



Designation: C1678 – 21

# Standard Practice for Fractographic Analysis of Fracture Mirror Sizes in Ceramics and Glasses<sup>1</sup>

This standard is issued under the fixed designation C1678; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This practice pertains to the analysis and interpretation of fracture mirror sizes in brittle materials. Fracture mirrors (Fig. 1) are telltale fractographic markings that surround a fracture origin in brittle materials. The fracture mirror size may be used with known fracture mirror constants to estimate the stress in a fractured component. Alternatively, the fracture mirror size may be used in conjunction with known stresses in test specimens to calculate fracture mirror constants. The practice is applicable to glasses and polycrystalline ceramic laboratory test specimens as well as fractured components. The analysis and interpretation procedures for glasses and ceramics are similar, but they are not identical. Different optical microscopy examination techniques are listed and described, including observation angles, illumination methods, appropriate magnification, and measurement protocols. Guidance is given for calculating a fracture mirror constant and for interpreting the fracture mirror size and shape for both circular and noncircular mirrors including stress gradients, geometrical effects, residual stresses, or combinations thereof. The practice provides figures and micrographs illustrating the different types of features commonly observed in and measurement techniques used for the fracture mirrors of glasses and polycrystalline ceramics.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the*

*Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

## 2. Referenced Documents

2.1 *ASTM Standards:*<sup>2</sup>

**C1145 Terminology of Advanced Ceramics**

**C1256 Practice for Interpreting Glass Fracture Surface Features**

**C1322 Practice for Fractography and Characterization of Fracture Origins in Advanced Ceramics**

## 3. Terminology

3.1 *Definitions:* (See Fig. 1)

3.1.1 *fracture mirror, n*—as used in fractography of brittle materials, a relatively smooth region in the immediate vicinity of and surrounding the fracture origin. **C1145, C1322**

3.1.2 *fracture origin, n*—the source from which brittle fracture commences. **C1145, C1322**

3.1.3 *hackle, n*—as used in fractography of brittle materials, a line or lines on the crack surface running in the local direction of cracking, separating parallel but noncoplanar portions of the crack surface. **C1145, C1322**

3.1.4 *mist, n*—as used in fractography of brittle materials, markings on the surface of an accelerating crack close to its effective terminal velocity, observable first as a misty appearance and with increasing velocity reveals a fibrous texture, elongated in the direction of crack propagation. **C1145, C1322**

3.2 *Definitions of Terms Specific to This Standard:*  
(See Fig. 1)

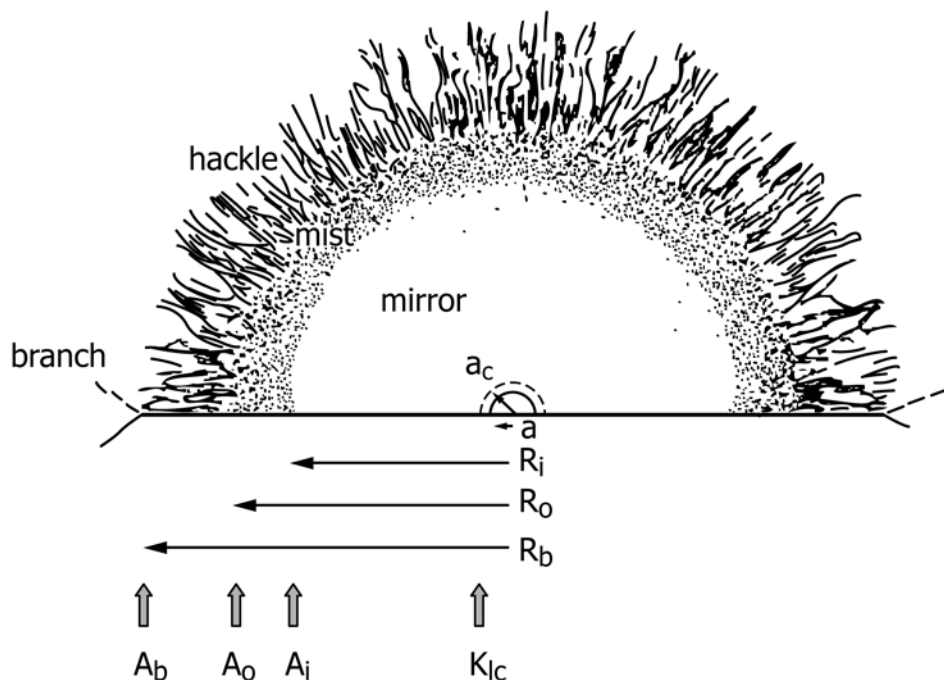
3.2.1 *mirror-mist boundary in glasses, n*—the periphery where one can discern the onset of mist around a glass fracture mirror. This boundary corresponds to  $A_i$ , the inner mirror constant.

