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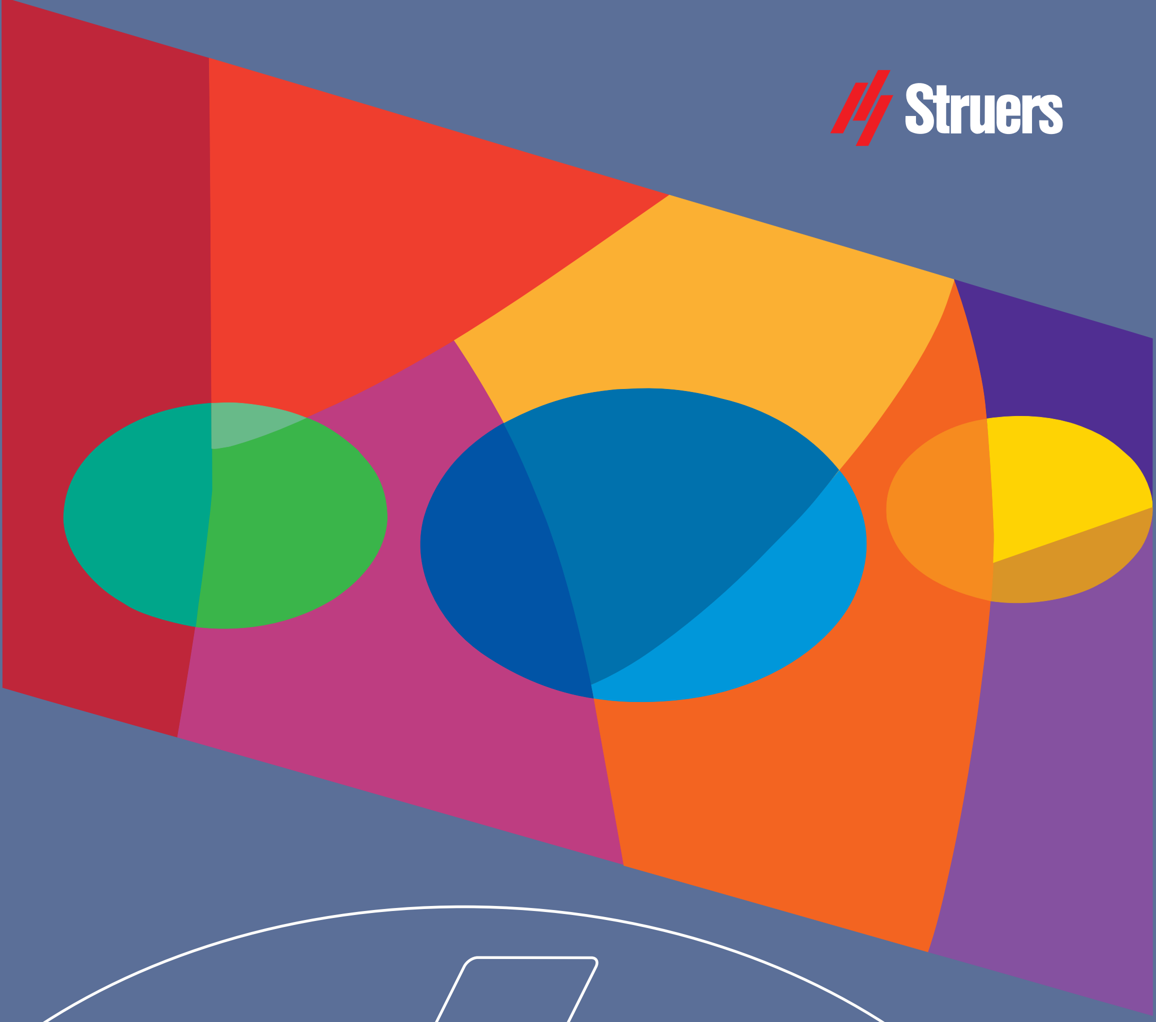

Your Guide to the Perfect Materialographic Structure

Metalog Guide

Metalog Guide™

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Struers

Metalog Guide

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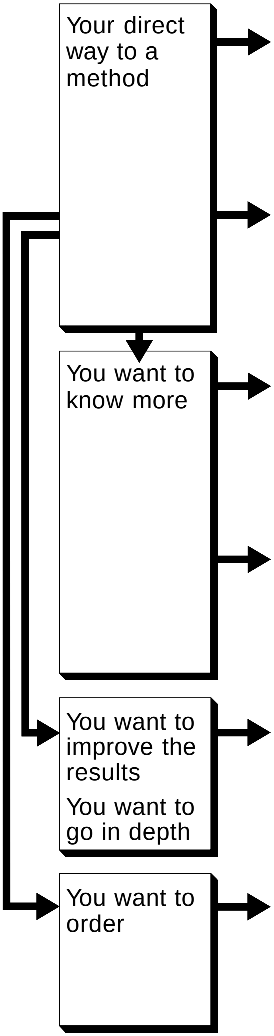


Your direct way to a method
You want to know more
You want to improve the results
You want to go in depth
You want to order

Preface

Dear Reader,

Metalog Guide has been developed to help you in your work with preparation of materialographic samples.
Our main goal when preparing Metalog Guide was to give you a shortcut to efficient sample preparation. Through a careful study of the preparation process new methods are developed and existing methods are improved.
We offer you 10 Metalog Methods, which will cover most of your needs for high quality, cost-efficient preparation.

Expert System – Metalog Master

Metalog Master, an important part of Metalog Guide, is an expert system, supporting you in your efforts to obtain „the perfect sample“ and helping sort out problems with difficult materials.
In addition, Metalog Master gives you in-depth information on materialographic preparation theory.

Metalog – Structure – Metalog Guide

Since 1970 Struers Metalog has helped metallographers worldwide. In 1981 we started the publication of Structure, the most widely distributed materialographic magazine in the world.
These two publications and the updated Metalog Guide are both part of our dialogue and cooperation with the users of our equipment and consumables. A dialogue which Struers considers to be of the utmost importance, in order to help us develop even better methods and products.
We hope Metalog Guide will be of benefit to you and we look forward to future cooperation.

Struers

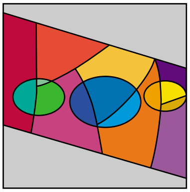
Overview

This **Metalog Guide** is your personal, comprehensive tool for sample preparation. It will give you efficient and systematic guidelines for your work with sample preparation using Struers equipment and consumables.

The **Metalog Guide** consists of the following chapters:

1. The Metalogram

A diagram for the selection of the correct preparation method according to the properties of a specific material.



2. Metalog Methods

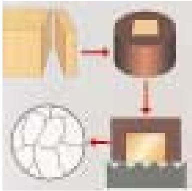
The Metalogram comprises 10 universally applicable preparation methods. These 10 methods employ Struers' vast range of consumables, and they cover all materials, regardless of hardness and ductility.

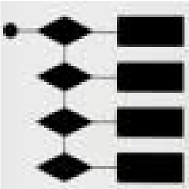
3. Struers Preparation Philosophy

Short introduction to the Struers definitions on sample preparation.

4. Metalog Process

A detailed description of the complete preparation process including tables for consumable selection, depending on the material's properties or specific requirements.





5. Metalog Master

A comprehensive guide on how to improve preparation results in a systematic way and a detailed description on preparation theory.

6. Consumables Specification

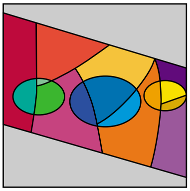
The consumables used in the Metalog Methods.

7. Miscellaneous

Index, list of literature and hardness conversion table.

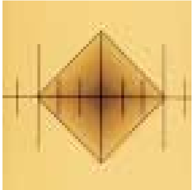
To find the preparation method for your material immediately, proceed to Chapter 1: **The Metalogram**. For additional information on preparation theory, see Chapters 3 and 4.

1. Metalogram

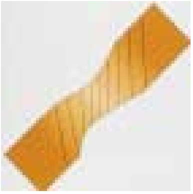


Introduction

In the Metalogram, we have chosen to display materials according to specific physical properties: hardness and ductility. The selection of a preparation method depends on these properties:



Hardness, the easiest attribute to measure is not sufficient information about a material to find the correct preparation method.



Ductility, the ability of a material to deform plastically is also important. How does a material actually respond to mechanical abrasion? Is it easily deformed, or do we get cracks and pull-outs during preparation?

The **Metalogram** displays materials according to both hardness and ductility, since both of these are factors in the selection of a preparation method.
For the preparation of materials which cannot be placed easily in the Metalogram, e. g. composites, coatings or other materials consisting of various phases or components, the following rules can be applied.

- Select a method which is suited for the material's predominant component.
- Check the samples after each step, and if preparation artifacts do occur consult Metalog Master for advice. The most common artifacts connected with the materials above: edge rounding, relief, pull-outs and porosity.
- Most plastics can be prepared according to the methods displayed in the Metalogram. However, some of the very soft thermoplastic materials can pose a problem due to plastic deformation. These materials can often be ground using SiC-paper up to a grit size of # 4000. DP polishing is omitted and the preparation is finished by OP polishing using OP-S or OP-U. If pick-up of SiC grains from the grinding paper occurs the paper can be covered with wax from e.g. candle to avoid this.

Description of the Metalogram

The x-axis represents the hardness in Vickers. The values are not shown in a linear way because the variety of preparation methods for softer materials is greater than for hard ones. The shape of the **Metalogram** results from soft materials generally being more ductile, and hard materials usually being more brittle.

Selection of a preparation method

First, find the hardness on the x-axis. Then, depending on the material's ductility, you either move upwards or downwards.
Unlike hardness, ductility is not easily defined in precise numbers. Materials must be placed on the y-axis according to your own previous experience.
You must have an idea of how a material will perform, that is, whether it is ductile or brittle.
To demonstrate our idea, we have displayed some materials in the Metalogram (see description below).
Ten preparation methods are the basis of the Metalogram. Seven methods, A-G, cover the complete range of materials. They are designed to produce specimens with the best possible results. In addition, three short methods, X, Y and Z, are displayed. These are methods for very quick, acceptable results.

Sample materials:

① MgAl alloy, cast

② Cu, pure

③ AlSi alloy

④ CuZn alloy, cast

⑤ Grey cast iron

⑥ Tool steel

⑦ Ball Bearing Steel 100 Cr6

⑧ WC/Co sintered carbide

⑨ Carbides in metallic matrix

⑩ Ceramic, Si_3N_4

2. Metalog Methods

Introduction

In this chapter you will find the preparation methods. A preparation method is a series of steps, in which material is removed mechanically from the sample surface by means of successively finer abrasives. A preparation method usually consists of the following steps:
Plane Grinding, PG
Fine Grinding, FG
Diamond Polishing, DP
Oxide Polishing, OP
(see detailed description in Chapter 4, **Metalog Process**).

