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TECHNICAL PAPER

Multispectral Array Technology – Meeting New Space Economics and Obligations

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ABSTRACT

For over 40+ years, Materion Precision Optics (formerly Barr Associates) has been providing cutting edge multispectral arrays for high end government sponsored programs (Landsat, VIIRs, etc.). By working closely and collaborating with our customers over the years, we have developed solutions to improve large angle scatter (LAS), ghosting, R%, stray light management, and channel-to-channel cross talk. We have also implemented mechanical solutions for stress balancing, opaque masking, dimensional tolerance and focal length matching. Our broad knowledge and understanding of these challenges gives us the unique ability to mitigate and balance them against the economics of ever expanding commercial applications. "New Space" is no longer about exploration and science alone. It is clearly a material enterprise where profit is a key component of success. New methods, technologies and capabilities are required to meet those needs. Our familiarity with technical requirements combined with our in-depth grasp of today's economics, allows us to reduce costs while maintaining high-end deliverables. Topics to be covered within this presentation include; how to leverage previous qualification testing, how to combine multiple customer requirements for cost sharing, how to minimize testing costs, and how to reduce complexity by scheduling and utilizing up front collaboration. In addition, there are references to anticipated advancements such as: expansion of our multispectral arrays beyond the VIS, NIR and SWIR and into the MW and LW; development of smaller stick widths; and improvement of ghosting through construction of parallelogram arrays.

Keywords: *Remote sensing, multispectral imaging, hyperspectral, earth observation, agricultural monitoring*

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MULTISPECTRAL ARRAY TECHNOLOGY – MEETING NEW SPACE ECONOMICS AND OBLIGATIONS

1. INTRODUCTION

Multispectral imaging has long been a cornerstone of earth observation and remote sensing satellites. In the past, this technology was extremely expensive to build and reserved for large government-sponsored programs (Landsat, VIIRS, etc.). Today, with the growth of marketable applications in space, this technology is moving towards more economically viable solutions. Materion's multispectral array technology has the capability to provide precisely that. This presentation will illustrate how Materion's 40+ years of space heritage enables us to be a key partner in the expansion and commercialization of space. While providing cutting edge capabilities and technologies, we are able to remain sensitive to market demands. The ARRAYTEC™ product line is specifically designed to meet these twofold requirements.

2. CHANGING LANDSCAPE

The multispectral imaging market is expected to grow to over $21 billion USD by 2023. A significant portion of that expansion will occur in what's referred to as "New Space." Gone are the days when performance alone determined success – now profitability will be key. In order to meet this challenge, companies will need to be agile, creative and extremely sensitive to market demands. At the same time, customers will require payloads to be smaller, cheaper and faster. This will make it critical for suppliers to maintain technological excellence. Essentially, industry is demanding high resolution imaging without the previously associated high cost.

3. HERITAGE AND TECHNOLOGY

With our extensive experience in complex optical manufacturing, Materion is uniquely positioned to provide leading-edge multispectral capabilities. Materion has supported a broad range of notable programs including: Landsat ,Worldview, Earthview, Joint Polar Satellite System (JPSS), James Webb Space Telescope (JWST), Cassini, Moderate Resolution Imaging Spectroradiometer (MODIS), Multi-Angle Imaging SpectroRadiometer (MISR), Geostationary Operational Environmental Satellite (GOES), Earth Observing-1(EO1), Lunar Reconnaissance Orbiter (LRO), Advanced Very-High-Resolution Radiometer (AVHRR), Infrared Atmospheric Sounding Interferometer (IASI), JASON, Sentinel Land Surface Temperature Retrieval (SLSTR), Sentinel-2, Hubble Space Telescope (HST), JunoCam, Himawari, Suomi National Polar-Orbiting Partnership (Sunomi NPP), Multispectral Thermal Imager (MTI), Moon Minerology Mapper (MMM), Mars Space Lab (MSL), as well as nearly every mission orbiting or landing on Mars. These represent a small sampling of the 100s of space programs on which we have built our 40+ year heritage. Materion has delivered literally tens of thousands of optical filters that have flown in space missions. Our products are also currently used in multiple commercial and government programs that require superior technological capabilities.

