TECHNotes

Published by Buehler, a division of Illinois Tool Works

Volume 7, Issue 8

Diamond for Any Occasion

By: Tim Weber and Chinedu Obasih

Introduction

Since Buehler's introduction of "diamond dust" in 1947, diamond abrasive has been an indispensable tool in metallographic sample preparation. Efficient material preparation requires rapid material removal, which in turn depends partly upon the hardness of the abrasive. Because diamond is considerably harder than other commonly available abrasives, material removal is significantly greater on a wide variety of materials. One must consider diamond size, shape (type) and carrier as well as the properties of the sample material when selecting diamond products. Selecting the right diamond product is important for proper metallographic preparation. This translates into reduced preparation time and improved surface finish. Indeed, reducing preparation time lessens the potential for polishing induced artifacts such as comet tailing, pull-out, relief and smearing.

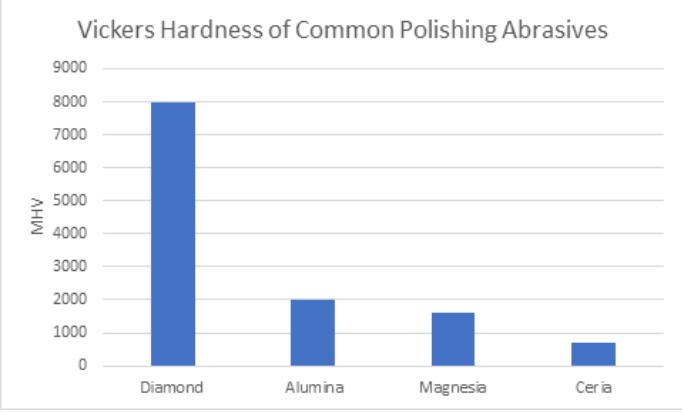

***Figure 1**. Hardness comparison of polishing abrasives. Harder abrasives correlate to increased removal rate and subsequent reduction in polishing time.*

Today Buehler provides a variety of diamond abrasive types, but which product is right for you?

At the time diamond was introduced to metallography, the only option was monocrystalline, naturally mined diamond in a wax-like carrier. Though expensive compared to alternate abrasives used at the time (alumina and magnesia), early studies showed one could effectively polish using very little diamond - just a few hundred milligrams would sufficiently charge a polishing cloth, a small fraction of the abrasive needed compared to alumina or magnesia.

Properly used, diamond is not only an efficient abrasive but also highly cost-effective. In fact, using more diamond abrasive than is needed does not further increase effectiveness, proper application is key.

In the 1950's manufacturing of diamond was developed by GE, this eventually led to availability of monocrystalline, manufactured diamond for metallographic preparation. Fully the equal of natural diamond in material preparation, manufactured diamond quickly became more economical and was not subject to supply variability of the natural diamond market.

In the 1970's manufactured polycrystalline diamond became commonly available. Polycrystalline diamond further improves polishing efficiency due to the increased number of cutting facets on the diamond particle.

Also in the 1970's, polishing suspensions - diamond abrasive suspended in a liquid that could be sprayed onto cloth surfaces - were made available. Suspensions greatly enhance ease of use and allow for automated dosing of abrasives for high-volume

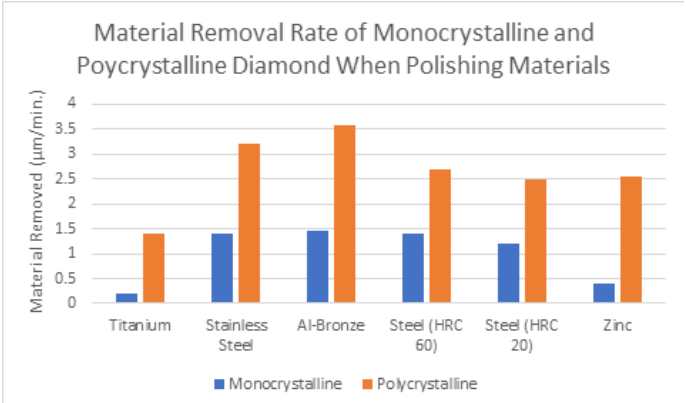

***Figure 2**. Material removal rate comparison of mono- and polycrystalline diamond. Use of polycrystalline diamond increases removal rate and reduces polishing time.*

Diamond Paste or Diamond Suspension?

