and form factors emerge.

Current Collectors, Terminal, and Housing:

Current collectors, terminals, and housing form the external and structural framework of batteries, contributing to electrical connectivity, mechanical integrity, and safety. Current collectors, often made of conductive materials like copper or aluminum foil, serve as pathways for electron flow between the external circuit and the electrodes. They ensure efficient current distribution and collection, thus influencing the battery's overall performance and efficiency. Terminals provide the interface for connecting batteries to external devices or circuits, enabling energy transfer. The housing encases the internal components, safeguarding against environmental factors, physical damage, and thermal events. Battery housings are engineered for robustness, heat dissipation, and containment in the event of rare thermal runaway. As battery technologies evolve, the optimization of current collectors, terminals, and housing materials and designs becomes integral to achieving enhanced energy storage capabilities while prioritizing safety and usability.

Figure 2: Nokia X3-00 Li-Ion battery. Ensuring the terminals are clean and free of defects prior to installation into a phone is critical to prevent damage to both the battery and phone.

Microscopes and Batteries

Microscopes for Inspecting Batteries:

Optical microscopes, including upright compound microscopes, inverted microscopes, and stereo light microscopes, offer valuable tools for inspecting various components of batteries at different scales. These microscopes provide researchers and engineers with insights into the structural and morphological features of battery materials, aiding in quality control, failure analysis, and research and development efforts. Here's how each type of microscope can be employed to examine different parts of a battery and what aspects to focus on during inspection.

1. Upright Compound Microscopes:

Upright compound microscopes have emerged as invaluable tools for the comprehensive analysis of battery components, facilitating a detailed examination of various critical elements such as electrolytes, electrodes, separators, current collectors, and terminal housings. This non-destructive and precise inspection technique enables researchers and engineers to gain insight into the microstructural properties and integrity of battery components, contributing to enhanced battery performance, longevity, and safety.

In the investigation of battery electrolytes, an upright compound microscope allows for the visualization of electrolyte distribution and the identification of potential irregularities, such as phase separation or the formation of undesirable byproducts. This analysis aids in optimizing electrolyte formulations and maintaining consistent composition throughout the battery, thereby promoting optimal ion transport and minimizing the risk of short circuits or capacity degradation. Moreover, the microscope enables researchers to study the interaction between electrolytes and other components, shedding light on potential chemical reactions that may influence overall battery functionality.

The electrodes, separator, current collector, and terminal housing represent intricate elements within a battery architecture, each playing a pivotal role in its overall performance. The use of an upright compound microscope permits high-resolution imaging of these components, enabling the characterization of electrode morphology, active material distribution, and the integrity of the separator. By inspecting the current collector, researchers can assess its uniformity and connectivity, crucial for ensuring efficient current flow within the battery. Furthermore, the terminal housing can be scrutinized for signs of corrosion, mechanical damage, or faulty insulation, all of which could compromise the battery's safety and operational efficiency. In essence, the application of upright compound microscopes in battery inspection facilitates a comprehensive understanding of microstructural features, aiding in the design, optimization, and quality control of advanced energy storage systems.

2. Inverted Microscopes:

Inverted microscopes are particularly useful for studying battery components that require a larger working distance or need to be observed in liquid environments. Researchers can analyze the morphology and behavior of electrolytes, separators, and solid electrolyte interfaces. In situ studies involving electrodes immersed in electrolytes can reveal dynamic processes such as lithium-ion diffusion and dendrite formation. Evaluating the structural stability of solid electrolyte materials under various conditions is critical for the development of safer and more efficient solid-state batteries.

Microscopes and Batteries

2. Inverted Microscopes:

Additionally, these microscopes facilitate the examination of separator thickness and uniformity, shedding light on its crucial role in preventing electrode short-circuits while offering insights into the spatial distribution of active materials. The intricate topography of current collectors and terminal housings can also be scrutinized, allowing for the detection of surface defects, corrosion, or irregularities that could compromise the overall functionality and stability of the battery. In essence, inverted microscopes serve as essential instruments for non-destructive and high-resolution analysis of battery components, enabling comprehensive quality control and informed design optimization.