Method evaluation

To obtain the best preparation regarding quality and costs, all preparation methods were thoroughly and critically evaluated. All methods include consumables belonging to the MD-System in order to assure effective preparation results with optimum reproducibility and flatness in the shortest possible time.
In addition, the MD-System offers the advantage of easy handling of grinding and polishing surfaces due to the magnetic support.

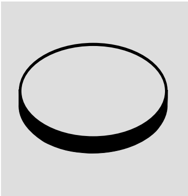
Two categories

We have designed seven methods which cover the entire range of materials. These methods provide the best possible results. In addition, three short methods are available. The short methods are perfectly suitable for a large number of materials, providing acceptable results.

Application

The preparation methods are designed for six mounted specimens of 30 mm diameter, clamped in a specimen holder of 160 mm diameter. The specimen area should be approximately 50% of the mount.
For specimens differing from these values, the preparation time or force may have to be adjusted, see page 15.
The methods are stated on pages 16-35.

Preparation parameters

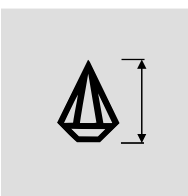


Surface

The grinding disc or polishing cloth used for preparation.
For the first preparation of a new material, always use the discs/cloths named in the respective preparation methods. To alter a method see the table on page 63 for an alternative grinding/polishing cloth.

Abrasive

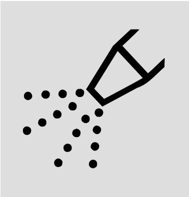
The abrasive used for grinding and polishing.
Diamond is the most widely used abrasive in all our methods. The only exceptions are the PG steps where SiC can be used for the softer types of materials, and the OP steps, in which colloidal silica is used to produce a scratch-free finish. As stated on page 99, the abrasive must have a hardness of 2.5 to 3 times the hardness of the material to be prepared. Never change to softer abrasives than suggested as this might lead to preparation artifacts.
The amount of abrasive applied depends on the grinding/polishing surface and the hardness of the samples.
The combination of cloths with low resilience and hard samples requires a larger amount of abrasive than cloths with high resilience and softer samples, because the abrasive particles are worn faster.



Grit/Grain size

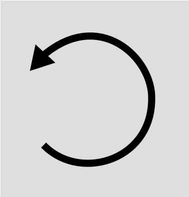
The grit (#) or grain size (µm) of the abrasive used.
The preparation is always started with the smallest possible grain size to avoid excessive damage to the samples. During the subsequent preparation steps, the largest possible intervals from one grain size to the next are chosen in order to minimize preparation time.

Lubricant



The liquid used for cooling and lubricating.
Depending on the type of material and the preparation stage, different types of lubricant can be used.
Blue and green lubricant are thin lubricants with high cooling and low smearing effect.
The blue lubricant is alcohol based, whereas the green lubricant is water based and does not contain any alcohol. The red lubricant has a high smearing and lower cooling ability.
For high material removal either blue or green lubricant is used, whereas the red is used especially for the polishing of soft and ductile materials.
Lubricant and abrasive should be applied separately. Depending on the type of material and the grinding/polishing disc used for preparation, different amounts of lubricant and abrasive have to be applied.
Generally it can be said that soft materials require high amounts of lubricant to avoid damage, but only small amounts of abrasive as there is only little wear on the abrasive.
Hard materials require less lubricant, but higher amounts of abrasive due to faster wear.
The amount of lubricant has to be adjusted correctly to get the best result. The polishing cloth should be moist, not wet. Excess lubricant will only flush the abrasive from the disc and remain as a thick layer between sample and disc, thus reducing material removal to a minimum.

Rotational speed (rpm)



The speed with which the grinding/polishing disc is rotating.
For PG a high disc speed is used to get a fast material removal.
For FG, DP and OP the same speed is used for both grinding/polishing disc and sample holder. They are also both turning in the same direction.
(See detailed explanation under polishing dynamics on page 87).
As we are working with loose abrasives, higher speeds would throw the suspension off the disc, thus requiring higher amounts of both abrasive and lubricant.

Force, Newton (N)

The total force with which the specimen holder or single specimen is pressed against the grinding/polishing disc.

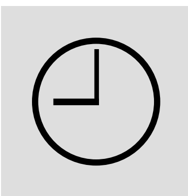
The force is expressed in Newton. The figures stated in the preparation methods are for a standard 6 specimens of 30 mm diameter, clamped in a specimen holder. The specimens are mounted, and the specimen area should be approximately 50% of the mount.

When running single specimens on e.g. Prepamatic-2 or Roto-Force-4, the force per specimen has to be set to 1/6 of the value stated in the preparation methods.

If the specimens are smaller, or there are fewer specimens in a holder, the force has to be reduced respectively to avoid damage such as deformations.

For larger specimens, the force should only be increased slightly. Instead, the preparation time should be extended. Higher forces increase the temperature because of higher friction, so thermal damage may occur.

For a more detailed description, please see the opposite page.



Time, minutes (min)

Preparation time, the time during which the sample holder is rotating and pressed against the grinding/polishing disc.

The preparation time is stated in minutes. It should be kept as short as possible to avoid artifacts such as relief or edge rounding.

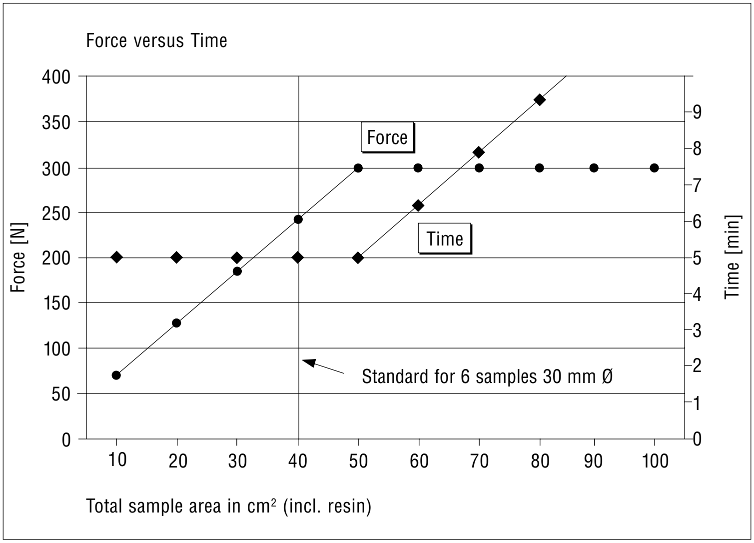
Depending on the sample size, the time may have to be adjusted.

For larger samples the time should be extended. The samples must be checked every minute to see when the next step can be started.

With samples smaller than the standard, the time should be kept constant and the force reduced.

For a more detailed description, please see the opposite page.

Adjustment of Preparation Parameters

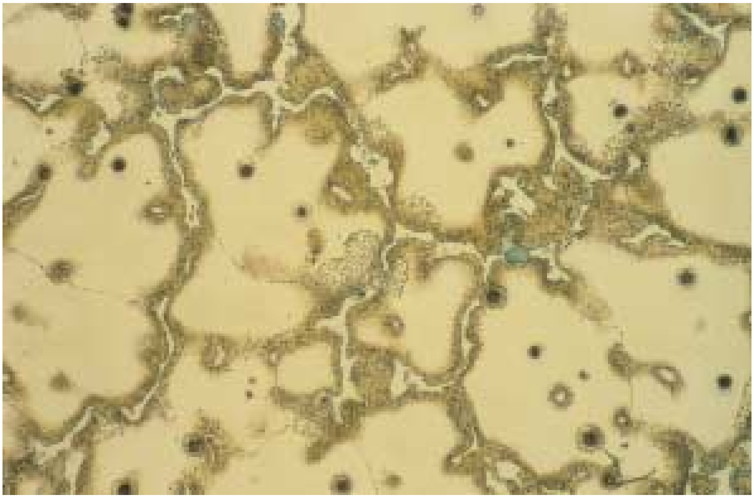


The above graph allows for the adjustment of the preparation parameters. The vertical line indicates the values for 6 samples, 30 mm diameter, in this case a force of about 250 N and a preparation time of 5 minutes.
For a different sample area (see table underneath), move on the x-axis to the left or right. The force should not be increased to more than 300 N. For larger sample areas the preparation time should be extended. For smaller sample areas the time should not be reduced to less than 5 minutes. Instead the force should be reduced. For other preparation steps in Metalog Guide, where different standard times or forces are stated, the values have to be changed accordingly. The following table is used for that purpose.

Sample Area in cm^2

No. of samples	**1**	**3**	**6**
25 mm diameter	5	15	29
30 mm diameter	7	21	42
40 mm diameter	13	38	75
50 mm diameter	20	59	118

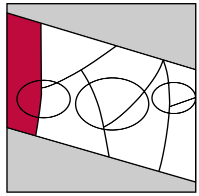
3 samples 25 mm dia. = 15 cm^2 → divide force by 3
3 samples 30 mm dia. = 21 cm^2 → divide force by 2
3 samples 40 mm dia. = 38 cm^2 → same force as stated
6 samples 25 mm dia. = 29 cm^2 → divide force by 1.5
6 samples 30 mm dia. = 42 cm^2 → standard sample size
6 samples 40 mm dia. = 75 cm^2 → increase force slightly, extend preparation time



Magnesium-aluminium cast alloy
Mag: 500x
Etchant: Molybdic acid

Cu58Zn42
Mag: 500x
Etchant: Klemm III

Metalog Method A



Grinding

Step	PG	FG
Surface	SiC-Paper	MD-Largo
Abrasive	SiC	DP-Suspension
Grit/ Grain size	# 320	9 µm
Lubricant	Water	Green / Blue
[rpm]	300	150
Force [N]	150	180
Time [min]	Until plane	5

Polishing

Step	DP 1	DP 2	OP
Surface	MD-Dur	MD-Mol	MD-Nap or MD-Chem
Abrasive	DP-Suspension	DP-Suspension	OP-S or OP-U
Grain size	6 µm	3 µm	-
Lubricant	Green / Blue	Red	-
[rpm]	150	150	150
Force [N]	180	150	60
Time [min]	4	3	1

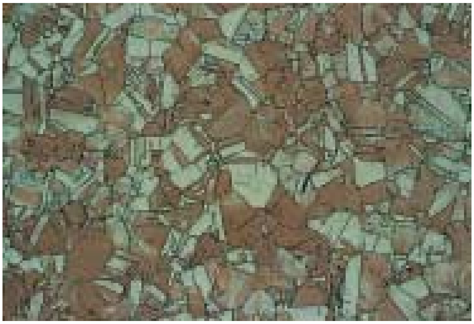
Consumables specification

For quick and easy access to exact specification of the necessary consumables, go to Chapter 6, ***Consumables specification*** *(page 101 ff)*

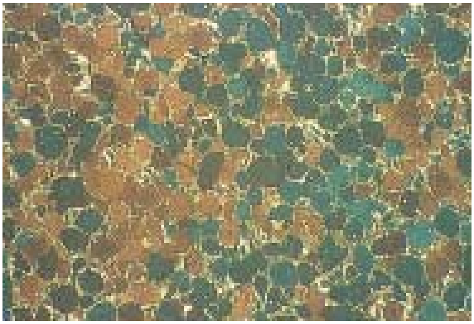
Improving the preparation method?