Diamond paste is the original form of diamond abrasive and has been available continuously for over 70 years. The paste is applied to polishing cloths and rubbed into the cloth fibers (with a gloved finger), as such it is often referred to as a "semi-fixed" abrasive. In practice, little diamond paste is needed for high-quality results, about four, 1" beads applied to an 8" polishing cloth, one in each quadrant, is sufficient.
Always use an extender such as MetaDi Fluid over diamond paste to ensure cloths remain properly lubricated.

The wax-like carrier used in diamond paste reduces tendency for abrasive to embed in sample materials that are prone

to embedding. This class of materials includes pure metals, low-melting temperature alloys and some refractory metals. Diamond paste also exhibits reduced tendency to rinse off polishing cloths, meaning charging of cloths with paste is less frequent than when working with suspensions. Paste may be advantageous in environments where control of abrasive application is of import, such as university settings, where abrasive can be applied by a supervisor and the charged cloths made available to users.

Diamond suspensions are more convenient to use than paste. These contain a proprietary blend of lubricants and additives to keep abrasive particles in suspension. Suspensions are sprayed onto cloths during polishing throughout the polishing cycle. Effective diamond suspensions depend upon highly precise particle grading and proper concentration. In application, one applies a few milliliters of diamond suspension to polishing cloths prior to use and about one milliliter per minute during material preparation (one milliliter is about one spray from dispenser bottles).

Crystal Structure: Polycrystalline or Monocrystalline?

Polycrystalline diamond has largely supplanted monocrystalline. This is due to greater efficiency of polycrystalline diamond (due to increased number of cutting facets per abrasive particle) as well as economy – today there is little if any cost advantage to use of monocrystalline diamond. The increased number of cutting surfaces increases material removal rate resulting in a faster polish. With the load being spread across more cutting surfaces, polycrystalline diamond also tends to polish with less deformation and creates a better surface finish than monocrystalline diamonds for a given abrasive size.

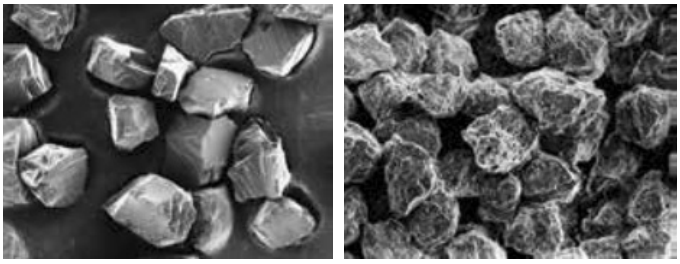

***Figure 3**. Monocrystalline diamond (left) vs. polycrystalline diamond (right). Note the increased number of cutting facets on polycrystalline diamond vs. monocrystalline. This means polycrystalline abrasive particles will remove material from samples regardless of orientation on the polishing cloth.*

Diamond Abrasive Discs

Diamond fixed into abrasive discs (DGD's, or diamond grinding discs) have been available since the 1960's. These discs are generally more aggressive than use of diamond on polishing cloths and are normally used in grinding stages of preparation. Diamond discs consist of diamond bonded to a backing using either resin or metal bond material. Resin-bonded discs are more economical, though metal-bonded discs tend to be more durable, making them very useful for grinding abrasion-resistant ceramics and tough metals.

The surface of diamond grinding discs may be interrupted or continuous. Interrupted surfaces are ideal for grinding ductile materials as the "channels" in the disc enable ground material to be rinsed freely away, preventing accumulation on the disc which can limit grinding effectiveness. Continuous discs are best for brittle materials such as ceramic or minerals, these discs tend to leave an improved surface finish relative to interrupted surface discs, however if used on ductile materials effective grinding life may be reduced.

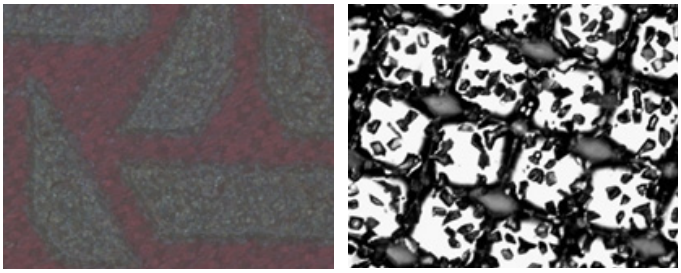

***Figure 4**. Contrast the interrupted surface (left) of a resin-bonded DGD Color versus the continuous surface (right) of the metal-bonded Apex DGD. In the interrupted surface diamond is bonded onto raised surfaces, leaving channels that enable rinsing of debris. The continuous surface is best for grinding abrasion-resistant, brittle materials.*

So which diamond product should I choose for my application?