3. Stereo Light Microscopes:

Stereo light microscopes are valuable tools for inspecting larger battery components, such as full cells or modules. These microscopes provide a three-dimensional view of the sample, enabling researchers to examine macroscopic features, assembly quality, and any physical defects. In battery pack assembly, stereo microscopes can help identify issues like misaligned cells, faulty connections, or improper insulation that could compromise the overall performance and safety of the battery.

Figure 3: SM7 PLAN Stereomicroscope

What to Look For

When using optical microscopes to inspect battery components, there are several key aspects to focus on:

Microstructure:

The microstructure of a battery electrode refers to the arrangement and distribution of active materials, particles, and pores. This can be examined using a brightfield compound microscope. The microstructure is important because it affects the battery's performance. For example, a uniform and well-dispersed microstructure will result in better electrochemical reactions and a longer battery lifespan.

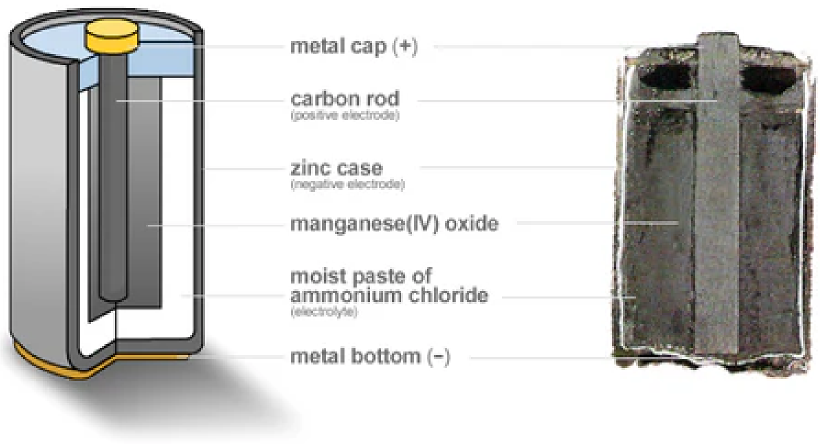


Figure 4: Cross-section of a typical Zinc battery. In quality control, the general microstructure of the metal oxides, casing, and carbon rods are inspected.

Coating Quality:

The coating quality of a battery electrode refers to the uniformity and thickness of the coating. This can be examined using a brightfield compound microscope. The coating quality is important because it affects the battery's performance. For example, an uneven coating may lead to uneven electrochemical reactions and a shorter battery lifespan.

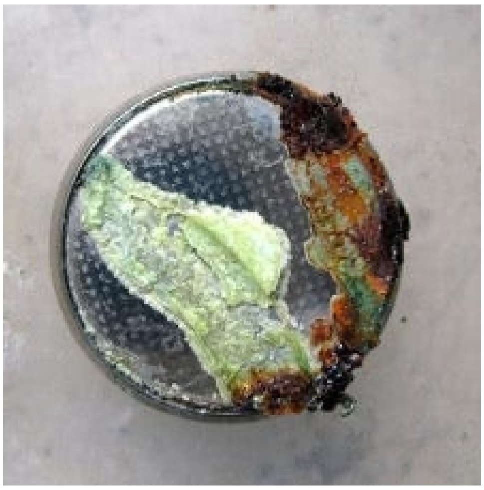


Figure 5: Example of battery which leaked and corroded. Ensuring even coating thickness of the battery may prevent these types of failures.

What to Look For

The brightfield compound microscope can also be used to examine the coating quality of battery electrodes. The uniformity of the coating can be assessed by looking for any areas where the coating is thicker or thinner than the rest of the electrode. The thickness of the coating can be measured by using a micrometer to measure the distance between the top of the coating and the bottom of the electrode.

Particle Size and Agglomeration:

The particle size and agglomeration of active materials in a battery electrode are important because they affect the battery's performance. Particle size affects the electrode's conductivity and energy density. Agglomeration can lead to poor conductivity and reduced capacity. These can be examined using a differential interference contrast (DIC) microscope. DIC microscopy can provide enhanced contrast and depth perception, which can be helpful for visualizing the microstructure of battery electrodes.

Separator Integrity:

The separator is a thin film that separates the positive and negative electrodes in a battery. It is important to inspect the separator for defects, such as pinholes or tears, which could result in internal short circuits and thermal runaway. This can be done using a stereo microscope. Stereo microscopes provide a three-dimensional view of the specimen, which can be helpful for visualizing defects in the separator.

