An infrared broadband thin-film polarizing beam splitter with high environmental reliability

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Keywords: Environmental reliability, Long-wave infrared, Optical coatings, Polarizing beam splitter

High-power lasers have numerous scientific and industrial applications. In this study, we present the development of a high-reliability infrared broadband thin-film polarizing beam splitter (PBS), which plays a critical role in laser beam splitting, modulation, shaping and isolation. Our work addresses the challenge of device failure due to tensile stress in Ge/YbF_3 multilayer coatings by incorporating ZnSe compensation layers in the multilayer design. We have systematically analysed the changes in the spectral and stress properties of the infrared PBS after incorporating ZnSe layers. The infrared PBS is operated at 45° and in the long-wave infrared (LWIR) band. For the preparation of the infrared PBS, we combine the percent of optical extrema monitoring (POEM) strategy with the high-temperature optical constants (HTOC) of Ge film for optical thickness monitoring. The HTOC of Ge film provides a more accurate theoretical transmittance monitoring curve, which gives the POEM strategy a more accurate baseline for real-time correction of trigger points, thus improving monitoring accuracy. The resulting PBS exhibits outstanding spectral characteristics, with p-polarization transmittance exceeding 96% and an extinction ratio surpassing 100:1 within the 10.6±0.15 μm band. Additionally, comprehensive tests verify its commendable environmental reliability.

An integrated order blocking filter for near infrared hyperspectral imaging system

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Keywords: grating dispersion, high order spectra, hyperspectral imaging, integrated filter

Hyperspectral imaging technology provides high spectral resolution information of objects on the Earth. Howerve, high order spectra of convex grating and infrared background radiation of objects have negative impacts on the image quality of system. Order blocking filter is recognized as an effective method to solve the problems. An integrated order blocking filter, of which the working spectrum covers from 1.0μm to 3.0μm, is designed and fabricated for the hyperspectral imaging system. According to analysis the working principle of reflective Offner convex grating dispersion, the optical substrate is divided into several areas to solve two problems. The short-cut filter and F-P bandpass filter layers are deposited on the corresponding areas of the substrate to block the higher-order spectra and solve the problem of no dispersion ability in zero order, respectively. The optical transmittance efficiency of the filter is higher than 93%, and the higher-order blocking efficiency can reach to OD4. Fine mask technique is adopted to ensure that the size of each adjacent area is less than 30μm, and the spectra utilization efficiency is improved effectively.

Backscattering measurement system for HR films of gravitational wave detection telescopes

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Keywords: Stray light, Surface scattering, gravitational wave detection

Telescope is the core payload of space-based detector and a key component for realizing inter-satellite interferometric measurements, aiming to improve light efficiency. Due to the transmit-receive design of telescope, 4-watt power laser is barely sufficient to supply 10-nanowatt laser at the receiving telescope due to the long arm length. Therefore, even weak backscattered light can cause significant disturbances to the final beat frequency signal. It places higher specifications on the design and measurement of stray light. In this paper, a measurement system is designed to measure ultra-low backscattered light. In order to effectively control stray light from other sources, we select sapphire as spectroscopic plate, and reduce surface scattering by controlling its RMS at 0.4nm. What's more, by designing the thickness of the spectroscopic plate and blackening all but the optical path, we have reduced the residual stray light reflected from the plate. We have also designed a baffle to block stray light through the inside walls. Experiment results obtained in clean room shows that the test level of stray light can be 10^{-8}, corresponding BRDF can be 10^{-5}.

Effect of laser peening without coating on electrochemical corrosion and microstructure behavior of Zr-4 alloys

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Keywords: Electrochemical corrosion, Laser Peening Without Coating (LSPwC), Pressurized water reactor (PWR), Surface modification, Zr-4 alloy

Zr-4 alloy has been widely used in fuel cladding of pressurized water reactors (PWRs). In this study, Zr-4 alloy was modified by laser peening without coating (LSPwC). Compared with the substrate, the electrochemical corrosion resistance of laser modified Zr-4 alloy has been improved. The surface morphology, phase structure, and element distribution of Zr-4 alloy were analyzed by scanning electron microscopy (SEM), energy dispersive spectroscopy (EDS), and X-ray diffraction (XRD). The depth of the strengthening layer of Zr-4 alloy after LSPwC was determined by residual stress in the surface and depth directions, as well as microhardness (HV). Mechanical twinning and grain refinement of samples were observed by Electron backscattered diffraction (EBSD), and the mechanism of LSPwC improving the electrochemical corrosion resistance of Zr-4 alloy was elucidated.