When grinding ductile materials, fixed-abrasive grinding discs such as the DGD color are ideal. These discs exhibit long life and are an effective replacement for silicon carbide paper, eliminating the need to change paper for every procedure and reducing disposal waste considerably. For most applications one diamond disc lasts about the same grinding time as 100 sheets of silicon carbide paper and is very similar in cost. Indeed, at times one diamond disc can replace multiple silicon carbide paper steps, leading to a more cost-effective solution while reducing preparation time.

Harder metallic materials including steels and superalloys should be ground using DGD Mosaic. This surface has been specially formulated for best material removal rate and lifetime on these materials, and are an excellent alternative to silicon carbide paper when using semi-automatic preparation.

In the event heavy grinding of large ductile samples is needed, the Apex coarse grinding disc (CGD) is recommended. These metal-bonded interrupted discs exhibit fast grinding with a very long useful life.
Grinding abrasion-resistant ceramics is best achieved using the metal-bonded DGD Ultra, while softer ceramics and minerals are effectively ground with the resin-bonded DGD.

Diamond pastes such as and MetaDi® Ultra Diamond Paste is ideal for materials that are prone to abrasive embedding. These materials include pure metals, low-melting point alloys and refractory metals. Diamond paste to provides a more gentle cutting action compared to diamonds in suspension. Always use an extender such as MetaDi Fluid with diamond paste to ensure the polishing cloth remains well lubricated and cooled.

For polishing applications MetaDi Supreme polycrystalline diamond suspension is the most effective choice for most material applications. It combines heavy diamond concentration, fine particle size distribution and a proprietary blend suspending agent that all combine to make this stand head and shoulders above other products in the market. MetaDi Supreme is ideal for manual application (spraying onto cloth surfaces by hand) or automated dispenser application using Burst dispensers.

Oil-based suspensions like Buehler's Oil-Based MetaDi are intended for water sensitive materials. These materials include some magnesium alloys, concrete and galvanized steel. They have more lubricity compared to water-based suspensions and tend to have lower removal rates. Diamond paste may also be used for these materials, in such a case be sure to apply a waterless extender such as lapping oil or ethylene glycol. Clean samples in ethanol between preparation steps and after polishing is complete.

Key Points to Remember

- Always use water when grinding with diamond grinding discs. Water keeps sample surfaces cool and flushes away ground debris from the disc, extending disc life and surface finish of samples.

• Choose polycrystalline diamond (MetaDi Supreme suspension or MetaDi Ultra paste) for highest efficiency at the lowest cost.

• Apply diamond sparingly - Buehler MetaDi is a highly efficient abrasive. MetaDi Supreme suspension only requires about 1 mL per minute of use (one spray from the dispenser bottle) for effective polishing. MetaDi diamond paste requires only a small amount (about four, 1" beads of paste per 8" cloth, about four, 1.5" beads per 12" cloth). This makes MetaDi diamond more cost-efficient relative to other diamond products on the market

• Use an extender such as MetaDi Fluid with diamond abrasives. When using suspensions, alternate application of MetaDi fluid with MetaDi Supreme, this saves cost and ensures cloths are properly lubricated. When using paste, apply MetaDi Fluid to the cloth after paste application. MetaDi fluid not only cools but lubricates, extending life of polishing cloths and improving surface finish of polished samples.

• Keep polishing time relatively short. Most polishing steps using diamond abrasives are completed in just 2 to 5 minutes, in contrast to polishing with aluminum oxide. This reduces tendency for polishing-induced artifacts and saves time.

• Diamond abrasive is more cost-efficient than alumina for polishing. When accounting for the cost of labor to mix alumina powders, extended polishing time required for alumina polishing and the inferior surface finish provided relative to diamond, there is little reason to choose alumina over diamond for most applications (with a few notable exceptions including some pure metals and glass fiber composites).

Refer to the Buehler SumMet guide for detailed information regarding polishing your material with MetaDi diamond.

BUEHLER

BUEHLER Worldwide Headquarters
North America-South America Offices
41 Waukegan Road
Lake Bluff, Illinois 60044-1699 USA
P: 800 BUEHLER (800-283-4537)
P: (847) 295-6500
www.buehler.com | info@buehler.com

European Headquarters
BUEHLER Germany
info.eu@buehler.com

BUEHLER France
info.eu@buehler.com

BUEHLER United Kingdom
info.eu@buehler.com

BUEHLER China
info.cn@buehler.com

BUEHLER Japan
info.japan@buehler.com

BUEHLER Asia-Pacific
info.asia@buehler.com