3.2.2 *mist-hackle boundary in glasses, n*—the periphery where one can discern the onset of systematic hackle around a

<sup>1</sup> This practice is under the jurisdiction of ASTM Committee C28 on Advanced Ceramics and is the direct responsibility of Subcommittee C28.03 on Physical Properties and Non-Destructive Evaluation.

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<sup>2</sup> For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.



NOTE 1—The initial flaw may grow stably to size  $a_c$  prior to unstable fracture when the stress intensity reaches  $K_{Ic}$ . The mirror-mist radius is  $R_i$ , the mist-hackle radius is  $R_o$ , and the branching distance is  $R_b$ . These transitions correspond to the mirror constants,  $A_i$ ,  $A_o$ , and  $A_b$ , respectively.

FIG. 1 Schematic of a Fracture Mirror Centered on a Surface Flaw of Initial Size (a)

glass fracture mirror. This boundary corresponds to  $A_o$ , the outer mirror constant.

3.2.3 *mirror-hackle boundary in polycrystalline ceramics*,  $n$ —the periphery where one can discern the onset of systematic new hackle and there is an obvious roughness change relative to that inside a ceramic fracture mirror region. This boundary corresponds to  $A_o$ , the outer mirror constant. Ignore premature hackle and/or isolated steps from microstructural irregularities in the mirror or irregularities at the origin.

3.2.4 *fracture mirror constant,  $(FI^{-3/2})$ ,  $n$* —an empirical material constant that relates the fracture stress to the mirror radius in glasses and ceramics.

#### 4. Summary of Practice

4.1 This practice provides guidance on the measurement and interpretation of fracture mirror sizes in laboratory test specimens as well as in fractured components. Microscopy examination techniques are listed. The procedures for glasses and ceramics are similar, but they are not identical. Guidance is given for interpreting the fracture mirror size and shape. Guidance is given on how to interpret noncircular mirrors due to stress gradients, geometrical effects, or residual stresses.

4.2 The stress at the origin in a component may be estimated from the mirror size.

4.3 Fracture mirror constants may be estimated from matched sets of fracture stresses and mirror sizes.

#### 5. Significance and Use

5.1 Fracture mirror size analysis is a powerful tool for analyzing glass and ceramic fractures. Fracture mirrors are

tell-tale fractographic markings in brittle materials that surround a fracture origin as discussed in Practices C1256 and C1322. Fig. 1 shows a schematic with key features identified. Fig. 2 shows an example in glass. The fracture mirror region is very smooth and highly reflective in glasses, hence the name “fracture mirror.” In fact, high magnification microscopy reveals that, even within the mirror region in glasses, there are very fine features and escalating roughness as the crack advances away from the origin. These are submicrometer in size and hence are not discernable with an optical microscope. Early investigators interpreted fracture mirrors as having discrete boundaries including a “mirror-mist” boundary and also a “mist-hackle” boundary in glasses. These were also termed “inner mirror” or “outer mirror” boundaries, respectively. It is now known that there are no discrete boundaries corresponding to specific changes in the fractographic features. Surface roughness increases gradually from well within the fracture mirror to beyond the apparent boundaries. The boundaries were a matter of interpretation, the resolving power of the microscope, and the mode of viewing. In very weak specimens, the mirror may be larger than the specimen or component and the boundaries will not be present.

5.2 Figs. 3-5 show examples in ceramics. In polycrystalline ceramics, the qualifier “relatively” as in “relatively smooth” must be used, since there is an inherent roughness from the microstructure even in the area immediately surrounding the origin. In coarse-grained or porous ceramics, it may be impossible to identify a mirror boundary. In polycrystalline ceramics, it is highly unlikely that a mirror-mist boundary can be detected due to the inherent roughness created by the crack-microstructure interactions, even within the mirror. The