Go to Chapter 5, ***Metalog Master*** *(page 61 ff)*

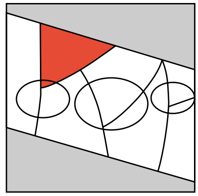
Copper pure
Mag: 50x
Etchant: Copper ammonium chloride



Malleable cast iron
Mag: 200x
Etchant: Nital



Titanium
Mag: 50x
Etchant: NH_4HF_2, 5% in H_2O
Titanium and materials of similar behaviour are prepared according to method B, but without the DP step. Instead, the OP step is extended, running 2 minutes at a time, OP-S is used with the addition of hydrogen peroxide and ammonia (96 ml OP-S, 2 ml H_2O_2, 2 ml NH_3)



Grinding

Step	PG	FG
Surface	MD-Primo 220	MD-Largo
Abrasive	SiC	DP-Suspension
Grit/ Grain size	-	9 µm
Lubricant	Water	Green / Blue
[rpm]	300	150
Force [N]	120	180
Time [min]	Until Plane	5

Polishing

Step	DP	OP
Surface	MD-Mol	MD-Nap or MD-Chem
Abrasive	DP-Suspension	OP-S or OP-U
Grain size	3 µm	-
Lubricant	Red	-
[rpm]	150	150
Force [N]	150	60
Time [min]	4	2

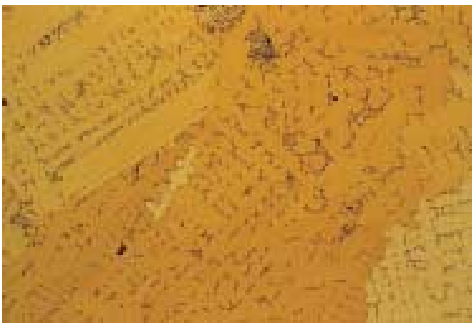
Consumables specification

For quick and easy access to exact specification of the necessary consumables, go to Chapter 6, ***Consumables specification*** *(page 101 ff)*

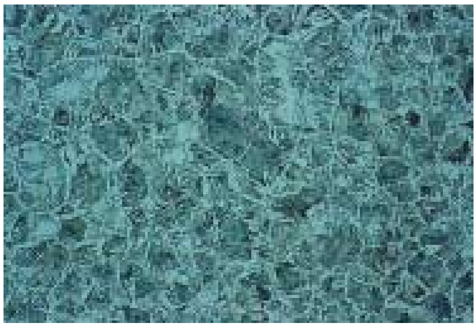
Improving the preparation method?

Go to Chapter 5, ***Metalog Master*** *(page 61 ff)*

Copper alloy with 37% Zn, cast
Mag: 50x
Etchant: Klemm III

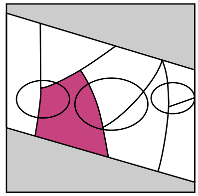


Medium carbon steel, overheated
Mag: 200x
Etchant: Nital



Eutectic copper alloy with 8.4% P
Mag: 100x
Etchant: Klemm III

Metalog Method C



Grinding

Step	PG	FG
Surface	MD-Primo 220	MD-Largo
Abrasive	SiC	DP-Suspension
Grit/ Grain size	-	9 µm
Lubricant	Water	Green / Blue
[rpm]	300	150
Force [N]	120	180
Time [min]	Until plane	5

Polishing

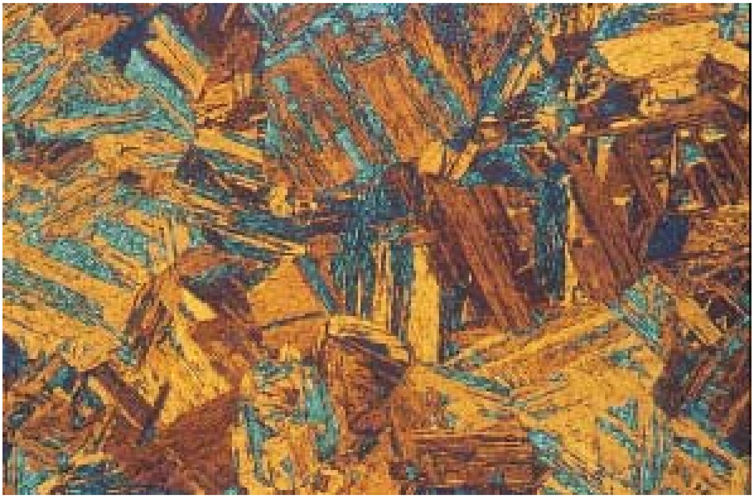
Step	DP	OP
Surface	MD-Dac	MD-Nap or MD-Chem
Abrasive	DP-Suspension	OP-S or OP-U
Grain size	3 µm	-
Lubricant	Green / Blue	-
[rpm]	150	150
Force [N]	180	60
Time [min]	5	1

Consumables specification

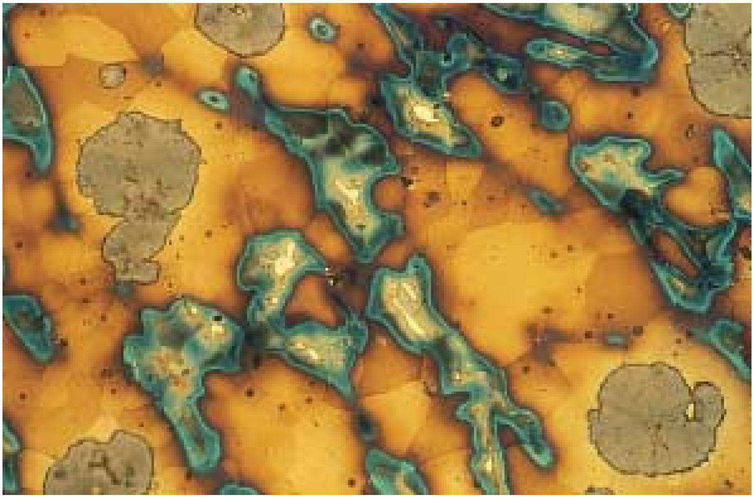
For quick and easy access to exact specification of the necessary consumables, go to Chapter 6, ***Consumables specification*** *(page 101 ff)*

Improving the preparation method?

Go to Chapter 5, ***Metalog Master*** *(page 61 ff)*

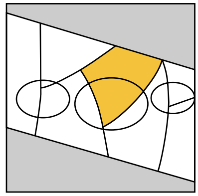


Low carbon steel
Mag: 100x
Etchant: Klemm I



Nodular cast iron
Mag: 50x
Etchant: Klemm I

Metalog Method D



Grinding

Step	PG	FG
Surface	MD-Piano 220	MD-Allegro
Abrasive	Diamond	DP-Suspension
Grit/ Grain size	-	9 µm
Lubricant	Water	Green / Blue
[rpm]	300	150
Force [N]	180	180
Time [min]	Until plane	4

Polishing

Step	DP	OP
Surface	MD-Dac	MD-Chem
Abrasive	DP-Suspension	OP-A
Grain size	3 µm	-
Lubricant	Green / Blue	-
[rpm]	150	150
Force [N]	180	90
Time [min]	4	2

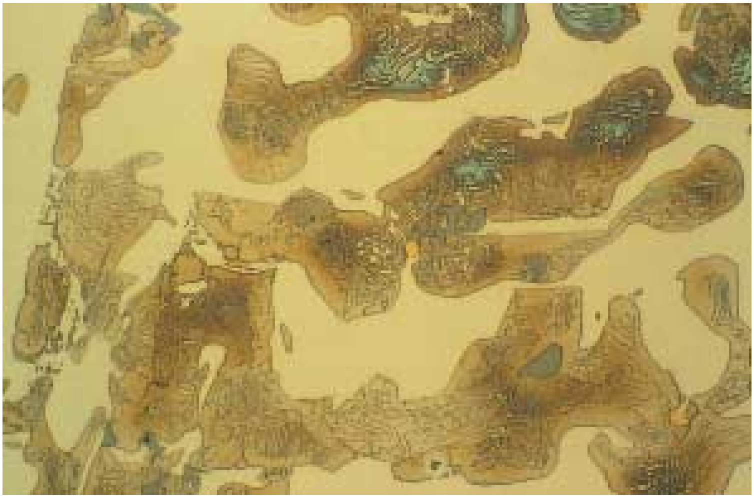
Consumables specification

*For quick and easy access to exact specification of the necessary consumables, go to Chapter 6, **Consumables specification** (page 101 ff)*

Improving the preparation method?

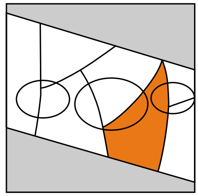
*Go to Chapter 5, **Metalog Master** (page 61 ff)*

100 Cr 6
Mag: 500x
Etchant: Nital



White cast iron
Mag: 500x
Etchant: Klemm I

Metalog Method E



Grinding

Step	PG	FG
Surface	MD-Piano 120	MD-Allegro
Abrasive	Diamond	DP-Suspension
Grit/ Grain size	-	9 µm
Lubricant	Water	Green / Blue
[rpm]	300	150
Force [N]	180	180
Time [min]	Until plane	4

Polishing

Step	DP 1	DP 2	OP
Surface	MD-Dur	MD-Nap	MD-Chem
Abrasive	DP-Suspension	DP-Suspension	OP-S or OP-U
Grain size	6 µm	1 µm	-
Lubricant	Green / Blue	Green / Blue	-
[rpm]	150	150	150
Force [N]	180	150	90
Time [min]	4	3	1

Consumables specification

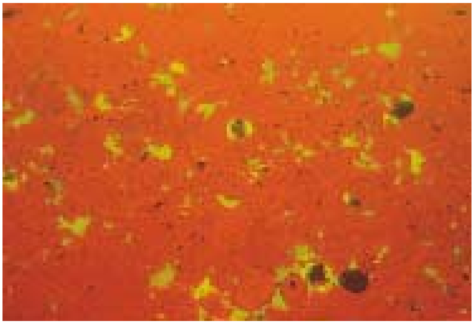
For quick and easy access to exact specification of the necessary consumables, go to Chapter 6, ***Consumables specification*** *(page 101 ff)*

Improving the preparation method?