Exposure response kinetics in UV photoresist characterized using in-situ spectroscopic ellipsometry and dynamic exposure modeling

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Keywords: Exposure response kinetcs; in-situ spectroscopic ellipsometry; two-step regression analysis; dynamic exposure modeling; UV photoresist

Investigating the exposure kinetics properties of UV photoresists is critical for gaining a comprehensive understanding of the lithography mechanism, allowing us to optimize the lithography process and create a more accurate computational lithography model. In this work, we propose an in-situ spectroscopic ellipsometry for characterizing the dynamic optical responses and the photochemical reaction properties of typical UV photoresist film during exposure. A two-step regression analysis algorithm, which consists of the dielectric function fitting based on the stratified optical model and the recursively iterative fitting of Dill's parameters based on the exposure process, has been proposed to extract the dynamic response parameters from the dynamic ellipsometric parameters. In-situ measurement experiments of 2000nm- and 1300nm-nominal-thick AZ5214 photoresist films exposed by a commercial UV light source with tunable power at a wavelength of 365 nm have been carried out to demonstrate the method. The comparison results concerning the film thickness, surface roughness, complex refractive index, and the Dill model parameters can validate the accuracy and reliability of the proposed method. With in-situ and long-term monitoring of the photoresist film under various exposure powers, the dynamic complex refractive index can be captured, showing the decay characteristics of the reaction rate concerning the reaction time. Through the linear regression of the steady-state reaction rate per unit photoactive compound concentration, the standard exposure rate constant can be accurately determined, whose thickness dependency has been revealed. Besides, we have proposed a patterned exposure simulation model consisting of an aerial image computation module and a photoresist photochemical reaction simulation module, which are used to evaluate the influence of the dispersion errors on the photoresist's latent images. As the exposure intensity and the exposure pattern contrast increase, the impact of dispersion error in the Dill parameters on the photoresist's latent images is more significant.

Infrared Optical Coatings for the Atmosphere Radiation Hyperspectral Sounder

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Keywords: complex refractive indices, cryogenic properties, infared optical coatings

Optical coatings are designed and produced for the Atmosphere Radiation Hyperspectral Sounder which operates in the spectral range 3.2–15.5mm. The choice of the substrates and thin-film materials is discussed. The complex refractive indices of these materials are determined. Several kinds of theoretical solutions are studied for designing different optical coatings such as broadband beam-splitter coatings for a Michelson-type interferometer used as a Fourier spectrometer, broadband antireflection coatings and dichroic coatings also filter coatings for cold optical systems. The cryogenic properties of these coatings are discussed at the same time.

nonlinear effect of optical coatings

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Keywords: optical coatings; nonlinear effect; ultrafast laser

Recently, the nonlinear effect of optical thin films are attracted more and more attention. In this presentation, we present the design method of multilayer coatings considering the nonlinear optical responses, study the nonlinear effect of different coating materials and the measurement approach for different nonlinear responses.

Optical and Physical Properties of Aluminum Oxide and Nitride Films Using Different Reactive HIPIMS Techniques

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Keywords: Aluminum oxide and nitride films, Deep oscillating magnetron sputtering (DOMS), Plasma-assisted reactive pulsed-DC magnetron sputtering (PAR-PDMS), Reactive HIPIMS, Superimposed HIPIMS-MF sputtering, and plasma-assisted reactive HIPIMS (PAR-HIPIMS).

Aluminum oxide and nitride films have a wide range of applications in wear resistance, corrosion, optics, optoelectronics, microelectronics, and other technology fields. High-power impulse magnetron sputtering (HIPIMS) has recently gained considerable attention in thin film sputtering and has been widely applied in various industrial sectors. It is a powerful technology for multilayer and nano-composite hard coatings that improve film adhesion. HIPIMS has also been used in optical thin film coatings for higher film density, higher index of refraction, and lower surface roughness can be obtained for the optical coatings. However, this process has issues, such as plasma instability, high arcing, and slow oxides or nitrides deposition rates. The generation of these issues is primarily due to the reactive gases that cause the formation of a dielectric layer on the sputtering target's surface, leading to the accumulation of surface charges and resulting in the dielectric breakdown phenomenon. In this study, we prepared aluminum oxide and aluminum nitride films using various deposition techniques, including reactive HIPIMS, superimposed HIPIMS-MF sputtering, deep oscillating magnetron sputtering (DOMS), plasma-assisted reactive pulsed-DC magnetron sputtering (PAR-PDMS), and plasma-assisted reactive HIPIMS (PAR-HIPIMS). The optical properties, surface characteristics, and residual stresses of aluminum oxide and nitride films were examined employing a UV-VIS-NIR spectrophotometer, spectroscopic ellipsometer, X-ray diffraction, and phase-shifting Twyman–Green interferometer. The results showed that different processes can modify film properties for various optical coating applications. DOMS and PAR-HIPIMS processes prevent arcing during aluminum oxide film deposition. When selecting film properties for optical coatings, it is essential to consider the specific requirements of each application. Techniques, especially PAR-HIPIMS, can modify these properties, prevent arcing during deposition, and produce high-quality optical thin films. Therefore, the PAR-HIPIMS process can improve the performance of aluminum oxide and nitride films for application in optical coatings.