While not all these programs employ our multispectral arrays, working on them expanded our knowledge, expertise and ability to qualify space products. All of our array products utilize the same capabilities, design techniques and deposition processes to support these programs. Collaborating closely with our partners, we have been able to improve in critical areas like (LAS), ghosting, R%, stray light management and channel-to-channel cross talk. We have developed mitigating mechanical solutions for stress balancing, opaque masking, dimensional tolerance and focal length matching and also have proven capability to provide assembled arrays with > 100 bands, stick widths < 25um, lengths > 150mm.

3.1 DEPOSITION TECHNOLOGY

Our deposition technologies include ion assist, magnetron sputtering, energetic sputtering, e-beam evaporation and ion beam sputtering. These enabling technologies provide filter deposition capability from the UV (180nm) through the far infrared (30um). Materion operates over 100 deposition systems worldwide. They vary in size from single spinner “one of” specialty systems to large volume manufacturing systems. All facilities are uniquely equipped to provide durable, robust, high-performance optical coatings.

3.2 MANUFACTURING TECHNOLOGY

In addition to our broad deposition technologies, we offer advanced micro-dicing and micro-assembly capabilities. With state-of-the-art dicing equipment and proprietary techniques, we have the expertise to size and manufacture stick widths as small as 20um with lengths as long as 180mm.

Our arrays are manufactured in two distinct ways: First, we offer monolithic arrays (Figure 1). These are multiple filters manufactured onto a single substrate. By employing our semi-conductor grade photolithography techniques, we can provide coated band areas of nearly any shape, size or configuration. Some of the benefits of a monolithic array are its excellent coplanarity and small feature size. Some of its drawbacks are limited band number, (typically three to six bands max as compounding yield becomes a factor), band-to-band cross talk (no internal separation between bands) and stress balancing.

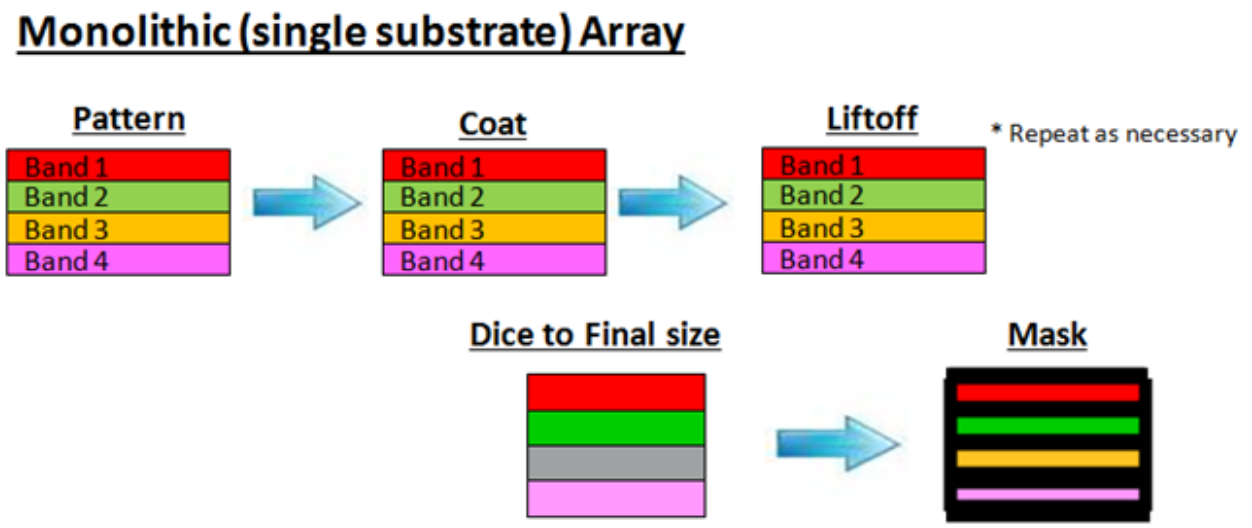

Figure 1. Materion Monolithic Arrays

The second type of array is: assembled or butcher-block (Figure 2). For these filters, we coat multiple wafers with different bands, dice these to stick size and assemble. Multiple deposition materials, substrates and substrate thicknesses (for focal length optimization) may be employed. Materion has delivered arrays with as many as 137 bands. We have also assembled arrays with sticks as narrow as 20um and with lengths as long as 150mm.