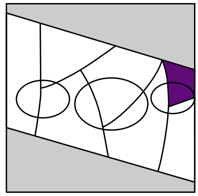
Go to Chapter 5, ***Metalog Master*** *(page 61 ff)*

Plasma spray coating, 88/12 WC/Co
Mag: 500x
Brightfield

Same as fig.1, most of the pores are filled with Epoxy and Epodye
Mag: 500x
Fluorescent light



Sintered carbide
Mag: 1000x,
DIC



Grinding

Step	PG	FG 1	FG 2
Surface	MD-Piano 120	MD-Allegro	MD-Largo
Abrasive	Diamond	DP-Suspension	DP-Suspension
Grit/ Grain size	-	9 µm	3 µm
Lubricant	Water	Green / Blue	Green / Blue
[rpm]	300	150	150
Force [N]	180	210	210
Time [min]	Until plane	5	5

Polishing

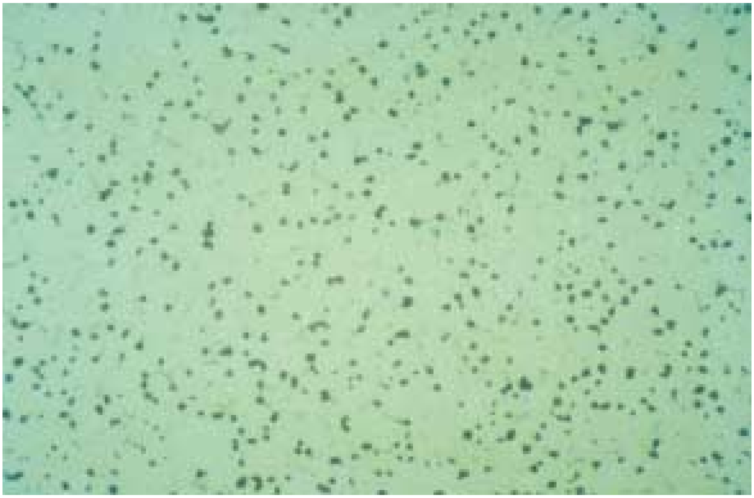
Step	DP	OP
Surface	MD-Dac	MD-Chem
Abrasive	DP-Suspension	OP-S or OP-U
Grain size	3 µm	-
Lubricant	Green / Blue	-
[rpm]	150	150
Force [N]	180	90
Time [min]	5	2

Consumables specification

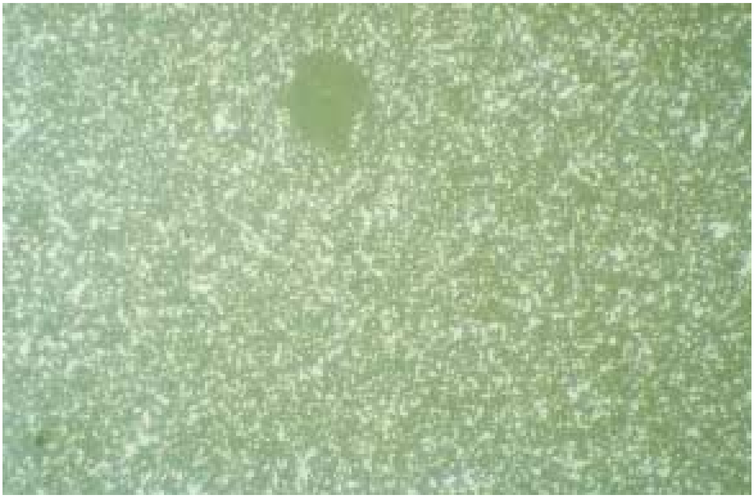
*For quick and easy access to exact specification of the necessary consumables, go to Chapter 6, **Consumables specification** (page 101 ff)*

Improving the preparation method?

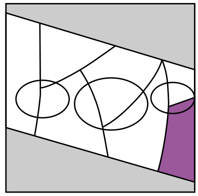
*Go to Chapter 5, **Metalog Master** (page 61 ff)*



ZrO_2
Mag: 200x



Si_3N_4
Mag: 500x



Grinding

Step	PG	FG 1	FG 2
Surface	MD-Piano 120	MD-Allegro	MD-Largo
Abrasive	Diamond	DP-Suspension	DP-Suspension
Grit/ Grain size	-	9 µm	3 µm
Lubricant	Water	Green / Blue	Green / Blue
[rpm]	300	150	150
Force [N]	180	210	210
Time [min]	Until plane	5	10

Polishing

Step	DP	OP
Surface	MD-Dac	MD-Chem
Abrasive	DP-Suspension	OP-S or OP-U
Grain size	3 µm	-
Lubricant	Green / Blue	-
[rpm]	150	150
Force [N]	180	60
Time [min]	8	2

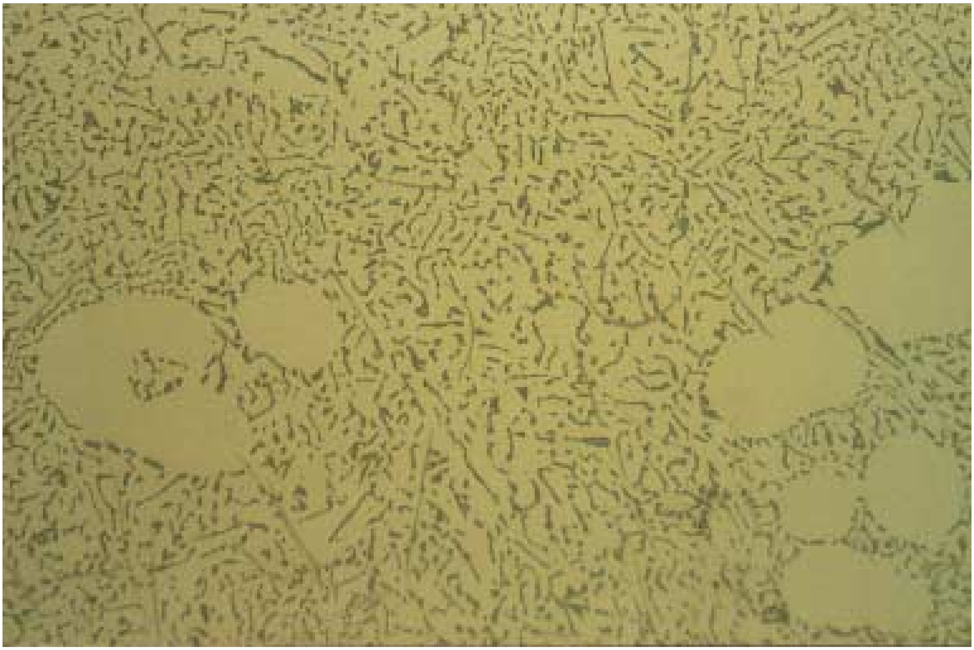
Consumables specification

For quick and easy access to exact specification of the necessary consumables, go to Chapter 6, ***Consumables specification*** *(page 101 ff)*

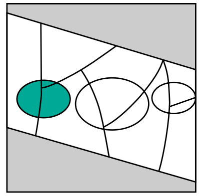
Improving the preparation method?

Go to Chapter 5, ***Metalog Master*** *(page 61 ff)*

AlSi alloy
Mag: 100x



Metalog Method X



Grinding

Step	PG	FG
Surface	MD-Primo 220	MD-Largo
Abrasive	SiC	DP-Suspension
Grit/ Grain size	-	9 µm
Lubricant	Water	Green / Blue
[rpm]	300	150
Force [N]	120	180
Time [min]	Until plane	5

Polishing

Step	DP
Surface	MD-Nap
Abrasive	DP-Suspension
Grain size	1 µm
Lubricant	Red
[rpm]	150
Force [N]	150
Time [min]	3

Consumables specification

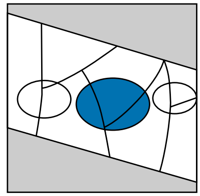
For quick and easy access to exact specification of the necessary consumables, go to Chapter 6, ***Consumables specification*** *(page 101 ff)*

Improving the preparation method?

Go to Chapter 5, ***Metalog Master*** *(page 61 ff)*

Tool steel
Mag: 200x
Etchant: Nital

Metalog Method Y



Grinding

Step	PG	FG
Surface	MD-Piano 120	MD-Allegro
Abrasive	Diamond	DP-Suspension
Grit/ Grain size	-	9 µm
Lubricant	Water	Green / Blue
[rpm]	300	150
Force [N]	210	210
Time [min]	Until plane	4

Polishing

Step	DP
Surface	MD-Plus
Abrasive	DP-Suspension
Grain size	3 µm
Lubricant	Green / Blue
[rpm]	150
Force [N]	180
Time [min]	4

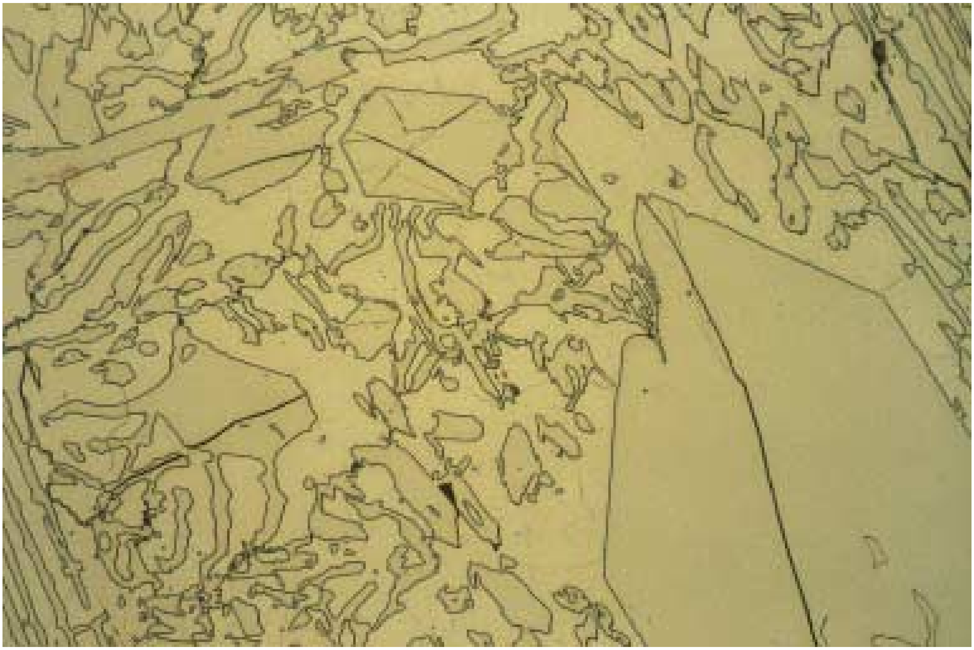
Consumables specification

For quick and easy access to exact specification of the necessary consumables, go to Chapter 6, ***Consumables specification*** *(page 101 ff)*

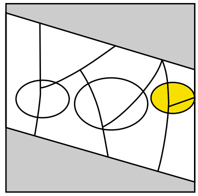
Improving the preparation method?

