Special Terminology Used in Fractography

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TERMS used to describe the features observed on the fracture surfaces of brittle materials have come to be used in different ways as a result of the varied interests and backgrounds of researchers in the ceramics and glasses field. Although a single system of nomenclature would be invaluable in aiding communication among fractographers, to date there is no universal acceptance of standard nomenclature. For this reason, this article on terminology associated with fractography is based on four primary sources, each of which is identifiable by the bracketed descriptor that accompanies each term. These include:

- [ASTM] ASTM Designation C 162, "Standard Terminology of Glass and Glass Products." Published under the jurisdiction of ASTM Committee C-14 on Glass and Glass Products, which is the direct responsibility of Subcommittee C-14.01 on Nomenclature and Definitions
- [FRECH.] V.D. Frechette, Markings on Crack Surfaces of Brittle Materials: A Suggested Unified Nomenclature, *Fractography of Ceramic and Metal Failures*, Special Technical Publication 827, ASTM, 1982, p 104–109
- [MECH.] V.J. Mecholsky, Jr., Department of Materials Science and Engineering, University of Florida, private communication, 1991
- [QUINN] G.D. Quinn, J.L. Swab, and M.J. Slavin, "A Proposed Standard Practice for Fractographic Analysis of Monolithic Advanced Ceramics," U.S. Army Materials Technology Laboratory, Watertown, MA, Nov 1990

Of the aforementioned sources, the ASTM-based material is specific to glasses. The terms taken from Frechette, Mecholsky, and Quinn *et al.* describe polycrystalline materials, with the emphasis of the latter source being fracture origins (both intrinsic volume and surface flaws).

These few pages should identify most of the common terms used in fractography. Additional fracture terms are discussed in the article "Descriptive Fractography," which follows in this Section.

anneal [ASTM]. To prevent or remove objectionable stresses in glassware by controlled cooling from a suitable temperature.

annealing [ASTM]. A controlled cooling process for glass designed to reduce thermal residual stress to a commercially acceptable level, and, in some cases, modify structure.

agglomerate [QUINN]. The clustering together of a few to many particles, whiskers, or fibers, or a combination thereof, into a larger solid mass.

arrest line [FRECH.]. Rib mark defining the crack front shape of an arrested crack prior to resumption of crack spread under an altered stress configuration. The duration of rest may be long to infinitesimal. See also *rib mark*.

arrest mark. See *dwell mark* [ASTM].

bending stress [ASTM]. A stress system that simultaneously imposes a compressive component at one surface, graduating to an imposed tensile component at the opposite surface of a glass section.

bifurcation [MECH.]. The separation of a material into two sections.

bump check. See *percussion cone* [ASTM].

butterfly bruise. See *percussion cone* [ASTM].

chatter sleek. See *frictive track* [ASTM].

cleavage crack [ASTM]. Damage produced by the translation of a hard, sharp object across a glass surface. This fracture system typically includes a plastically deformed groove on the damaged surface, together with median and lateral cracks emanating from this groove.

cleavage crack (crystalline) [MECH.]. A crack which proceeds across the grain, that is, a transgranular crack in a single crystal or in a single grain of a polycrystalline material.

contact stress [ASTM]. The tensile stress component imposed at a glass surface immediately surrounding the contact area between the glass surface and an object generating a locally applied force.

crack [QUINN]. A line of fracture without complete separation.

crack branching [MECH.]. The separation of a material into two or more segments.

crescent crack [ASTM]. Damage having the appearance of a crescent, produced in a glass surface by the frictive translation of a hard, blunt object across the glass surface. The crescent shape is concave toward the direction of translation on the damaged surface.

dwell mark [ASTM]. A fracture surface marking which resembles a pronounced ripple mark, the presence of which indicates that the fracture paused at the location of the dwell mark for some indeterminable length of time; also known as arrest mark.

fabrication traces [FRECH.]. Anomalous markings which may appear on crack surfaces where the developing crack encounters regions of unusual weakness, density, or elastic modulus, introduced, usually inadvertently, during fabrication.

feather [ASTM]. A striation having the appearance of a feather. See also *striation* [ASTM].

fine hackle. See *hackle* [ASTM].

flexure stress [ASTM]. The tensile component of the bending stress produced on the surface of a glass section opposite to that experiencing a locally impinging force.