Stereo microscopes use two lenses to create a three-dimensional image of the specimen. This can be helpful for visualizing defects in the separator, such as pinholes or tears.

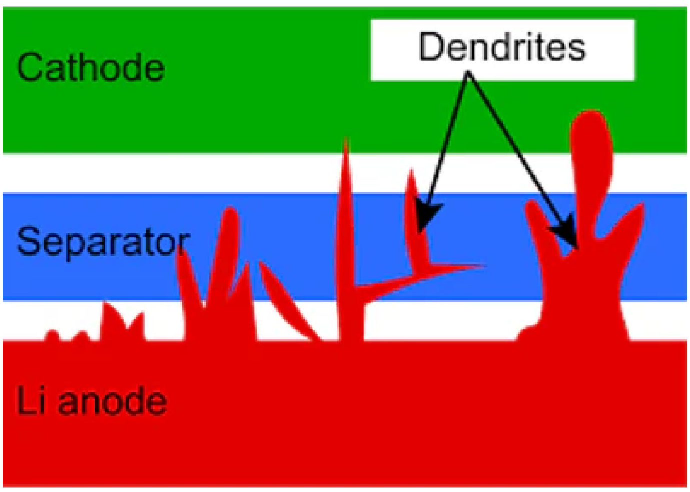


Figure 6: Schematic of dendrites penetrating the separator. Optical Microscopes can be used to identify these defects.

Summary

In the dynamic landscape of battery technology, the quest for improved efficiency, sustainability, and compactness has led to the emergence of cutting-edge solutions like solid-state and lithium-air batteries. These innovations hold the potential to revolutionize energy storage, shaping a future where electronics, transportation, and renewable energy systems are more powerful, durable, and environmentally friendly. Electrodes, electrolytes, separators, current collectors, terminals, and housing collectively constitute the intricate architecture of batteries, with each element playing a crucial role in performance and safety. Leveraging the capabilities of optical microscopes, including upright compound microscopes for comprehensive analysis, inverted microscopes for in-situ observations, and stereo light microscopes for macroscopic inspections, researchers gain vital insights into microstructural features and macroscopic defects. Through meticulous examination of microstructure, coating quality, particle characteristics, dendrite formation, separator integrity, and assembly defects, these microscopes facilitate informed design optimization, quality control, and enhanced battery performance. As advancements in battery technology persist, the synergy between innovative battery designs and microscopic analysis promises a future of increasingly efficient, reliable, and safer energy storage solutions.

SM7 Series

The First Motic Stereo Plan-Apochromat: Enjoy and Be Surprised.

Power in any Aspect

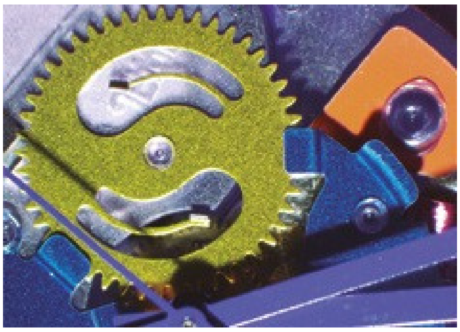
The SM7 features an optical performance with true colour reproduction, high resolution and low distortion. A stand with Incident/Transmitted LED light supplies variable illumination.

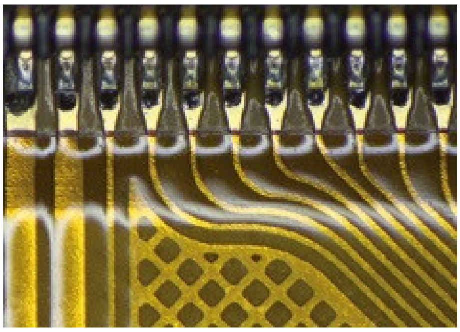
Stand Design

Ultra-flat stand bases for a relaxed positioning of hands and forearms facilitate lengthy preparation work. Pick your C. Elegans nema- todes from the petri dish, mount your gearwheel into the clockwork. The advanced ergonomic design maximizes efficient usage and minimizes fatigue.

Flexibility for Individual Demands

A variety of objectives and eyepieces allow tailoring a personal SM7. Upgrade your workplace with ergonomic stands and powerful optics, whether Apochromatic colour fidelity is in focus or improved resolution power.