Go to Chapter 5, ***Metalog Master*** *(page 61 ff)*

Carbides in metallic matrix
Mag: 200x



Metalog Method Z



Grinding

Step	PG	FG
Surface	MD-Piano 120	MD-Allegro
Abrasive	Diamond	DP-Suspension
Grit/ Grain size	-	9 µm
Lubricant	Water	Green / Blue
[rpm]	300	150
Force [N]	180	210
Time [min]	Until plane	4

Polishing

Step	DP
Surface	MD-Dac
Abrasive	DP-Suspension
Grain size	3 µm
Lubricant	Green / Blue
[rpm]	150
Force [N]	180
Time [min]	6

Consumables specification

For quick and easy access to exact specification of the necessary consumables, go to Chapter 6, ***Consumables specification*** *(page 101 ff)*

Improving the preparation method?

Go to Chapter 5, ***Metalog Master*** *(page 61 ff)*

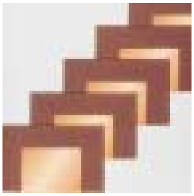
3. Preparation Philosophy

The aim of materialographic sample preparation is to reveal the **true structure** of the sample, whether it is metal, ceramic, sintered carbide or any other solid material.
The easiest way to accomplish this is with a **systematic preparation** method.
When our work routinely involves examining the same material, in the same condition, we want to achieve the same result each time. This means that the preparation result must be **reproducible.**
Our philosophy is based on these four criteria:

1. Systematic preparation

Sample preparation follows certain rules which are valid for most materials.
Different materials with corresponding properties (hardness and ductility) respond similarly and require the same consumables during preparation.
Therefore, we can display all materials in the **Metalogram** according to their properties, and not because they belong to a certain material group.
We look at our consumables from a **scientific point of view** to define their performance, and thus determine their best application.
This systematic approach has resulted in the **Metalog Methods** and the **Metalog Master**, which are the basis of the **Metalog Guide**.
In the **Metalog Master**, you can obtain advice on how to perfect sample preparation through an uncomplicated question/ answer cycle.

2. Reproducibility



Once a preparation method has been developed and adjusted, it should produce exactly the same results for the same material, every time it is carried out. This requires consumables of a high standard and uniform quality. Another essential factor is control of the preparation parameters such as:
Rotational speed and direction,
Force on the specimens,
Amount and type of abrasive and lubricant,
Preparation time.
These factors in preparation have a definite influence on the final result. Many of them can be adjusted and controlled only by automatic equipment.

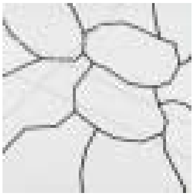
3. True structure

Theoretically, we are interested in examining a specimen surface which shows us a precise image of the structure we are to analyze.

Ideally, we require the following:
No deformation
No scratches
No pull-outs
No introduction of foreign elements
No smearing
No relief or rounded edges
No thermal damage.

Using mechanical preparation, however, it is almost impossible to achieve all of the above-mentioned conditions. There will be minimal damage to the structure which cannot be revealed with an optical microscope. This minimal damage does not influence the examination results.

This nearly perfect condition, with only superficial damage remaining, is commonly called the **true structure.**



4. Acceptable preparation results

Only in a few cases it is necessary to obtain the **true structure.** For most examinations a few scratches or slightly rounded edges do not matter. We need an **acceptable preparation result.** The finished surface has only to be as good as is needed for a particular analysis. Any preparation in excess of that requirement will only add to the overall cost of the preparation.

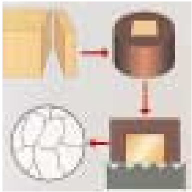
Cost-efficient preparation

Apart from the requirements to the finished surface, the overall cost of preparation is interesting for us. Preparation time, operator time and the amount of consumables used for the total preparation process are important factors.

The cheapest consumables do not always give the lowest price per sample. The lifetime of each single product and of course the quality of the surface it produces are of relevance. If, for example, a PG step is chosen only because of its high material removal, the following FG step may have to be extended due to excessive deformations introduced by the PG step. This must be considered when calculating the total preparation time and cost.

If you are interested in getting more information on cost savings, please contact your local Struers dealer.

4. Metalog Process

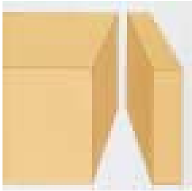


Introduction

The preparation process is divided into several stages which must be executed correctly to ensure a satisfactory result.
The three stages, **cutting, mounting** and **mechanical preparation,** will be explained in detail in the following pages.
No matter which result we want to achieve, the preparation must be performed systematically to ensure reproducible results.

Automatic equipment

For all three stages of preparation, automatic equipment will provide the best results in the shortest possible time, and in the most economical way.



Cutting

Depending on the size or shape of a piece of material, it may need to be sectioned.
A plane surface, with as little deformation as possible, is required to facilitate and expedite further preparation. Consequently, the most appropriate sectioning method is **abrasive wet cutting**, which will introduce the least amount of damage in relation to the time needed.

Note: The sample taken must represent the features of the parent piece from which it is cut.

Struers offers a complete range of machines for cutting of materialographic samples - from high-capacity cutting of very large workpieces to precision cutting of even the most delicate specimens. The programme of cut-off equipment covers all material and capacity requirements, including both automatic and manual machines.

Accutom-50 *is a precision table top cut-off machine and grinding machine for precise and deformation-free cutting. Equipped with sample rotation or oscillation. Pre-set constant feed speed in the range of 0.005 - 3.00 mm/s. Variable wheel speed up to 5,000 rpm, positioning accuracy of 5 µm, and adjustable force limit. Additional application areas of Accutom-50: precise serial cutting of all materials, grinding of thin sections, and target grinding on components*

Exotom-100 *is a sturdy cut-off machine designed for the production environment. High cutting power and a spacious and accessible cutting chamber make Exotom-100 ideal for cutting large items or large volume production. The unique ExciCut feature means fast and cold cutting, less wear on the cut-off wheel and plane and deformation-free specimen surfaces. With the optional AxioCut module very large workpieces can be cut. Exceptionally easy to operate, two simple controls put the operator in full charge of the cutting action*

Abrasive wet cutting

Abrasive wet cutting employs a cut-off wheel consisting of an abrasive and a binder.
Cooling liquid flushes the wheel to avoid damaging the sample with frictional heat. The coolant also removes debris from the cutting area.

Choice of wheel

Depending on the material to be cut, wheels of different composition may be needed. The hardness and ductility of the material influence the choice of cut-off wheel.
Ceramics or sintered carbides are sectioned with diamond in either a metal or a bakelite bond.
For ferrous materials, aluminum oxide (Al_2O_3) in a bakelite binder is typically used. Cubic boron nitride (CBN) is also increasingly used for the harder types of ferrous materials.
Non-ferrous metals are cut with silicon carbide (SiC) in bakelite.

Design of wheel

Apart from the abrasive particles, the basic difference between diamond/CBN wheels and SiC/Al_2O_3 wheels is the design.
The diamond/CBN wheels have a long-lasting performance due to the extreme hardness of the abrasive particles and the durable binders used to hold these particles in place. Only a thin layer of abrasive is placed on the circumference of a metal disc (continuous rim). These are long-term consumable wheels.
The other abrasives, SiC and Al_2O_3, wear faster and are less expensive. Therefore, the complete body of the wheel consists of abrasive and binder. These are called consumable wheels.

Wheel characteristics

1. Long-term consumable wheels (fig. 1)

Diamond wheels are available with two variations, with different binders for the abrasive particles. These are wheels with a **metal bond** and wheels with a **bakelite bond**. Both are used for cutting extremely hard materials. The metallic bond is used for the more brittle materials, such as ceramics. The bakelite bond is used to cut materials like sintered carbides.
CBN wheels are available only with a bakelite bond, and are used for cutting very hard ferrous materials, like white cast iron or the like.

2. Consumable wheels (fig. 2)

The cutting characteristics of these wheels vary with the properties of the bond. Binders can be classified according to their “hardness”, or their ability to retain or discard abrasive grains. **“Hard”** wheels retain the abrasive grains better than **“soft”** wheels. The “soft” wheels are used to cut hard, brittle materials because new, sharp abrasive grains are supplied continuously as the softer bond breaks down. Wheels with a harder bond should be used when cutting soft and ductile materials. In addition, wheels with a harder bond are more economical because they wear slower.
The correct choice of cut-off wheel for a specific material is highly important. Only the proper wheel ensures low deformation and a plane surface. A better surface after cutting allows you to obtain the required preparation result faster.

Fig. 1

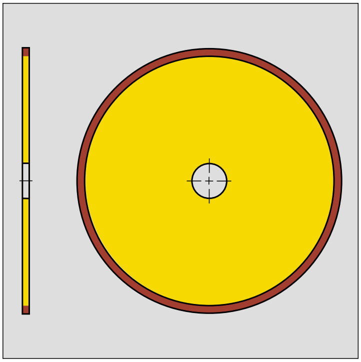
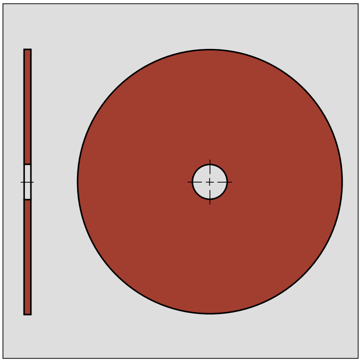


