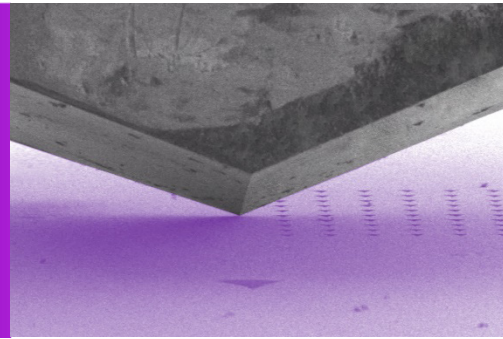


# How to Select a Nano Indenter<sup>®</sup> Tip



## 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 five main types of indenter tips, each with a different geometry for a variety of applications:

- Berkovich
- 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.

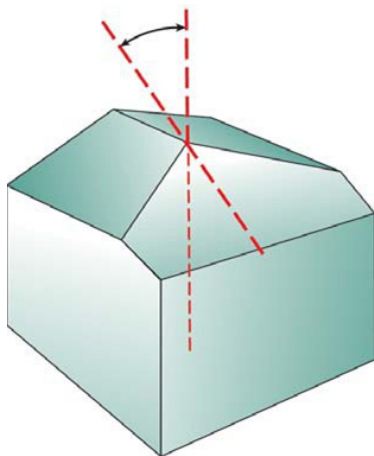


Figure 1. The Berkovich indenter tip is defined as a three-sided pyramid with an included angle of 142.3°.

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

There are many applications suitable for the Berkovich indenter tips. Some examples include:

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

## 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 2.

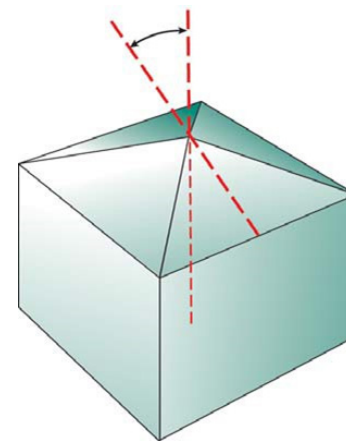


Figure 2. The Vickers indenter tip is defined as a four-sided pyramid.

### Vickers Recommended Applications

There are many applications suitable for the Berkovich indenter tips. Some examples 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 3. The centerline-to-face angle for this indenter is  $34.3^\circ$ , whereas for the Berkovich indenter it is  $65.3^\circ$ . 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.

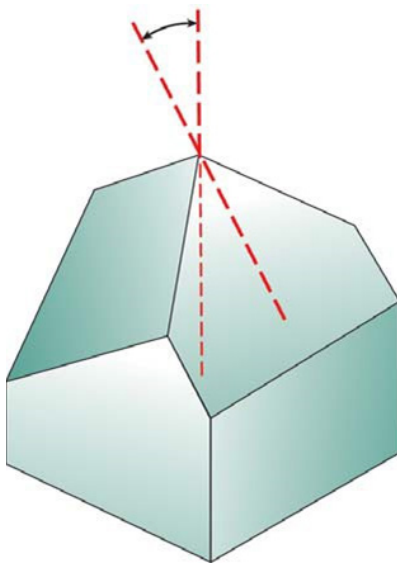


Figure 3. The Cube-Corner indenter tip is defined as a three-sided pyramid, with a centerline-to-face angle of  $34.3^\circ$ .

### Cube-Corner Recommended Applications

There are many applications suitable for the Cube-Corner indenter tips. Some examples include:

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

### Cone

The cone indenter tip, shown in Figure 4, 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. 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.

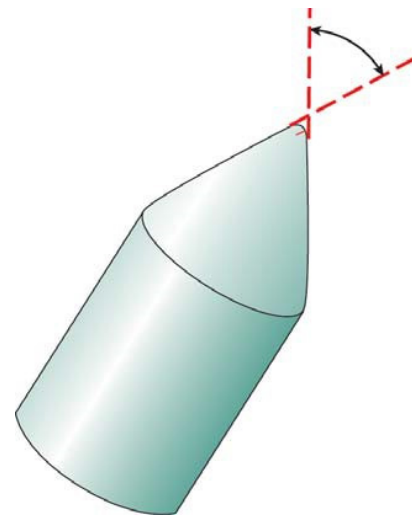


Figure 4. The Cone indenter tip.

### Cone Recommended Applications

There are many applications suitable for the Cone indenter tips. Some examples 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 5) 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.

**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.

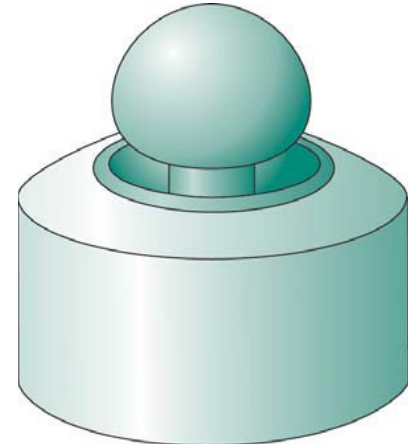
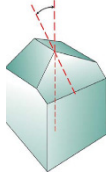
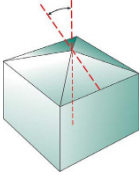
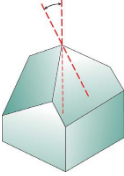
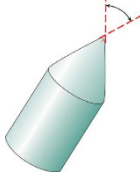
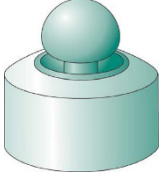


Figure 5. The sphere indenter tip.

					
	Berkovich	Vickers	Cube-Corner	Cone (angle $\psi$ )	Sphere (radius R)
<b>Shape</b>	3-sided pyramid	4-sided pyramid	3-sided pyramid w/ perpendicular faces	Conical	Spherical
<b>Applications</b>	Bulk materials, thin films, polymers, scratch, wear, MEMS, imaging	Bulk materials, films and foils, scratch, wear	Thin films, scratch, fracture toughness, wear, MEMS, imaging	Modeling, scratch, wear, imaging, MEMS	Scratch
<b>Centerline-to-face angle, <math>\alpha</math></b>	65.3°	68°	35.2644°	-	-
<b>Area (projected), A(d)</b>	24.56d <sup>2</sup>	24.504d <sup>2</sup>	2.5981d <sup>2</sup>	$\pi a^2$	$\pi a^2$
<b>Volume-depth relation, V(d)</b>	8.1873d <sup>3</sup>	8.1681d <sup>3</sup>	0.8657d <sup>3</sup>	-	-
<b>Projected area/face area, A/A<sub>f</sub></b>	0.908	0.927	0.5774	-	-
<b>Equivalent cone angle, <math>\psi</math></b>	70.32°	70.2996°	42.28°	-	-
<b>Contact radius, a</b>	-	-	-	d·tan $\psi$	(2Rd-d <sup>2</sup> ) <sup>1/2</sup>

**KLA SUPPORT**

Maintaining system productivity is an integral part of KLA's yield optimization solution. Efforts in this area include system maintenance, global supply chain management, cost reduction and obsolescence mitigation, system relocation, performance and productivity enhancements, and certified tool resale.

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