SM7 Series

Motic SM7: High-Precision Galilean Optics

Galilean Optical System

The Galilean Optics of the SM7 show a 7:1 Zoom system, resulting in a standard magnification range of 8X-56X. A 10-Position Click-Stop helps to set precise magnifications in case repeatable measurements are required. The standard optical setup can be varied by exchanging objectives and/or eyepieces.

Superior Optics

For the best possible image results, a 1X Plan-Apochromatic objective with a Working Distance of 81mm is available. True-colour reproduction combined with improved Field Flatness and minimized image defects: both the world of living beings and technical samples are covered by our SM7 stereomicroscope.

Resolution Power for Tiny Details

Besides minimized chromatic and spherical aberrations, it is the resolution of the 1X Apochromatic objective which makes the SM7 especially interesting for technical applications. 36% more resolution power, an increase worth mentioning.

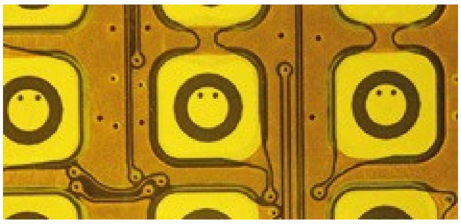
Powerful vizualisation for both eyes and camera

Eyepieces

The High eyepoint eyepieces 10X/22 suit spectacle wearers and offer a diopter adjustment range within +5/-8 dpt. Easy use of reticles is Motic's top model standard.

Observation Tubes

Our Trinocular head is supplied with a 100:0/20:80 2-position beam split, providing sufficient light to the camera port even under lowlight conditions. C-Mount cameras are adapted to the respective camera sensors. Besides the standard Binocular tube, a 60° inclination tube is available to meet special OEM demands.



SM7 Series

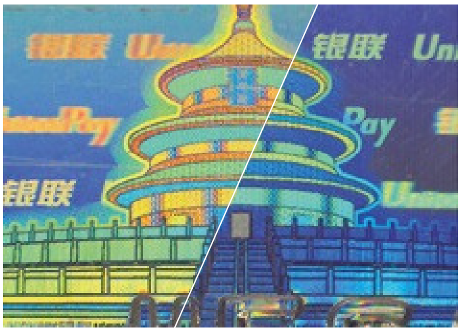
Illumination is the Second Key for the Safe of Information

Illumination

For years LEDs are replacing Halogen light sources in business and private life. A low energy consumption, a long lifetime and, especially for living samples, a low heat production are the main arguments.

Transmitted / Incident Light Stands

The SM7 Stand for transparent and opaque specimen incorporates 3W LEDs for both types of illumination, with separate controls for mixed samples. An optional 4-segment ring illuminator is meant for the standard stand. Herewith surface topographies can be visualized by activating different illumination angles. The SM7 features signifi- cantly flat stand bases for ergonomic positioning of hands and forearms. Long preparation work can be done without early fatigue. For ESD sensible work, Motic’s ESD and surge protection system complies with both UL and CL standards and regulations. An essential feature for electronic and electric quality control environments.



