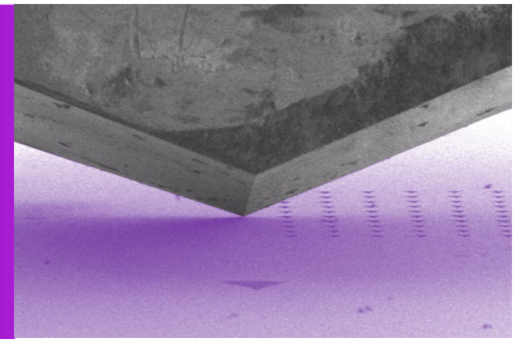
How to Select a Nano Indenter® Tip



Introduction

It is important to select the correct tip for your nanoindentation application. KLA Instruments™ offers high precision indenter tips that enable the finest quality data for your research. Our indenter tips are designed to meet all of your demanding applications. This application note can be used as a guide in the selection process to determine the best tip for your needs.

There are six main types of indenter tips, each with a different geomtery for a variety of applications:

- Berkovich
- Flat Punch
- Vickers
- Cube-Corner
- Cone
- Sphere

Berkovich

The Berkovich indenter tip is the most frequently used indenter tip for instrumented indentation testing (IIT) to measure mechanical properties on the nanoscale. The Berkovich indenter tip, shown in Figure 1, is a three-sided pyramid that can be ground to a point, thus maintaining self-similar geometry at very small scales. This geometry is often preferred to the Vickers indenter tip, which is a four-sided pyramid.

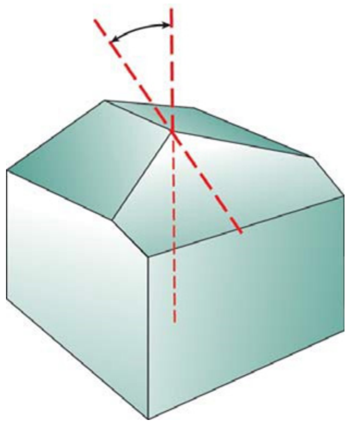


Figure 1. The Berkovich indenter tip is defined as a three-sided pyramid with an included angle of 142.3°.

The Berkovich indenter tip is ideal for most testing purposes. It is not easily damaged and can be readily manufactured. It induces plasticity at very small loads, which produces a meaningful measure of hardness. The Berkovich indenter tip has an included angle of 142.3°, which minimizes the influence of friction.

Berkovich Recommended Applications

Example applications suitable for the Berkovich indenter tips include:

- Bulk materials
- Thin films
- Polymers (E' > 1GPa)
- Scratch testing
- Wear testing
- Micro-electromechanical systems (MEMS)
- In-situ imaging

Flat Punch

The flat punch indenter tip is used for measuring yield stress-strain, and is defined by a truncated cone, as shown in Figure 2. Different diameter punches are available to support various applications.

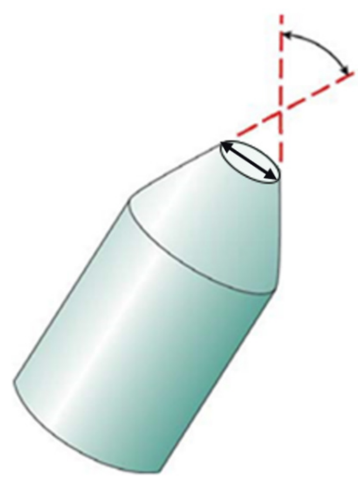


Figure 2. The Flat Punch indenter tip is defined as a truncated cone.

Flat Punch Recommended Applications

Example applications suitable for the Flat Punch indenter tips include:

- Polymers
- Stress-strain measurement

Vickers

The Vickers indenter tip is also used in IIT to measure mechanical properties on the nanoscale, and is defined by a four-sided pyramid, as shown in Figure 3.

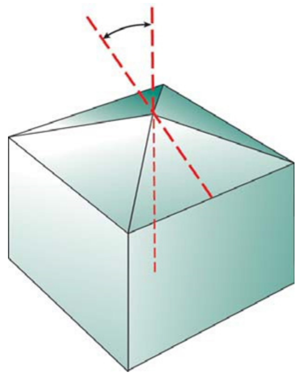


Figure 3. The Vickers indenter tip is defined as a four-sided pyramid.

Vickers Recommended Applications

Example applications suitable for the Vickers indenter tips include:

- Bulk materials
- Films and foils
- Scratch testing
- Wear testing

Cube-Corner

The Cube-Corner indenter tip is a three-sided pyramid with mutually perpendicular faces arranged as the corner of a cube, as shown in Figure 4. The centerline-to-face angle for this indenter is 34.3°, whereas for the Berkovich indenter it is 65.3°. The sharpness of the cube corner produces much higher stresses and strains in the area of the contact, which is useful in producing very small, well-defined cracks around hardness impressions in brittle materials. These cracks can be used to estimate fracture toughness at very small scales.