Fig. 2



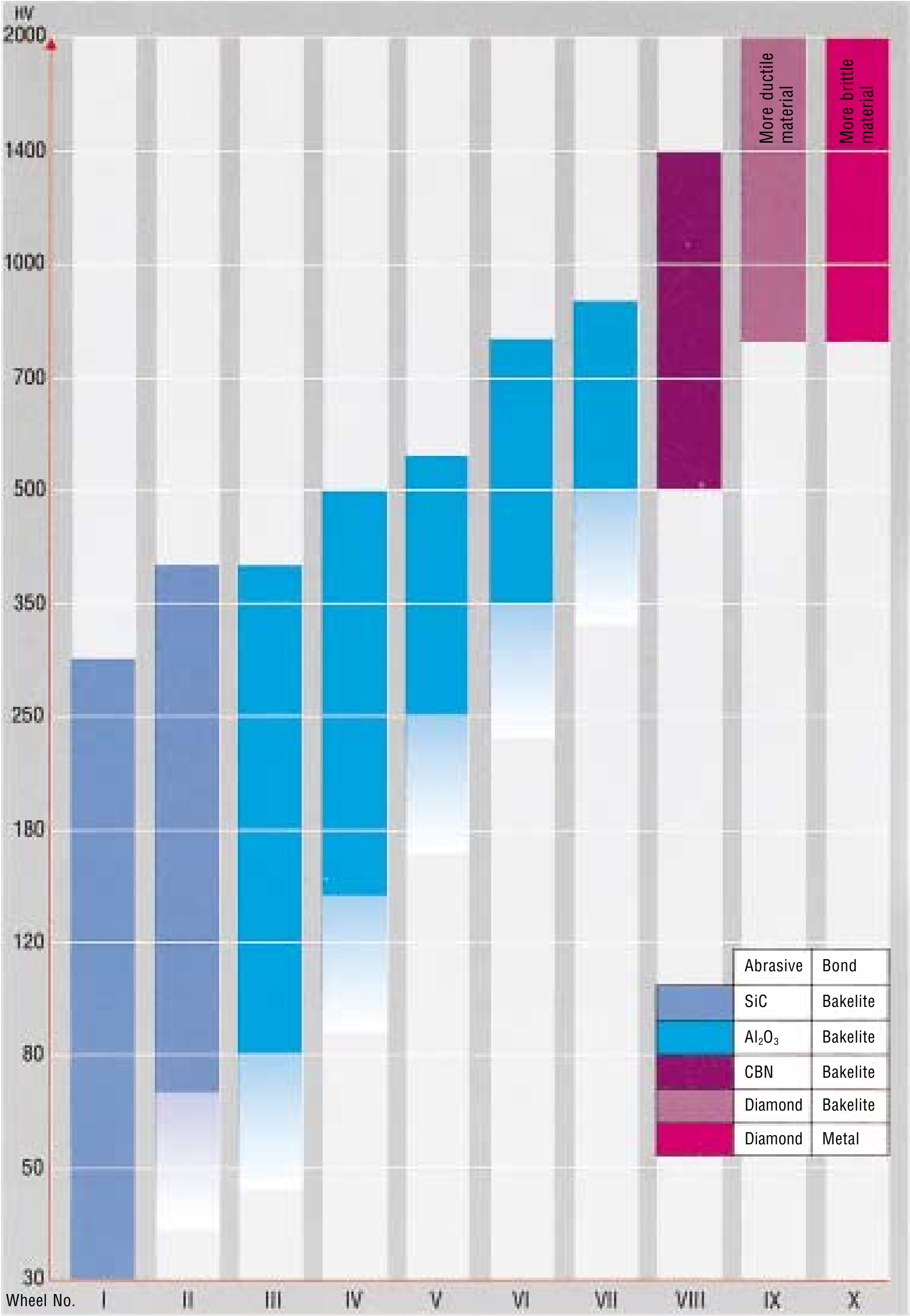
Selection of Cut-off Wheels

	Cut-off Machines	Exotom-100 Magnutom	Exotom	Unitom-5/-50 Unitom-2	Discotom-2/5 Labotom-3	Accutom-2 Accutom-5/50	Accutom-5 Accutom-50	Minitom
Wheel no	Application	Code	Code	Code	Code	Code	Code	Code
	Plastic, very soft metals						370SA**	
I	Non-ferrous soft metals	106MA	86EXO	56UNI	36TRE	357CA	459CA	355CA*
II	Very ductile metals (Ti)	106MA	90EXO	56UNI	40TRE	357CA	459CA	
III	Soft ferrous metals	104MA	84EXO 8UEXO	54UNI	35TRE	357CA	457CA	355CA*
IV	Medium soft ferrous metals	104MA 8UEXO	84EXO	54UNI	34TRE 37TRE	357CA	457CA	355CA*
V	Medium hard ferrous metals	102MA 202MA	83EXO 8UEXO	53UNI	33TRE	356CA	456CA 45UCA	355CA*
VI	Hard ferrous metals	102MA	81EXO	51UNI	32TRE	356CA	456CA	355CA*
VII	Very hard ferrous metals	101MA	81EXO	51UNI	31TRE	355CA*	355CA*	355CA*
VIII	Extremely hard ferrous metals				38TRE*	355CA*	355CA*	355CA*
IX	Sintered carbides Hard ceramics	25EXO 26EXO	25EXO 26EXO	25EXO 26EXO	24TRE	352CA	452CA	352CA
X	Minerals and ceramics				25TRE	330CA	430CA	330CA

**Abrasive: CBN*
***Sawblade*

To select a cut-off wheel:

1. Go upwards on the y-axis of the overview on the right page until you find the hardness value of your material.
2. Move to the right, until you cross the cut-off wheel fitting for your application.
   If you only have one material to cut, find the wheel where your material's hardness is placed as close to the middle as possible.
   For two or more materials, see if you can find a wheel which covers the whole hardness range.
   The bars which fade out at the bottom represent wheels which can be used for lower hardness also. However, this is not a very economical solution, and it should only be used in exceptional cases.
3. Find the number (I-X) of the respective wheel, and see the table above for the code of the correct wheel for your cut-off machine.


HV
2000
1400
1000
700
500
350
250
180
120
80
50
30
Wheel No.
I
II
III
IV
V
VI
VII
VIII
IX
X
More ductile material
More brittle material
Abrasive Bond
SiC Bakelite
Al_2O_3 Bakelite
CBN Bakelite
Diamond Bakelite
Diamond Metal

Mounting

Samples can be embedded in resin to facilitate their handling and to improve the preparation result. Specimens which need perfect edge retention or protection of layers require mounting.

Note: For the best possible result, samples should be cleaned prior to mounting. The surface must be free from grease and other contaminants for the best possible adhesion of resin to sample.

A complete range of mounting presses is available from Struers. For medium and large laboratories ProntoPress-10 and ProntoPress-20, the last mentioned with 2 mounting units, and for smaller laboratories LaboPress-1 and LaboPress-3 are recommended. All mounting presses can be used with mounting cylinders from 25 mm (1") to 50 mm (2").

Epovac vacuum impregnation unit for embedding and impregnation of porous materials

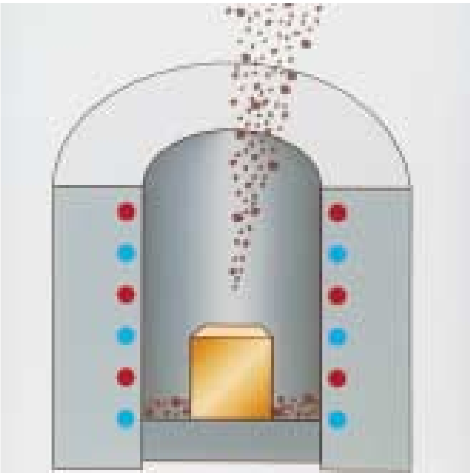
ProntoPress-20 is a mounting press with matchless flexibility and reproducibiblity. ProntoPress-20 has Advanced Process Control and is very easy to operate

Mounting techniques

Two techniques, hot compression mounting (also called hot mounting) and cold mounting are available for these different tasks, as well as several resins.
In the table on page 53, resins are displayed according to their properties.
To simplify the choice between hot compression mounting and cold mounting, both techniques are explained.

Hot compression mounting

The sample is placed in the mounting press (see figure), the resin is added, and the sample is processed under heat and high pressure.
Two types of hot mounting resins are available:
1. Thermosetting resins cure at elevated temperatures. They are also called **duroplastics**.
2. Thermoplastic resins soften or melt at elevated temperatures and harden during cooling.
Although thermosetting resins could be ejected at high temperatures, it is advisable to cool the mounts under pressure. This will result in the least shrinkage and maintain good adhesion between resin and sample.
All Struers mounting presses use water cooling to allow the shortest possible mounting time.



Hot Mounting Resins

Resin	Application	Specific property	Material
ConduFast	Electropolishing	Electrically conductive Very low shrinkage	Acrylic resin with iron powder filler, Thermoplastic, Gray
SpeciFast	Glass clear mounts Porous samples Surface electrical insulator for ConduFast	Transparent Medium shrinkage	Acrylic Thermoplastic
PolyFast	Edge retention	Very low shrinkage Medium removal rate	Phenolic resin with carbon filler Thermosetting, Black
	Examination in scanning electron microscope	Electrically conductive Low emission in the vacuum chamber	
IsoFast	Edge retention Planeness	Low shrinkage Low removal rate	Dialylphtalate with glass fibre filler Thermosetting, Green
DuroFast	Edge retention Planeness	Very low shrinkage Good adhesion Very low removal rate	Epoxy with mineral filler Thermosetting, Black
MultiFast	Routine examination Backup resin	Low shrinkage Medium removal rate	Phenolic resin with wood flour filler, Thermosetting, Black
MultiFast Green	Routine examination Colour marking	Low shrinkage Medium removal rate	Phenolic resin with wood flour filler, Thermosetting, Green
MultiFast Brown	Routine examination Colour marking	Low shrinkage Medium removal rate	Phenolic resin with wood flour filler, Thermosetting, Brown
Pre-Mount	Serial mounting of uncomplicated shapes	Easy to handle Low shrinkage Medium removal rate	Phenolic resin with wood flour filler. In tablet form Thermosetting, Black

Curing times	Dia. 25 mm (1")	Dia. 30 mm (1¼")	Dia. 40 mm (1½")	Dia. 50 mm
Heating / Cooling time	min.	min.	min.	min.
ConduFast	4 / 3	5 / 3	6 / 4	7 / 4
SpeciFast	5 / 8	6 / 8	7 / 10	8 / 12
PolyFast	5 / 3	6 / 3	7 / 4	8 / 4
IsoFast	5 / 3	6 / 3	7 / 4	9 / 4
DuroFast	5 / 3	6 / 3	7 / 4	8 / 4
MultiFast	5 / 3	6 / 3	7 / 4	9 / 4
MultiFast Green*	7 / 3	8 / 3	10 / 4	12 / 4
MultiFast Brown	5 / 3	6 / 3	7 / 4	9 / 4
Pre-Mount	5 / 3	6 / 3	7 / 4	9 / 4

The heating times refer to a heating temperature of 180 °C. The heating and cooling times may be shorter for samples with large surface areas and high heat conductivity.
** MultiFast Green has longer heating times due to a lower heating temperature of 150 °C*

Cold mounting

The sample is placed in a mould (see figure). The correct amounts of two or three components are measured carefully by either volume or weight. Then they are mixed thoroughly and poured over the sample.

Three types of cold mounting resins are available.

