PARTICLE IMPACT DAMAGE STUDY ON OPTICAL LENS MATERIALS

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Wind-borne particles are known to rapidly damage optical lenses despite the presence of a protective coating, resulting in increased light scattering and reduced optical transmission. Protective optical coatings are often characterized by scratch tests[1,2] or rubbing-type abrasion[3] which do not accurately predict resistance to blown sand and other intermediate speed impacts.[4] Comparisons between the kinetic energy of a particle of quartz to that of the energy necessary to create new surface area of an impact site in polycarbonate will be presented for the purpose of designing a better anti-scratch coating.

Optical lens materials were mounted in a custom made sand blowing apparatus and exposed to sub-angular quartz sand of 400 micron size at a constant air velocity of 16.5 m/s. Lens materials tested included uncoated polycarbonate, silica based anti-scratch coated polycarbonate, glass, sapphire, and clear silicone rubber to provide a range of surface hardness and tensile strengths to elucidate which material parameters provide the most resistance to particle damage. The surfaces of the samples were then imaged using SEM and 3-D profilometry. SEM imagery of damage sites was performed using a Zeiss EVO60 at selected magnifications. Profilometry scans were taken of damaged surfaces using a Veeco Dektak 8 system at 300μm x 300μm scan area with a 0.2μm high aspect ratio tip using 1 mg of force.

Profilometry measurements revealed an increase in surface area of 0.004 mm^2 for a single impact in uncoated polycarbonate. Using the reference value range, 0.630-0.945 J/mm^2, for the specific surface energy of polycarbonate,[5] the energy necessary to create this increase in surface area was determined to be 2.52 – 3.78 mJ according to the established Griffith fracture theory. The kinetic energy of the silica particle as a point mass was calculated and was 0.0967 mJ. Since the energy to create new surface area in polycarbonate by fracture was much larger than the kinetic energy of the sand particle, this suggested that the failure mode was viscous flow and not crack propagation. In the case of glass impacted by blowing sand, the fracture energy was identified as two orders of magnitude lower than that of the particle kinetic energy. This difference in fracture and viscous flow in the substrates was observed in the SEM images to be presented.

The kinetic energy of the impacting particle is believed to be a key parameter in designing new protective coatings that guard against damage from particle impacts. Knowing the particle kinetic energy and the change in surface area of an impact site, the total energy transferred to the material causing irreversible deformation can be quantified. This means that if the nature of the failure is identified as either brittle or ductile, appropriate changes in either fracture toughness or material viscosity could be made to enhance coating performance.

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