Computational Imaging and Optical Computation with Functionally Graded Ceramics

Background: Complex and multi-element lenses are part of every high performance camera and require many optical surfaces of precise curvature. This complexity is required because of the use of bulk glasses with a uniform index of refraction and dispersion, which are inherent to the optical materials. High performance imaging could be accomplished in a single optical element if curvatures and arbitrary index gradients were readily fabricated in materials. This would yield general improvements in performance, as well as, reductions in system size and weight (key drivers for USAF applications), and simplify the design process.

Project Details: One path for making complex graded index optical devices is through the use of rapid prototyping technology to "print" three dimensional objects composed of different optical materials to make graded index components. A key challenge to implement this technology is the availability of precursor materials or "inks" to print them from. There are many different rapid prototyping or additive manufacturing techniques such as extrusion based systems, ink jet printing, powder spray and stereo lithography. As well, there are many different candidates for materials that could be the precursor to optical gradients including glasses, polycrystalline ceramics and polymer blends. The materials system and processing window define, to some extent, what type of additive process can be used. So the identification of an appropriate material system is one approach to developing this technology further. Ultimately, we need a material that can be fabricated with a graded composition in the final sample and which possess a small domain size compared with the wavelength that it will be used at (visible 400-700nm, IR 2-20microns, Thz 30+microns) in order to limit scatter and yield a transparent optical material for that wavelength.

Purpose: The goal of this project is to develop and test materials as a precursor for 3D printed gradient optical components. We are especially interested in ceramic materials for any IR wavelength range in the spectral region of 2-20microns, but other wavelength ranges and materials are also of interest. Investigations of mixed oxide, oxide-nitride, and dopant concentrations in glass and ceramic materials fabricated from powered precursors that could be deposited in an additive manufacturing or 3D printing scheme are of primary interest. A key attribute of the system is that it has the potential for high optical quality (low scatter, small domain size) and the ability to sustain smooth index gradient of 0.1 or greater over a 1cm length scale.

Expectations: Success of the capstone project will be the identification of materials system that can be incorporated into an additive manufacturing process and the demonstration of some properties which show this potential. This can be substantiated in a variety of ways, including by example components or graded samples for characterization. The key characteristics to show are that a gradient of composition can be formed in a sample where the optical properties can then be measured. Example components include a flat plate, lens or film. Testing support can be provided for determining the index gradient achieved, the haze and scatter in the material, the wavelength transmission and dispersion, as well as, the overall optical quality.

The second key to success in this project will be an understanding and documentation of the materials and process space that was explored. As the various candidate materials are examined and it is determined where successful candidates are, it will be important for teams to document systems and process conditions that did and did not achieve the desired result in order to extract materials trends and guide future work.

Finally, the enabling knowledge derived from this project is the map of combined process conditions and materials precursors that are connected to specific optical properties which are demonstrated in your samples, such as the final index of refraction, which can then be used by others for design and process control in additive manufacturing schemes.

Skills Needed:

1) Innovation and creativity;
2) Reading and understanding complex academic research;
3) Some expertise in ceramic materials chemistry and preparation;
4) knowledge of typical ceramics processing techniques and the ability to gain familiarity with high rate processing techniques;
5) basic knowledge of optical properties and characteristics.

Sponsor:

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