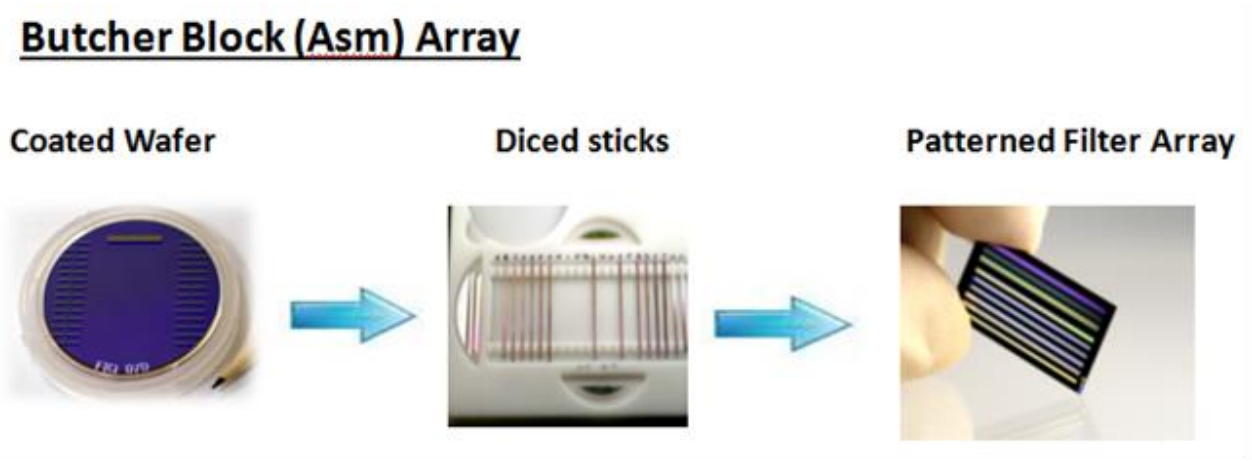

Figure 2. Materion Assembled (butcher-block) arrays

The strength of our manufacturing capabilities, combined with our high performance deposition technology, and technological expertise, allowed us to develop a unique product line to meet the needs of our customers. We created the product line called ArrayTec™. Its express purpose is to provide high tech commercial solutions to all the expanding industries where multispectral sensing is required.

4. ARRAYTEC™

The Materion ArrayTec™ product line was developed to provide low cost, fast turn, agile solutions to serve the expanding commercial market for multispectral imaging and sensing. Using existing earth observation bands (Table 1) previously engineered and developed over the years from other space programs, we can offer superior performance at cost effective pricing. We can also reduce the long lead times typically associated with space-qualified optical components. Our space qualification is realized through similarity of design, processes and heritage experience. Our coating lot sizes are increased for the purpose of cost sharing. The substrate materials and thicknesses are defined. Combining these procedures allows us to devise sophisticated technical solutions for multispectral arrays. Our ArrayTec™ product line offers two distinct types of filters to address individual customer requirements.

The first ArrayTec™ filter option targets the previously mentioned need for market sensitivity (cost, time performance). The second option makes use of Materion's longstanding ability to engineer and manufacture customized solutions for all wavelengths, sizes and substrate materials. The differences between these two options are discussed in further detail in the following sections.

4.1 ARRAYTEC™ - SELECT

The ArrayTec™ Select filter is perfect whether your need is for mid-size to prototype satellites or high volume applications. It provides everything you need at just the right cost. By narrowing filter choices, we are able to deliver multispectral arrays with shorter lead times but without sacrificing quality or service. ArrayTec™ Select uses the same technology as the ArrayTec™ Custom to provide superior stray light and crosstalk reduction and enhanced cosmetics. You can choose one aperture mask, and up to eight filters, from our selection of standard VIS/NIR imaging bands. Filters can be sized to meet your specifications.

CW(nm)	BW(nm)
443	20
490	50
531	36
565	36
665	31
675	450
783	30
865	40

Table 1. List of available ARRAYTEC™ SELECTband choices

4.2 ARRAYTEC™ - CUSTOM

ArrayTec™ Custom provides endless possibilities. Materion will partner with you to create the optimal solution for your application. Our scientists are experienced in stray light reduction coating design and can customize each filter to the exact specification necessary from UV to LWIR. Custom ArrayTec™ Filters can utilize multiple aperture masks and provide maximum stray light control. They are available in a variety of shapes and sizes, including butcher block and checkerboard patterns.