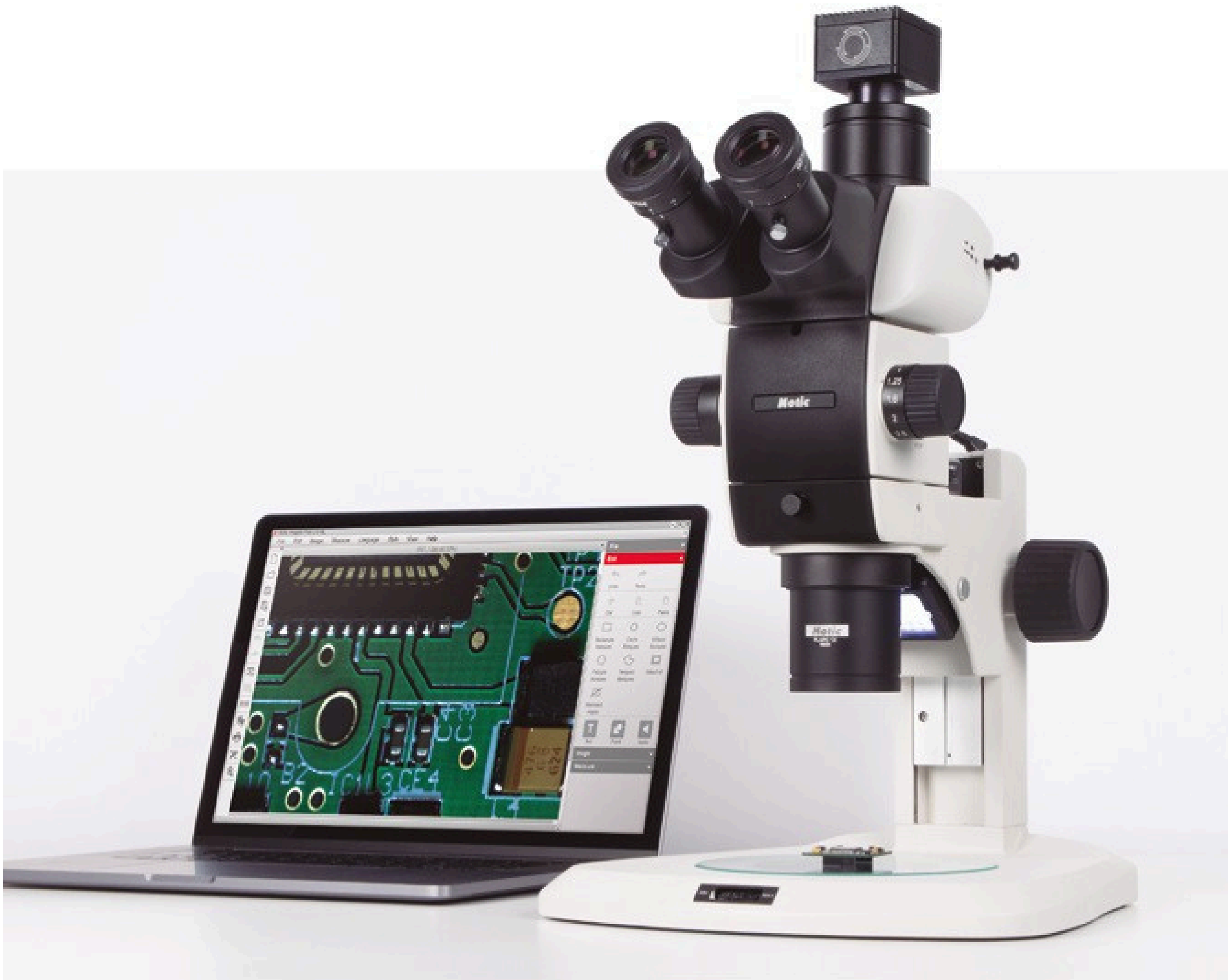
Moticam S-Line

Scientific-Grade Microscope Cameras

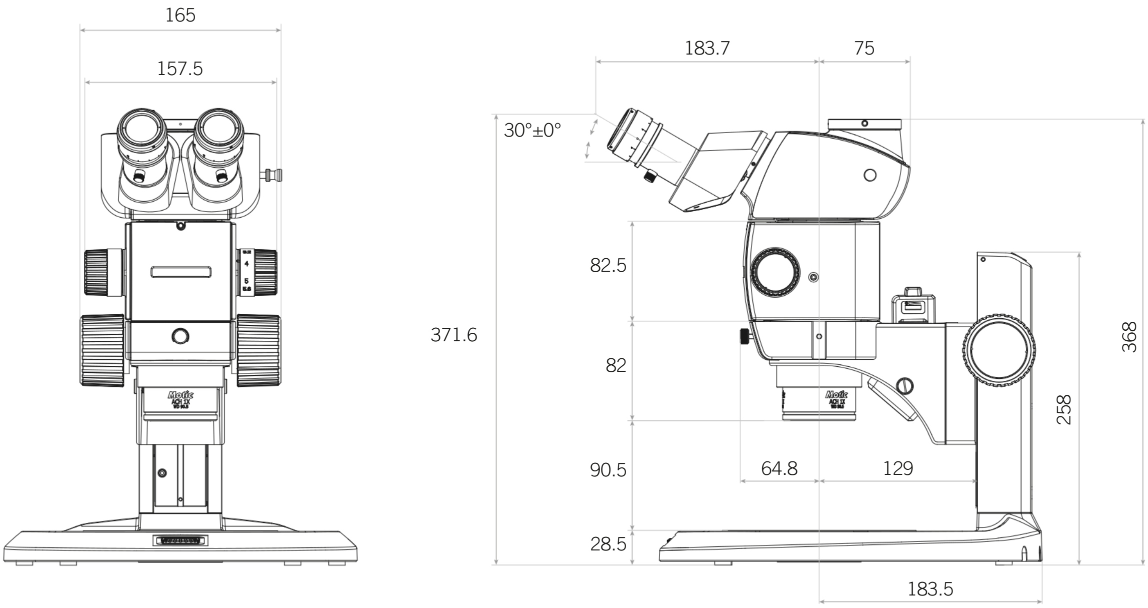
The new Moticam S-line marks a further step in Motic's digital microscopy. By utilizing the latest sCMOS sensors coupled with our own PCB design and on-board image management, each Moticam S series promises professional digital results at an affordable price. This MoticamS-line is designed and manufactured completely in-house under strict German quality guidelines. Whether for Clinical, Research or Industrial, this new generation of Moticams has got the answer for every demand. At Motic, we believe in making High-level Digital Microscopy affordable for everyone. You surely will enjoy this camera line.