Pixel-level Spectral Filter and Its Applications

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Keywords: Filter, Image sensor, Pixel level, Spectral, Spectroscopic

Pixel-level spectral filter is a novel spectroscopic element. Its spectral channel is one-to-one correspondence with the imaging sensor’s pixel. Pixel-level spectral filter can be integrated with the imaging sensor and simplify the spectroscopic system. By using pixel-level spectral filter as a spectroscopic element, spectral imaging devices can realize miniaturization, lightweight, and snapshot spectral imaging. This presentation introduces several pixel-level spectral filters working in visible, near infrared and short-wavelength infrared region. Then we report the integration between pixel-level spectral filter and imaging sensor. Finally, by combination of spectroscopic and imaging techniques, we report spectral imaging sensor ingegrated with pixel-level spectral filter inside and its applications.

Preparation Technology of Medium Reflective Film for Large Aperture Planar Mirrors

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Keywords: Large aperture planar mirrors□high reflectivity□high threshold

Large aperture planar mirrors are the core components of large optical systems, and the preparation of all dielectric high reflectivity and high threshold thin films is the bottleneck process of this core component. With the development of scientific research, the demand for large optical systems is becoming increasingly prominent, and the aperture of planar mirrors is becoming larger and larger. This article takes the actual preparation of a 1770mm aperture flat mirror as an example to introduce several key technologies of large aperture dielectric reflection films, including adjusting film thickness uniformity, film forming process, designing and measuring spectral reflection efficiency, and introducing related equipment.

Randomized Metallic Mesh-based Multiband Optical Window for Low-diffraction EMI-shielding

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Keywords: EMI shielding, Optical window, multi-band AR-coatings, randomized metallic mesh

This study introduces an advanced electromagnetic interference (EMI) shielding multiband optical window, which significantly enhances the performance of electro-optical systems in electromagnetically active environments. Unlike traditional solutions that rely on periodic metallic mesh structures, our structure incorporates a randomized metallic mesh. This innovative approach not only achieves a remarkable reduction in high-order diffraction optical energy by 78% but also surpasses the electromagnetic shielding effectiveness threshold of 20 dB within the 12–18 GHz frequency band. A high-efficiency optimization process for designing randomized metallic mesh structure is proposed to eliminate the need for complex modeling and simulation. Furthermore, we apply a multiband antireflection coating, consisting of a nine-layer ZnS/YbF_3 stack, to achieve an efficient antireflection effect, yielding an exceptional average optical transmittance of 87% within the 0.4-0.7μm band, 89.8% at 1.064μm, and 80% across the 3-5μm band. With its outstanding optical and EMI shielding performance, along with enhanced durability and environmental stability, the proposed multiband optical window presents a groundbreaking solution for applications requiring high-quality optical imaging and effective EMI protection. This work not only demonstrates the feasibility of such designs but also paves the way for future innovations in optical window technology.

Research on High Reflective Reflective Film in 2.9-meter Aperture Mirror Surface

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Keywords: highly reflective film□2.9meter aperture□ion assisted deposition

Large aperturemirrors are key components in large optical systems.They are often used in main optical systems, and requiring the reflective film to have high reflectivity over a wide spectral range. The development process of the film layer for large-diameter mirrors is high-risk, and mirror aperture above 2.5 meters in the world are mostly coated with mirror facing up or mirror facing vertically. In this study, the mirror face down and ion beam assisted deposition coating method were used to develop a 2.9 meter mirror high reflectivity reflective film. Through the study of coating process and uniformity within a 2.9 meter aperture, a high reflectivity reflective film with uniform spectrum and excellent reliability was obtained within a 2.9 meter aperture.

Research on the application of composite materials in high-power laser coatings

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Keywords: composite materials, laser coatings, laser-induced damage threshold, optical performance

Laser coatings are the key elements of high-power laser systems, and their optical performance and laser-induced damage threshold (LIDT) directly affect the output power of the laser systems. The intrinsic properties of coating materials are crucial factors that affect LIDT. Traditionally, there is a trade-off between the required optical performance and LIDT because suitable candidate coating materials are limited. In this report, a variety of high-power laser coatings have been realized by introducing composite materials such as mixture materials and nanolamination materials and optimizing the coating design. The properties of the composite material-based coatings have been studied and compared with the traditional laser coatings, showing improved results for the former.

