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Broadband plasma sprayed anti-reflection coating for millimeter-wave astrophysics experiments

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The next generation of Cosmic Microwave Background (CMB) polarimetry experiments will attempt to detect the faint primordial B-mode signal from gravitational waves. With modern millimeter-wave detectors limited by photon shot noise, we can only increase sensitivity by increasing the optical throughput. Additionally, we must observe at multiple frequency bands to accurately characterize the spectral dependence of galactic foreground emission and separate it from the CMB signal. This requires broadband anti-reflection (AR) coated refractive elements with maximum optical throughput. Modern CMB polarimetry experiments use several cryogenically cooled refractive elements made of high dielectric constant and high thermal conductivity material, alumina and silicon. Their high dielectric constants require multiple layers of AR coating with different dielectric constants to minimize reflection at their dielectric boundary. We have developed a plasma sprayed AR coating technology for millimeter-wave astrophysics experiments with cryogenic optics which achieves minimal dissipative loss and broad bandwidth and is easily and accurately applied. Plasma spraying is a coating process through which melted or heated materials are sprayed onto a substrate. We can tune the dielectric constant of the coating by mixing hollow ceramic microspheres with alumina powder as the base material. By spraying low loss ceramic materials with a tunable dielectric constant, we can apply multiple layers of AR coating for broadband millimeter-wave detection. Applying ceramic coatings on ceramic lenses offers an additional benefit of preventing cryogenic delamination of the coatings. We report on methodology of coating application and measurement of uniformity, repeatability, transmission property and cryogenic adhesion performance.