Key features

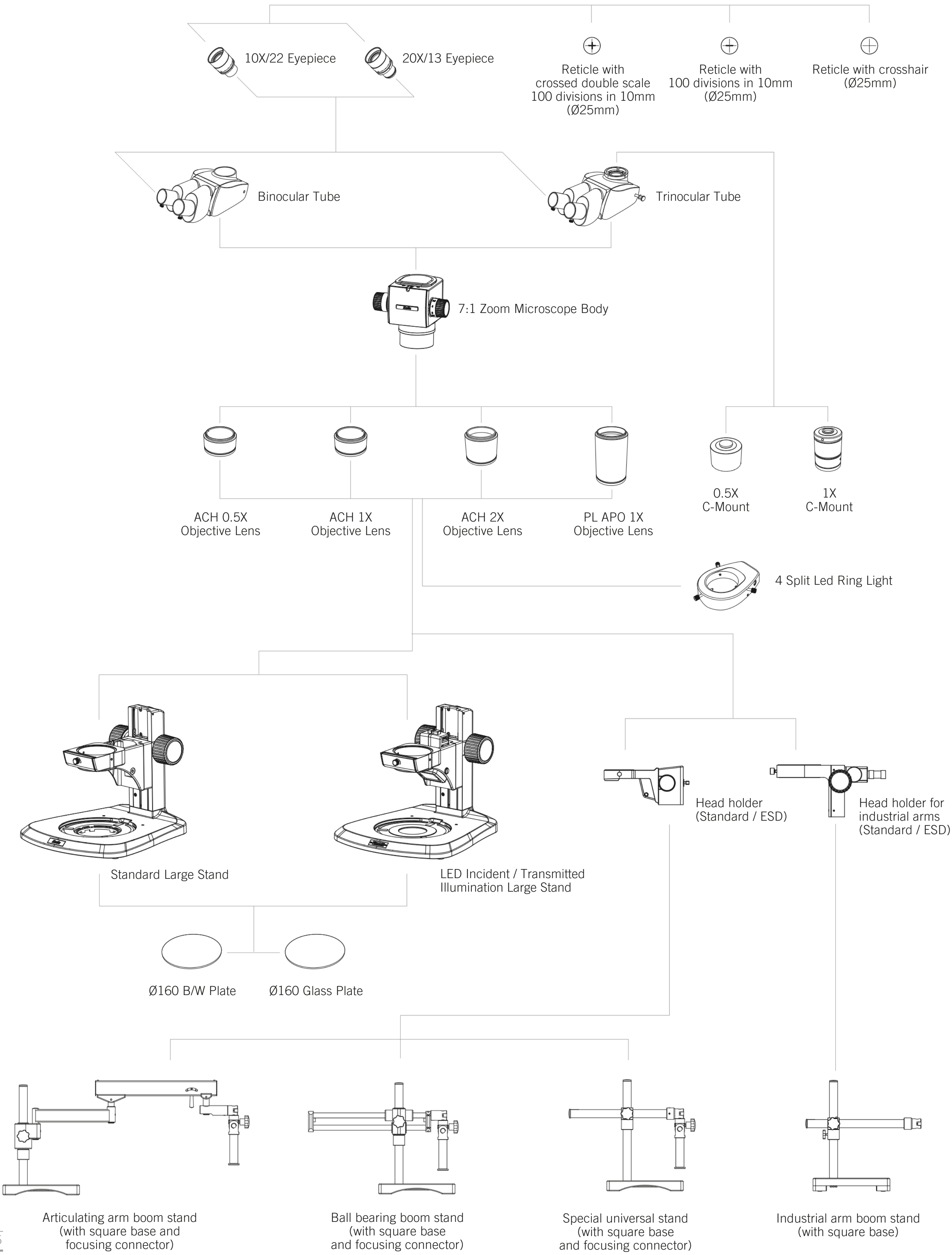
- Super-Fast Frame Rates
- USB 3.1 Data Transfer
- True color reproduction
- sCMOS Sensor
- Up to 20MP Resolution
- Rolling and Global shutter models