Cube-Corner Recommended Applications

Example applications suitable for the Cube-Corner indenter tips include:

- Thin films
- Scratch testing
- Fracture toughness
- Wear testing
- MEMS
- In-situ imaging

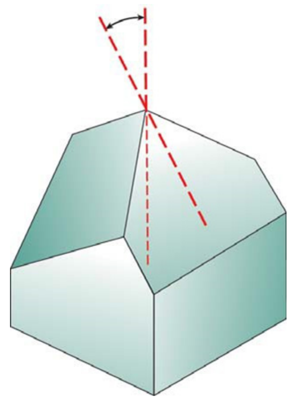


Figure 4. The Cube-Corner indenter tip is defined as a three-sided pyramid, with a centerline-to-face angle of 34.3°.

Cone

The cone indenter tip, shown in Figure 5, has a sharp self-similar geometry, and the simplicity of its conical symmetry makes it attractive from a modeling standpoint. Many models used to support IIT are based on conical indentation contact.

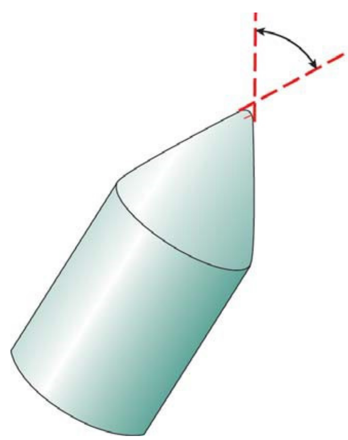


Figure 5. The Cone indenter tip.

The cone is also attractive because the complications associated with the stress concentrations at the sharp edges of the indenter are absent. However, very little IIT testing has been conducted with cones. The primary reason is that it is difficult to manufacture conical diamonds with sharp tips, making them of little use in the small-scale work around which most of IIT has developed. This problem does not apply at larger scales, where much could be learned by using conical indenters in IIT experimentation.

Cone Recommended Applications

Example applications suitable for the Cone indenter tips include:

- Scratch testing
- Wear testing
- Micro-electromechanical systems (MEMS)
- In-situ imaging

Sphere

Stresses develop differently during indentation when using a spherical indenter tip (shown in Figure 6) compared to either a Berkovich or Vickers tip. For spherical indenters, the contact stresses are initially small and produce only elastic deformation. As the spherical indenter is driven into the surface, a transition from elastic to plastic deformation occurs, which can theoretically be used to examine yielding and work hardening, and to recreate the entire uniaxial stress-strain curve from data obtained in a single test. IIT with spheres has been most successfully employed with larger-diameter indenters. At the micron scale, the use of spherical indenters has been impeded by difficulties in obtaining high-quality spheres made from hard, rigid materials. This is one reason the Berkovich indenter has been the indenter of choice for most small-scale testing, even though it cannot be used to investigate the elastic-plastic transition.

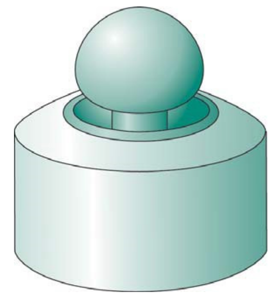


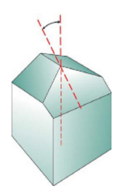
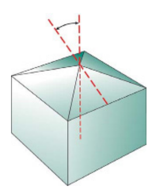
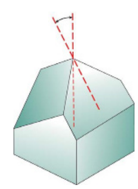
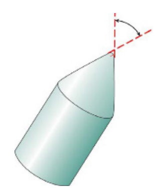
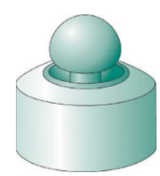
Figure 6. The sphere indenter tip.

Sphere Recommended Applications

The Sphere indenter tip is typically used for scratch testing.

Custom Shape

At times, standard geometry indenters may not achieve the desired results. KLA Instruments Applications Engineers work with the customer to choose a custom-designed indenter geometry to best suit their application.

						
	Berkovich	**Flat Punch**	**Vickers**	**Cube-Corner**	**Cone (angle ψ)**	**Sphere (radius R)**
Shape	3-sided pyramid	Truncated cone (diameter 2a)	4-sided pyramid	3-sided pyramid w/ perpendicular faces	Conical	Spherical
Applications	Bulk materials, thin films, polymers, scratch, wear, MEMS, imaging	Polymers, stress-strain measurement	Bulk materials, films and foils, scratch, wear	Thin films, scratch, fracture toughness, wear, MEMS, imaging	Modeling, scratch, wear, imaging, MEMS	Scratch
Centerline-to-face angle, α	65.3°	-	68°	35.2644°	-	-
Area (projected), A(d)	$24.56d^2$	πa^2	$24.504d^2$	$2.5981d^2$	πa^2	πa^2
Volume-depth relation, V(d)	$8.1873d^3$	-	$8.1681d^3$	$0.8657d^3$	-	-
Projected area/face area, A/A_f	0.908	1.0	0.927	0.5774	-	-
Equivalent cone angle, ψ	70.32°	-	70.2996°	42.28°	-	-
Contact radius, a	-	a	-	-	$d \cdot \tan\psi$	$(2Rd-d^2)^{1/2}$

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