Research on the key technology of 2-meter ultra-wide spectrum composite membrane system

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Keywords: CSST ultra-wide spectrum High reflectivity Composite film system non-uniformity

The China Space Station Telescope (CSST) is equipped with a 2-meter primary mirror. The back-end module of the telescope consists of multiple modules, resulting in a complex composition of the working band and wide coverage area. It encompasses wavelengths ranging from 250nm near ultraviolet to terahertz, including visible light, near infrared, and short-wave infrared. The reflectance requirements for different spectra are as follows: an average reflectance better than 0.86 in the 0.25-0.32μm spectrum, an average reflectance better than 0.91 in the 0.32-0.4μm spectrum, an average reflectance better than 0.96 in the 0.4-0.9μm spectrum (repeated), an average reflectance better than 0.95 in the 0.9-1.75μm spectrum, and an average reflectance better than 0 .96 in the 1.75 -2.0 μ m spectrum.The difference between minimum and average reflectances of each individual mirror should be less than 5% across all working spectra.

Therefore, it is necessary to plate the SiC mirror in the main optical system with a high-demand reflective film that exhibits high reflectivity across all mentioned bands.To meet this requirement while considering ultra-wide spectral range and service life requirements,a composite film system structure composed of metal reflective film and UV-enhanced multilayer dielectric film was designed.The design ensures compliance with specified index requirements.Improvement on non-uniformity of film layer was achieved using our self-developed equipment measuring up to 4 meters,resulting in controlled non-uniformity within ±1% for film thickness.

Structural and optical properties of novel NiV-based multilayer mirrors for the soft X-ray region

by Zile Wang | Zhe Zhang | Jialian He | Angelo Giglia | Qiya Zhang | Runze Qi | Qiushi Huang | Shengzhen Yi | Zhong Zhang | Zhanshan Wang | Tongji University | Tongji University | Tongji University | CNR Istituto Officina Materiali | Tongji University | Tongji University | Tongji University | Tongji University | Tongji University | Tongji University

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Keywords: NiV/Ti multilayer, NiV/V multilayer, interface, reflectivity, structure

Novel NiV($Ni_{93}V_7$)/Ti multilayer has been investigated for operation in the wavelength region of 350-500 eV. It is expected to be fabricated for application in the Z-pinch plasma diagnostic, reflecting the emission lines of plasma at the grazing incidence angle. The NiV/Ti multilayer shows superior structural and optical performance compared to conventional Ni/Ti multilayer. The grazing incidence X-ray reflectivity (GIXR) results show that replacing Ni with NiV in multilayer decreases interface widths and enhances the contrast of refractive index between the absorber and spacer layers. X-ray diffuse scattering (XRS) and grazing-incidence small-angle X-ray scattering (GISAXS) measurements indicate that NiV/Ti multilayer has lower interface roughness and smoother growth. In accordance with the X-ray diffraction (XRD) and transmission electron microscope (TEM) measurements, the improvement of interface quality of NiV/Ti multilayer compared with Ni/Ti can be attributed to the suppression of the crystallization of Ni inside the structure, by reason of the introduction of V. The improvement of structure contributes to the enhancement in reflectance. Under the grazing incidence of 13°, a peak reflectivity of 25.1% is achieved for NiV/Ti multilayer at 429 eV, while 17.7% for Ni/Ti at 427 eV. Based on these, a novel NiV/V multilayer is also be synthesized and studied for the application of grazing-incidence optical system of the plasma diagnostic at 500eV.

Vanadium Dioxide-Based Perfect Absorber with Switchable Narrowband to Broadband Absorption Capabilities

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Keywords: absorber, multilayer film, vanadium dioxide

We present a novel absorber design utilizing the phase-change properties of vanadium dioxide (VO_2). Building upon a three-layered absorber structure anchored on a metallic reflective layer, we introduce an enhanced microstructure configuration. This design exhibits versatility in switching between narrowband and broadband absorption. Prior to the phase transition of VO_2, the structure predominantly demonstrates a narrowband absorption, peaking at 4.2μm with an efficiency exceeding 99%. Following the phase transition, the absorber displays broadband absorption, capturing over 90% of the incident light within the 3.5-5μm spectrum. Notably, our design permits precise modulation of the narrowband absorption peak's position without significantly affecting its broadband absorption features. Leveraging the principles of multilayer film theory, this absorber can be conveniently tailored to other spectral ranges, as exemplified by our design adaptation for the 8-10μm wavelength. Through detailed simulations, we expound on the underlying mechanisms governing both the narrowband and broadband absorption phenomena. Collectively, our findings pave the way for innovative advancements in perfect absorber designs.