1. Epoxy

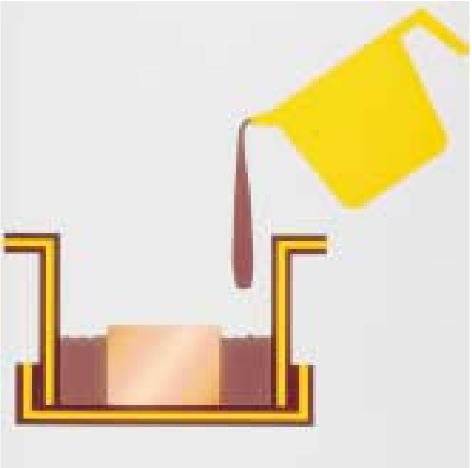
Epoxies have the lowest shrinkage of all cold mounting resins. The curing time is relatively long, but the adhesion to most materials is excellent. They are also used for vacuum impregnation. Epoxy resins polymerize through a chemical reaction after being mixed in the correct proportions. The hardened epoxy is duroplastic, and not affected by moderate heat or chemicals.

2. Acrylic

Acrylics are easy-to-use resins with short curing times and negligible shrinkage. They consist of self-polymerizing components which harden upon the addition of a catalyst. Hardened acrylic is thermoplastic and chemically resistant.

3. Polyester

Polyesters belong to the catalyzed system, like acrylics. Curing times are relatively short and the hardened sample is duroplastic.



Cold Mounting Materials

Name	Application	Features	Curing time	Mounting cups
SpeciFix-20	Epoxy	Vacuum impregnation Porous samples Mineralogical samples	8 h.	Multiform
SpeciFix-40	Epoxy	Vacuum impregnation Porous samples Mineralogical samples	3.5 h. at 50 ºC	Multiform
Epofix	Epoxy	Vacuum impregnation Porous samples Mineralogical samples	8 h.	Multiform
Caldofix	Epoxy	Vacuum impregnation Porous samples Mineralogical samples	1.5 – 2 h. at 70-80 ºC	Multiform
MetaFix-20	Acrylic	Serial mounting Irregularly shaped samples	15 min.	Multiform Flexiform Seriform
Citofix	Acrylic	Serial mounting Irregularly shaped samples	7 – 10 min.	Multiform Flexiform Seriform
Durofix-2	Acrylic Mineral filler	Serial mounting Edge retention Irregularly shaped samples	15 min.	Multiform Flexiform Seriform
Acryfix	Acrylic	For routine work	9 – 10 min.	Multiform Flexiform Seriform
Triofix-2	Polyester / Acrylic / Mineral filler	Edge retention Planeness	15 – 18 min.	Multiform Flexiform
Serifix	Polyester	Serial mounting	45 min.	Multiform Flexiform Seriform

Choice of mounting techniques

Depending on the number of samples and the quality required, both mounting techniques have certain advantages.

Hot mounting is ideal for large numbers of samples coming to the lab successively. The resulting mounts will be of high quality, uniform size and shape, and require a short process time.

Cold mounting is suitable for a large series of samples coming to the lab simultaneously, and also for single samples.

In general, hot mounting resins are less expensive than cold mounting resins. However, a mounting press is required for hot mounting.

Some cold mounting resins can be used for vacuum impregnation.

Vacuum impregnation

Porous materials, like ceramics or sprayed coatings, require vacuum impregnation. All pores connected to the surface are filled with resin. Consequently, the resin reinforces these fragile materials. Preparation artifacts like pull-outs, cracks or unopened porosity can be minimized.

Only Epoxy resins can be used for vacuum impregnation, due to their low viscosity and their low vapour pressure. EpoDye, a fluorescent dye, can be mixed with epoxy to allow easy identification of all filled pores in fluorescent light.

Mounting Materials

Application / Specific properties

Hot	ConduFast	SpeciFast	PolyFast	IsoFast	DuroFast	MultiFast	Pre-Mount
Curing time, < 20 min.	✓	✓	✓	✓	✓	✓	✓
Easy handling							✓
Edge retention			0	x	x		
Electrolytic polishing	✓						
SEM			✓				
Hard				✓	✓		
Mineral filler					✓		
Planeness			0	x	x		
Protection of layers			0		x		
Transparent		✓					
Wear resistant				x	x		

✓ Recommended for all materials   0 For soft materials (<HV 400)   X For hard materials (>HV 400)

Cold	SpeciFix -20	SpeciFix -40	Epofix	Caldofix	MetaFix -20	Citofix	Durofix-2	Acryfix	Triofix-2	Serifix
Curing time, < 20 min.					✓	✓	✓	✓	✓	
Curing time, < 4 h.		✓		✓						✓
Curing time, > 4 h.	✓		✓							
Edge retention	0	0	0	0			x		x	
Hard							✓		✓	
Low curing temperature	✓		✓							
Mineral filler							x		x	
Planeness	0	0	0	0			x		x	
Protection of layers	✓	✓	✓	✓					x	
Translucent					✓	✓		✓		
Transparent	✓	✓	✓	✓						✓
Vacuum impregnation	✓	✓	✓	✓						
Wear resistant							✓		✓	
Use with EpoDye	✓	✓	✓	✓						
Use with AcryDye					✓	✓		✓		

✓ Recommended for all materials   0 For soft materials (<HV 400)   X For hard materials (>HV 400)

Mechanical Preparation

Introduction

Mechanical preparation is the most common method of preparing materialographic samples for microscopic examination. Abrasive particles are used in successively finer steps to remove material from the surface, until the required result is reached.
As described in Chapter 3, Struers Preparation Philosophy, samples can be prepared to the perfect finish, the **true structure**, or the preparation can be stopped when the surface is acceptable for a specific examination.
It is the particular type of analysis or examination that determines the specific requirement to the prepared surface. No matter what we want to achieve, the preparation must be carried out systematically and in a reproducible way to secure the optimal result at the lowest cost.

Definition of processes

Mechanical preparation is divided into two operations: **grinding** and **polishing**. For more detailed theoretical explanations of both processes, see Chapter 5, Metalog Master.
Struers' range of equipment for mechanical preparation is second to none. A large number of machines for grinding and polishing is available, meeting all demands on capacity, preparation quality and reproducibility.
The methods in the Metalog Guide have been developed in connection with automatic equipment, because experience has shown that reproducibility and high preparation quality is conditioned by automation. In addition, automation is a great money saver due to controlled consumption of consumables.
A combination of Struers' equipment and consumables for mechanical preparation is the best guarantee for the highest quality at the lowest cost per sample.

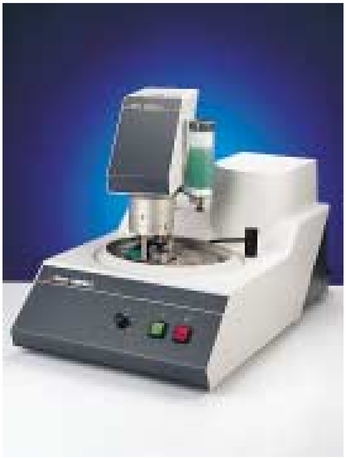
Struers offers a comprehensive programme of grinding and polishing machines meeting all demands for capacity, preparation quality and reproducibility in large as well as small laboratories. From the high capacity, fully automatic preparation systems to small manual or semi-automatic grinding and polishing machines.

Prepamatic-2 *- A fully automatic machine especially well-suited for laboratories where high reproducibility is essential*

The ***Abra*** *series of sturdy designed work-horses for high volume grinding and polishing*

The modular and most versatile ***RotoSystem*** *with a wide range of possible product combinations*

The ***LaboSystem*** *for low volume materialographic laboratories*



MD System™

The **MD-System™** is a comprehensive line of grinding discs and polishing cloths with metallic backings available in 200 mm, 250 mm and 300 mm diameters. A single magnetic disc, positioned on the grinding and polishing machine throughout the preparation process, is used to support the preparation surfaces.
The grinding discs in the MD-System™ make it possible to reduce the typical grinding process involving SiC-Paper to typically two steps, and cut total preparation time. At the same time the preparation quality is tremendously improved compared to SiC-Paper.

The **MD-System™** ensures
- Easy handling and exchange of the preparation surfaces
- No trapped air bubbles or wrinkles when fixing the polishing cloth
- Low maintenance
- Fewer preparation steps and reduced preparation time
- High, consistant material removal
- Perfectly plane specimens without edge rounding, relief or smearing

Magnetic Supporting Disc

MD-Disc™ is the supporting disc for all preparation surfaces. One disc is sufficient to support all preparation surfaces, so both space and money can be saved.

Plane Grinding Surfaces

For plane grinding three discs are available. **MD-Primo™** contains SiC abrasive in a resin bond. It can be used for soft, nonferrous materials in the HV 40-150 hardness range.
MD-Piano™ contains diamonds in a resin bond, and can be used for materials with a hardness HV >150. They feature long-lasting surfaces for optimal material removal at a constant rate.

The service life of the discs is comparable to about 60 or 100 pieces of SiC-Paper respectively. **MD-Forte**™ contains diamonds in a nickel bond. The nickel bond is much stronger than a resin bond and grants a longer lifetime compared to MD-Piano™. It can be used for all materials with a hardness HV > 40.
All plane grinding discs work with water as lubricant, and can be used for manual and automatic preparation.

Fine Grinding Surfaces

MD-Largo™ and **MD-Allegro**™ are composite discs for one step fine grinding. MD-Largo™ is used for soft materials in the HV 40-150 hardness range, and is also recommended for fine grinding of composite materials. MD-Allegro™ is used for materials with a hardness HV > 150. Both discs are used together with diamond suspension or spray and a lubricant.
MD-Piano 1200™ is a fine grinding disc containing diamonds in a resin bond. It can be used for materials with a hardness HV >150. MD-Piano 1200™ is especially well-suited for manual fine grinding. Water is applied as lubricant.

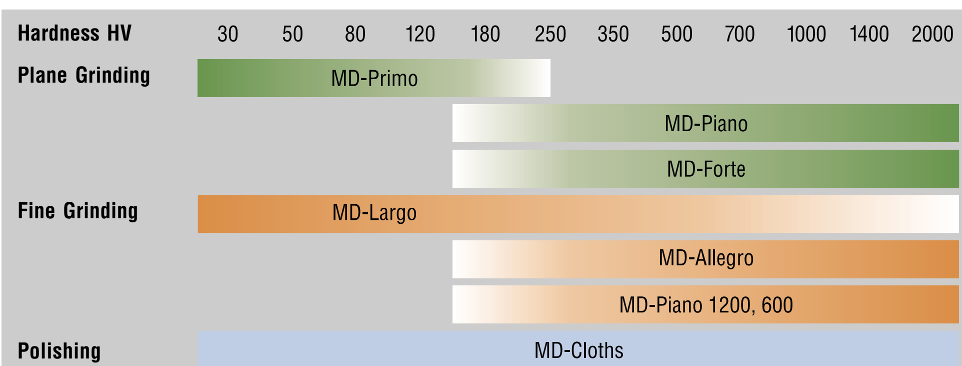
Polishing Surfaces

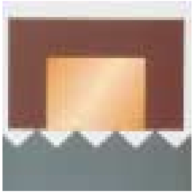
MD-Cloths™ are available in a variety of naps and materials for all polishing procedures. They eliminate the need for separate platens for each polishing step, and the risk of trapped air bubbles or wrinkles when fixing the polishing cloth on a supporting disc.