5. FUTURE IMPROVEMENTS

As the imaging industry continues to evolve and demand more cost-conscious functionality, Materion is committed to enhancing its capabilities in multispectral filer arrays for picosats, unmanned aerial vehicles and commercial fields including spectroscopy, multispectral sensing and color matching. Our goal is to expand our ArrayTec™ filters to include bands beyond the VIS/NIR to SWIR, MWIR & LWIR regions, narrower stick widths (more bands / detector), parallelogram arrays (to reduce stray light) and more.

5.1 SWIR – LWIR

Materion currently provides a wide range of bandpass filter solutions in the 1.2um - 14.5um range. These coatings use a variety of deposition materials (ZnS, ZnSe, Si, SiO, Ge, YF3, etc.) and processes. These bandpasses are coated onto a number of different substrate materials (Ge, ZnS, Si, etc.) and thicknesses. As industry requirements become more standardized (as in the VIS/NIR range), Materion plans to enlarge the options of our ArrayTec™ Select product line.

5.2 PARALLELOGRAM ARRAYS

The newest addition to our ArrayTec™ Custom product line is the parallelogram micro-array. These provide a very rugged, high performance alternative to standard butcher-block, patterned filter array or diffraction gratings. They may be designed and built for use with any focal plane array detector from UV to LWIR. To meet customer requirements, the micro arrays will be built to match the light incident angle of the optical system. The parallelogram construction (Figure 3) consists of individual elements precision-diced (Figure 4) with as many bands as desired and with a pitch as small as 0.100mm

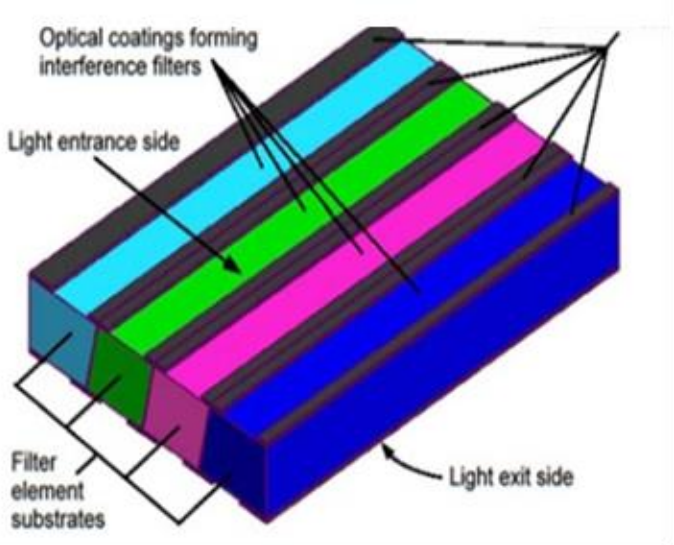

Figure 3. Materion Parallelogram array

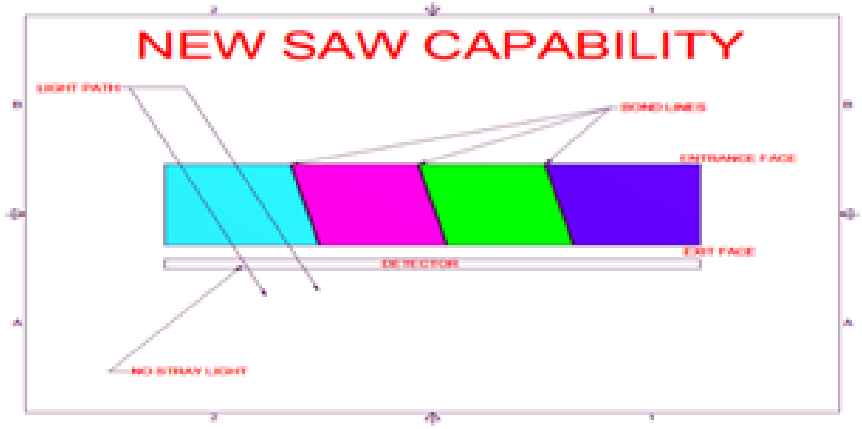

Figure 4. Parallelogram array stick dicing

6. CONCLUSIONS

With over four decades of experience producing complex optical coatings and assemblies for space-based programs, Materion offers highly engineered solutions for multispectral imaging. Whether for high-end, one-of-a-kind programs or economical solutions for high-volume commercial applications, we have the products to meet your requirements.

REFERENCES

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