forking [ASTM]. A phenomenon in which a propagating fracture in a fracture system branches into two or more new fractures, each separated from its immediate neighbor by an acute angle.

fracture surface markings [ASTM]. Fracture surface features that may be used to determine the fracture origin location and the nature of the stress that produced the fracture.

fracture system [ASTM]. That family of related fracture surfaces lying within an object, having a common cause and origin.

frictive track [ASTM]. A series of crescent cracks lying along a common axis, paralleling the direction of frictive contact; also known as a chatter sleek.

frosted area. See *hackle* [ASTM].

gray area. See *hackle* [ASTM].

hackle [ASTM]. A finely structured fracture surface marking giving a matte or rough-

ned appearance to the surface, having arying degrees of coarseness. Finely tructured hackle is variously known as fine ackle, frosted area, gray area, matte, mist nd stippled area. Coarsely structured hackle s also known as *striation* [ASTM].

kle [FRECH.]. A line on the crack surface, unning parallel to the local direction of racking, separating parallel but noncoplanar portions of the crack surface. See lso *mist hackle*, *shear hackle*, *twist hackle*, and *wake hackle*.

ckle marks [ASTM]. Fine ridges on the racture surface of the glass, parallel to the lirection of propagation of the fracture.

rtzian cone crack. See *percussion cone* ASTM].

rtzian stress. See *contact stress* [ASTM].

ıge stress [ASTM]. The tensile component of the bending stress generated on the same surface of a glass section, but not displaced from the site of a locally impinging force.

pact bruise. See *percussion cone* [ASTM].

:lusion [QUINN]. A foreign body from other than normal composition enclosed in the matrix.

ergranular fracture [MECH.]. The remnant of a crack which proceeded between a grain. Compare with *transgranular fracture* [MECH.].

tersection scarp [FRECH.]. A line, of any shape, which is the locus of intersection of two portions of a crack with one another. This is exemplified by intersection of a portion of a slow crack running wet with a portion not wetted. See also *transition scarp*.

teral crack [ASTM]. A crack produced beneath and generally paralleling a glass surface during the unloading phase of mechanical contact with a hard, sharp object. See *cleavage crack*.

achining damage [QUINN]. Atypical or excessively large surface microcracks or damage resulting from the machining process; for example, striations, scratches, impact cracks. Note: Small surface and subsurface damage is intrinsic to the machining damage.

nirror region [MECH.]. The comparatively smooth region which symmetrically surrounds a fracture origin. The mirror region ends in a microscopically irregular manner at the beginning of the mist region.

nedian crack [ASTM]. Damage produced in glass by the static or translational contact of a hard, sharp object on the glass surface. The crack propagates into the glass perpendicular to the original surface. See *cleavage crack*.

nist hackle [FRECH.]. Markings on the surface of a crack accelerating close to the effective terminal velocity, observable first as a mist on the surface and with increasing velocity revealing a fibrous texture elongated in the direction of cracking and coarsening up to the stage at which the crack bifurcates. Velocity bifurcation or velocity forking is the splitting of a single crack into two mature diverging cracks at or near the effective terminal velocity of about half the transverse speed of sound in the material. See also *bifurcation*.

percussion cone [ASTM]. Damage produced by contact stresses generated by mechanical contact of a hard, blunt object with a glass surface. Typically, it has the appearance of a semi-circular or circular crack on the damaged surface, propagating into the glass, flaring out with increasing depth into a cone-shaped crack; also called impact bruise, butterfly bruise, bump check, and Hertzian crack.

pit [QUINN]. A defect created by exposure to the environment, for example, corrosion, wear, or thermal cycling.

pore [QUINN]. (1) A small opening, void, interstice, or channel within a consolidated solid mass or agglomerate, usually larger than atomic or molecular dimensions. (2) An internal cavity which may be exposed by cutting, grinding, polishing, or fracture to become a pit, pock, or hole. (3) A discrete cavity or void in a solid material or a cavity or void larger than the typical porosity that might be present.

porous region [QUINN]. A three-dimensional zone of porosity or microporosity of higher concentration than is normally found in the matrix.

porous seam [QUINN]. A two-dimensional area of porosity or microporosity of higher concentration than is normally found in the matrix.

radial crack [MECH.]. Damage produced in brittle materials by a hard, sharp object pressed onto the surface. The resulting crack shape is semi-elliptical and generally perpendicular to the surface.

