POLISHING

Purpose

Polishing produces a smooth, flat, deformation-free, and scratch-free surface, which is bright, shiny, and mirror-like in appearance with sharp edges and good differentiation between the constituents. Polishing minimizes all fine surface irregularities left over during the grinding operation. A polished surface is essential for observations of stained and etched surfaces in a high-power reflected-light (metallurgical) microscope and for detailed microstructural evaluations including secondary and backscatter electron imaging and x-ray microanalysis in a scanning electron microscope. Polishing operations should not introduce "extraneous structures" such as damage on the surface, pitting, scratches, dragging out of inclusions, comet tailing, staining, or relief. Grain mounts, small finely ground sections of concrete, mortar, and other building materials, and uncovered thin sections of materials can be polished by using various polishing abrasives and lubricants on polishing cloths attached to a horizontal rotary wheel. Prolonged polishing can introduce relief or height difference due to differential rates of abrasion of soft and hard components.

Polishing Abrasives

Unlike grinding abrasives, the smallest of which are around 5-µm in size, polishing abrasives are usually from 5-µm to submicron in size. Traditional polishing abrasives are: (a) diamond paste or suspension in distilled water, oil, or in an appropriate carrier, (b) deagglomerated aluminum oxide in powder form or in suspension in distilled water, or in an organic solvent (ethylene glycol, alcohol, kerosene, glycerol), or in polishing oil, and (c) amorphous silicon dioxide in colloidal suspension. Water-based carrier is avoided in polishing water-sensitive materials. Cerium oxide, chromium oxide, magnesium oxide, or iron oxide are sometimes used for polishing specific materials (e.g., glass). Diamond pastes or suspensions containing either virgin natural diamond, or, synthetic monocrystalline, or more effective polycrystalline forms of diamonds are excellent polishing abrasives and have been used for metallurgical polishing since the late 1920s. Aqueous fine alumina powders and slurries, such as Buehler's MicroPolish deagglomerated alumina powders and suspensions of alpha alumina (0.3-µm size) and gamma alumina (0.05-µm size) slurries (or suspensions) are good for final polishing (either in sequence or singularly) with medium nap polishing cloths. As mentioned in grinding, deagglomerated alumina produced by the sol-gel process produces a better surface polish than fine alumina abrasives of the same size produced by the traditional calcination process (which always includes some agglomeration). Colloidal amorphous silica suspension is common in metallurgical applications and produces a good surface polish in rocks and concrete; crystallization of amorphous silica on evaporation and its precipitation on the surface, however, can introduce scratches, which can be avoided by a 10-15 second spray of water on the polishing cloth at the end of a cycle. Diamond abrasives usually produce less surface relief than other abrasives.

Polishing Cloths

A good polishing cloth should: (a) hold the abrasive media, (b) have a long life, (c) not contain any foreign material, which may cause scratches, (d) have appropriate hardness/softness and low, medium, or high nap (fiber) depending on the polishing abrasive used, and (e) be clean of any processing chemicals (such as dye), which may react with the sample. Many cloths of different fabrics, weaves, or naps are available. Napless or low nap cloths are good for coarse polishing with diamond abrasives. Napless, low, medium, and occasionally high nap cloths are good for final polishing. A “hard” polishing cloth that does not have a nap is good for minimizing surface relief. A “soft” cloth that has a nap controls scratching and produces a better quality surface finish. Usually, successively finer sized diamond or alumina abrasives on moderately hard to hard napless or low-nap polishing cloths (e.g., Buehler’s TexMet) are used for coarse to fine polishing, and softer, submicron-sized deagglomerated alumina or colloidal silica abrasives on a soft, napped cloth (e.g., Buehler’s MicroCloth) is used for the final polishing.

Polishing Methods

Coarse polishing involves the use of successively finer (from 6 or 5-µm to 1-µm) diamond or alumina abrasives charged onto napless or low-nap polishing cloths. *Intermediate and fine polishing* involve the use of successively finer sub-micron-sized (0.3-µm and 0.05-µm) deagglomerated alumina or diamond abrasives on napless or low nap to medium nap polishing cloths. *Mechanical polishing* indicates procedures involving the use of polishing abrasives on cloths; the cloths may be attached to a rotating wheel or a vibratory polisher bowl; the samples may be held by hand, held mechanically in a fixture such as a conditioning ring in a roller arm, or merely confined within the polishing area. *Electrolytic polishing*, common in metallurgical applications, involves a slow sample removal rate (1-µm per minute) and creates a slightly wavy surface, which increases the difficulty of focusing at high magnifications; the method is not common in cement and concrete polishing. *Manual hand polishing* involves holding sample by hand with controlled pressure onto the polishing wheel, rotating it opposite to the rotational direction of the wheel, and back and forth rotation from center towards the edge of the wheel to ensure even distribution of abrasive and uniform wear of polishing cloth. *Automated polishing* involves the use of a mechanical polishing device, either a simple one or a rather sophisticated, minicomputer, or microprocessor controlled unit, which can grind and polish a single or multiple (up to half a dozen or more) samples simultaneously with a higher degree of quality than hand polishing and at a reduced consumable cost. Samples in an automated device are either held in place rigidly and pressed onto the cloth by a central force on the sample holder (produces best surface flatness and edge retention), or, held in place loosely and force is applied to each sample by a piston and planarity is achieved individually rather than collectively. Polishing time depends on abrasive size, cloth type, force applied, and wheel speed, which usually varies from 2 to 5 minutes for each step of polishing. An unnecessary long time spent in polishing is not only wasteful but can also produce undesirable surface relief.

Cleaning and Drying after Polishing

A polished surface should be cleaned ultrasonically for 30-40 seconds with a solvent having a high flash point or no flash point. Excessive ultrasonic cleaning, however, can damage the surface. Sample can also be washed by swabbing with a liquid detergent solution, rinsed in running water, or with forcefully sprayed alcohol or ethanol, and then dried. Thorough cleaning of the surface after grinding and polishing are important to remove the abrasive residues and their interference during x-ray microanalysis in SEM. Rapid drying of the ground/polished surface can be done by applying a stream of forced warm air or compressed air to the surface.