SM7 Series Dimensions



SM7 Series System Overview



SM7 Series Technical Specifications

Sku	1100201800061	1100201800021	1100201800071	1100201800031
Name	**SM7-P A1X**	**SM7TR-P A1X**	**SM7-P APO1X**	**SM7TR-P APO1X**
Optical system	Galilean infinity optical design. Common Main Objective (CMO)			
Observation tube	Binocular head	Trinocular head	Binocular head	Trinocular head
Inclination	30º inclined			
Trinocular light split	-	100:0/20:80	-	100:0/20:80
Interpupillary distance	55-75mm			
Diopter adjustment	On both eyepieces, +5/-8 diopter			
Eyepieces	Widefield WF10X/22mm with diopter adjustment			
Objectives system	Zoom, ratio 7:1			
Objectives classification	Plan Achromat		Plan Apochromat	
Objectives	0.8X~5.6X (10-step)			
Working distance	90mm		81mm	
Stand type	Fixed-arm stand			
Head holder	For Ø76mm head			
Focus mechanism	Coarse focusing system with tension adjustment			
Focusing stroke	120mm			
Incident illumination	-			
Transmitted illumination	-			
Transformer	-			
Power supply	-			
Accessories included	Dust cover, Black/White plate Ø160mm			
Dimensions LxWxH	367x290x372mm			
Base	310x290mm			
Column/Arm	254mm			
Net weight	6.9 Kg	7 Kg	7 Kg	7.1 Kg
CONTRAST TECHNIQUES				
Brightfield	Brightfield			

1100201800081	1100201800041	1100201800091	1100201800051	Sku
SM7-TLED A1X	**SM7TR-TLED A1X**	**SM7-TLED APO1X**	**SM7TR-TLED APO1X**	Name
Galilean infinity optical design. Common Main Objective (CMO)				Optical system
Binocular head	Trinocular head	Binocular head	Trinocular head	Observation tube
30º inclined				Inclination
-	100:0/20:80	-	100:0/20:80	Trinocular light split
55-75mm				Interpupillary distance
On both eyepieces, +5/-8 diopter				Diopter adjustment
Widefield WF10X/22mm with diopter adjustment				Eyepieces
Zoom, ratio 7:1				Objectives system
Plan Achromat		Plan Apochromat		Objectives classification
0.8X~5.6X (10-step)				Objectives
90mm		81mm		Working distance
Fixed-arm stand with incident & transmitted illumination				Stand type
For Ø76mm head				Head holder
Coarse focusing system with tension adjustment				Focus mechanism
120mm				Focusing stroke
LED 3W with intensity control				Incident illumination
LED 3W with reflector and intensity control				Transmitted illumination
External				Transformer
110-240V (CE)				Power supply
Dust cover, Glass plate Ø160mm				Accessories included
367x290x372mm				Dimensions LxWxH
310x290mm				Base
254mm				Column/Arm
7.3 Kg	7.4 Kg	7.4 Kg	7.5 Kg	Net weight
				CONTRAST TECHNIQUES
Brightfield				Brightfield

Motic®

Canada | China | Germany | Spain | USA

See the SM7 in action

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