rib mark [FRECH.]. A curved line on the crack surface, usually convex in the general direction toward which the crack is running. The term is useful in referring to a mark of this shape until its specific nature is learned.

ripple mark. See *Wallner line* [ASTM].

river marks [MECH.]. Cleavage steps on individual grains of a polycrystalline material or on a single crystal. These markings spread out away from the point of origin. These are a special case of *twist hackle*.

scratch [ASTM]. Any marking or tearing of the surface produced in manufacturing or handling, appearing as though it were done by a sharp instrument.

scratch-resistant coatings [ASTM]. Coating applied to glass surfaces to reduce the effects of frictive damage. See also *frictive track*.

second-phase inhomogeneity [QUINN]. A microstructural irregularity related to the nonuniform distribution of a second phase, for example, an atypically large pocket of a second phase or a second-phase zone of composition or crystalline phase structure different than the matrix material.

sharks teeth [ASTM]. A striation consisting of dagger-like step fractures starting at the scored edge and extending to or nearly to the compression edge.

shear hackle [FRECH.]. A *hackle* generated by interaction of a shear component with the principal tension under which the crack is running.

step fracture. See *striation* [ASTM].

stippled area. See *hackle* [ASTM].

strain [ASTM]. Elastic deformation due to stress.

stress [ASTM]. Any condition of tension or compression existing within the glass, particularly due to incomplete annealing, temperature gradient, or inhomogeneity.

striation [ASTM]. A fracture surface marking consisting of a separation of the advancing crack front into separate fracture planes. Also known as coarse hackle, step fractures, or lances. Striation may also be known as sharks teeth and whiskers.

surface void [QUINN]. A void which is located at the surface of a material and is a consequence of processing, that is, a surface reaction layer, as distinguished from a volume distributed flaw such as a *pore* or *inclusion*.

temper [ASTM]. (1) The degree of residual stress in annealed glass measured polarimetrically or by polariscopic comparison with a reference standard. (2) Term sometimes employed in referring to *tempered glass* [ASTM].

tempered glass [ASTM]. Glass that has been subjected to a thermal treatment characterized by rapid cooling to produce a compressively stressed surface layer.

thermal shock [ASTM]. A rapid change in temperature imposed on a glass body.

thermal stress [ASTM]. The stress produced by a temperature differential within a glass body.

transgranular fracture [MECH.]. The remnant of a crack which proceeded across a grain. Compare with *intergranular fracture*.

transition scarp [FRECH.]. A *rib mark* generated when a crack changes from one mode of growth to another, as when a wet crack accelerates abruptly from Region II (plateau) to Region III (dry) of a crack acceleration curve.

twist hackle [FRECH.]. A *hackle* that separates portions of the crack surface, each of which has rotated from the original crack plane in response to a twist in the axis of principal tension. In a single crystal, a twist hackle separates portions of the crack surface, each of which follows the same cleavage plane, the normal to the cleavage plane being inclined to the principal tension. In a bicrystal or polycrystalline material, a hackle is initiated at a twist grain boundary.

wake hackle [FRECH.]. A hackle line extending from a singularity at the crack front in the direction of cracking, as upon encounter with an *inclusion*.

Wallner line [ASTM]. A fracture surface

marking, having a wavelike profile in the fracture surface. Such marks frequently appear as a series of curved lines, indicating the direction of propagation of the fracture from the concave to the convex side of a given Wallner line. (synonymous with ripple mark).

Wallner lines [FRECH.]. Rib marks with wavelike contour caused by temporary excursion of the crack front out of plane in response to a tilt in the axis of principal tension induced by an elastic pulse. The Wallner line is the locus of interception of the spreading pulse with successive points along the running crack front. There are three classifications of Wallner lines. For a primary Wallner line, the elastic pulse is generated by the encounter of some portion of the crack front with a singularity in the specimen, such as a discontinuity at the free surface or within the specimen, or any localized stress field or elastic discontinuity. For a secondary Wallner line, the elastic pulse is generated by a discontinuity in the progress of the crack front, typically mist-hackle details. For a tertiary Wallner line, the elastic pulse, or train of pulses, is generated from outside the crack front by mechanical shock or by vibration of the specimen resulting from stress release by cracking.

whiskers. See *striation* [ASTM].