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Impact-Induced Glass Transition in Elastomeric Coatings[1]

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When an elastomer layer is applied to the front surface of steel, the resistance to penetration by hard projectiles increases significantly. It is not obvious why a soft polymer should affect this property of metals, and most rubbers do not. However, we have found that a few are very effective; the requirement is that the polymer undergo a viscoelastic phase transition upon impact. This means that the frequency of its segmental dynamics correspond to the impact frequency. The latter is estimated as the ratio of the projectile velocity to the coating thickness, and is on the order of 10^5 s^{-1} for the experiments herein. Our data and a non-linear dynamics finite-element analysis offer support for this resonance condition as a primary mechanism underlying the penetration-resistance of elastomer-coated metal substrates. The impact-induced phase transition causes large energy absorption, decreasing the kinetic energy of the impacting projectile. However, this energy absorption only accounts for about half the enhanced stopping power of the elastomer/steel bilayer. An additional mechanism is lateral spreading of the impact force, resulting from the transient hardening of the elastomeric during its transition to the glassy state – the modulus of the rubber increases 1000-fold over a time period of microseconds. The penetration-resistance is a very nonlinear function of the coating thickness. Moreover, tests on various metals show that hardness is the principal substrate parameter controlling the contribution of the coating.

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