Storage Cabinets

To store the MD-System preparation surfaces, two stackable storage carousels called **MD-Concert**™ and **MD-Concertino**™ are available. The storage cabinets allow the preparation discs to dry effectively and protect them against contamination.

Application Areas





Grinding

Introduction

The first steps of mechanical material removal are called grinding. Proper grinding removes damaged or deformed surface material, while introducing only limited amounts of new deformation. The aim is a plane surface with minimal damage that can be removed easily during polishing in the shortest possible time.
Grinding can be divided into two individual processes.
Plane **G**rinding, **PG**
Fine **G**rinding, **FG**

PG

The first grinding step is usually defined as Plane Grinding, PG. Plane Grinding ensures that the surfaces of all specimens are similar, despite their initial condition and their previous treatment. In addition, when several specimens in a holder need to be processed, they must all be in the same level, or “plane”, for further preparation.
Relatively coarse, fixed abrasive particles are used to remove material quickly.
Depending on a material’s properties, different types of abrasives can be utilized.
SiC is mostly used for plane grinding of soft materials (< 150 HV) as with the MD-Primo.
Al_2O_3 can be employed for ferrous materials.
Diamonds, as in the MD-Piano, are used for grinding of materials > 150 HV, like harder ferrous metals, ceramics or sintered carbides.
However, with the introduction of the fine grinding discs MD-Allegro and MD-Largo, PG is not always necessary for the preparation of single specimens.

FG

Fine grinding produces a surface with such a small amount of deformation that it can be removed during polishing. For soft materials (< 150 HV) and composite materials with a soft matrix, MD-Largo should be used. For harder materials (> 150 HV) the MD-Allegro should be employed.

MD-Largo and MD-Allegro are used together with diamond suspensions. The unique surfaces of the discs allow the diamond particles to become partly embedded. The firm location of the diamond particles enables high material removal with a low degree of deformation. At the same time MD-Allegro and MD-Largo ensure perfect flatness and offer the advantage of minimum maintenance.

Metalog Process

Polishing

Like grinding, polishing must remove the damage introduced by previous operations. This is achieved with steps of successively finer abrasive particles.
Polishing can be divided into two different processes.
Diamond **P**olishing, **DP**
Oxide **P**olishing, **OP**

DP

Diamond is used as an abrasive to accomplish the fastest material removal and the best possible planeness. There is no other abrasive available which can produce similar results. Because of its hardness, diamond cuts extremely well through all materials and phases.

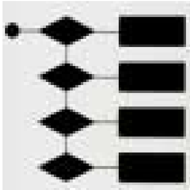
OP

Certain materials, especially those which are soft and ductile, require a final polish for optimum quality. Here, oxide polishing is employed.
Colloidal silica, with a grain size of approximately 0.04 µm and a pH of about 9.8, has shown remarkable results. The combination of chemical activity and fine, gentle abrasion produces absolutely scratch-free, deformation-free specimens. **OP-U** is an all-round polishing suspension that provides perfect results with all types of materials. **OP-S** can be used together with reagents that increase the chemical reaction.
This makes **OP-S** suited for very ductile materials.
An acidic alumina suspension, **OP-A**, is used for final polishing of low and high alloy steels, nickel-based alloys and ceramics.

Consumables

Polishing is carried out on polishing cloths (see overview on page 106). For diamond polishing, a lubricant must be used. The choice of cloth, diamond grain size and lubricant depends on the material to be polished. The first steps are usually done on cloths with low resilience and, with a low viscosity lubricant. For final polishing, cloths with higher resilience and, for soft materials, a lubricant with high viscosity is used.
In the ten Preparation Methods in Chapter 2 the most appropriate cloths for the specific materials are recommended.

5. Metalog Master



Introduction

Metalog Master is a tool to perfect preparation methods. Here all potential preparation artifacts are discussed and possible improvements shown step by step (see pages 64-95).
To simplify these instructions, we will use standard terminology, which will be defined at the beginning of each section. At the end of this chapter (pages 96-99) you will find a detailed description of the theory on material removal and abrasives.

Preparation artifacts

Below is a list of preparation artifacts. Photomicrographs illustrating the individual faults are shown on the respective pages.

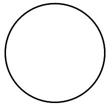
General Rules

To improve the preparation of a particular material, make sure that it has been prepared according to a suitable method from the Metalogram.
There are a few basic rules which should always be followed:

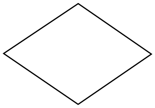
- *If a material is prepared for the first time, the samples should be examined after every step under the microscope. This makes it easier to see when preparation artifacts occur.*
- *Before proceeding to the next step, be sure that all damage from the previous step, such as scratches, pull-outs or embedded grains, is removed completely. If this is not the case, artifacts from an early step might show up on the finished surface, and it would be impossible to be sure where they originated. You must know where the artifacts start to be able to improve the method.*
- *Keep preparation times as short as possible. Times which are longer than necessary, waste consumables and may even damage the sample, for example with edge rounding and relief.*
- *New polishing cloths or grinding discs may need to be "run in" for a short time, or dressed or cleaned before use to give the best results.*

The Expert System

The information on how to improve preparation results or how to avoid specific artifacts is displayed in a logical system: four different types of boxes are used to display the different information categories.

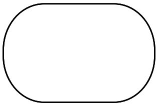


What you see when you examine the sample



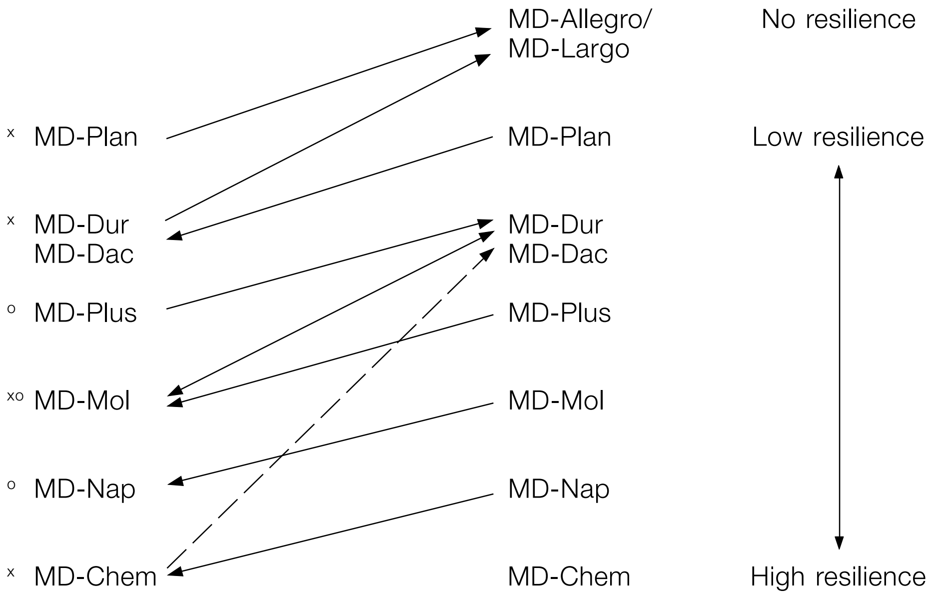
A question concerning the preparation method or technique

An explanation on what has happened and how to solve the problem



What to do next

Grinding / Polishing Surfaces



If you have relief or edge rounding, go →

If you have scratches or deformation, go ←

In certain cases MD-Dur can also be used for OP-Polishing
— — — — — —

x Napless cloth
o Cloth with nap

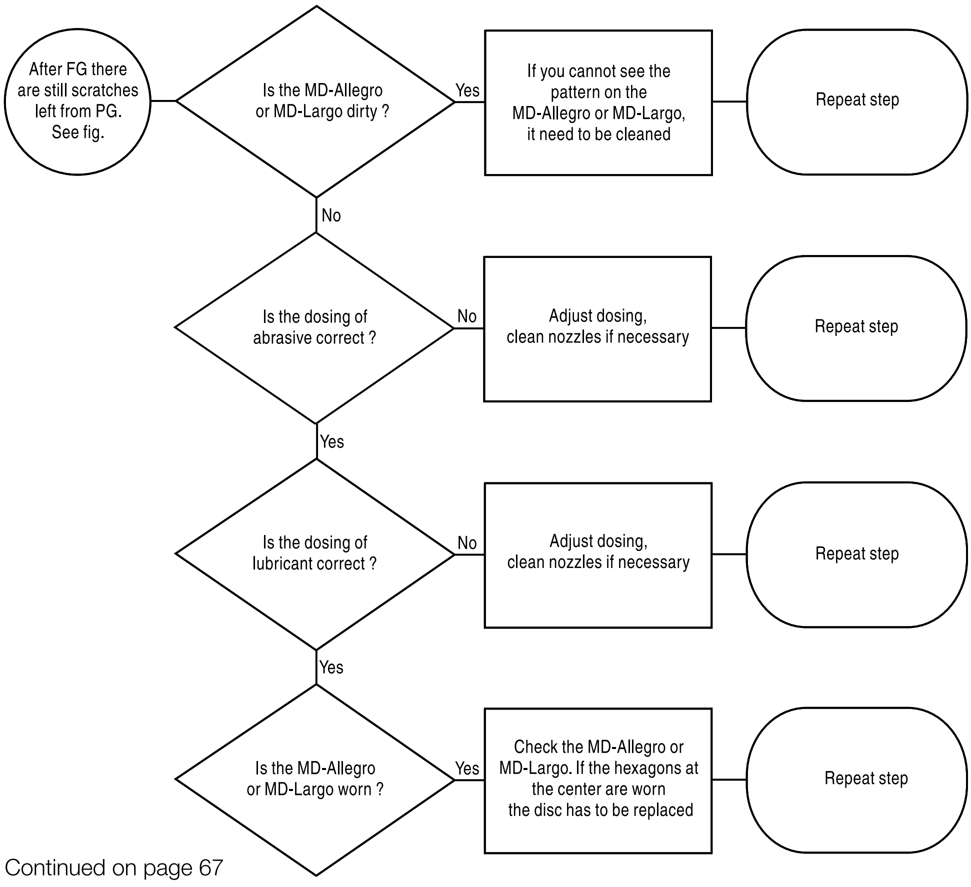
Scratches

Scratches are grooves in the surface of a sample, produced by the points of abrasive particles.

After FG, scratches from PG are still visible
Mag: 200x

Scratches

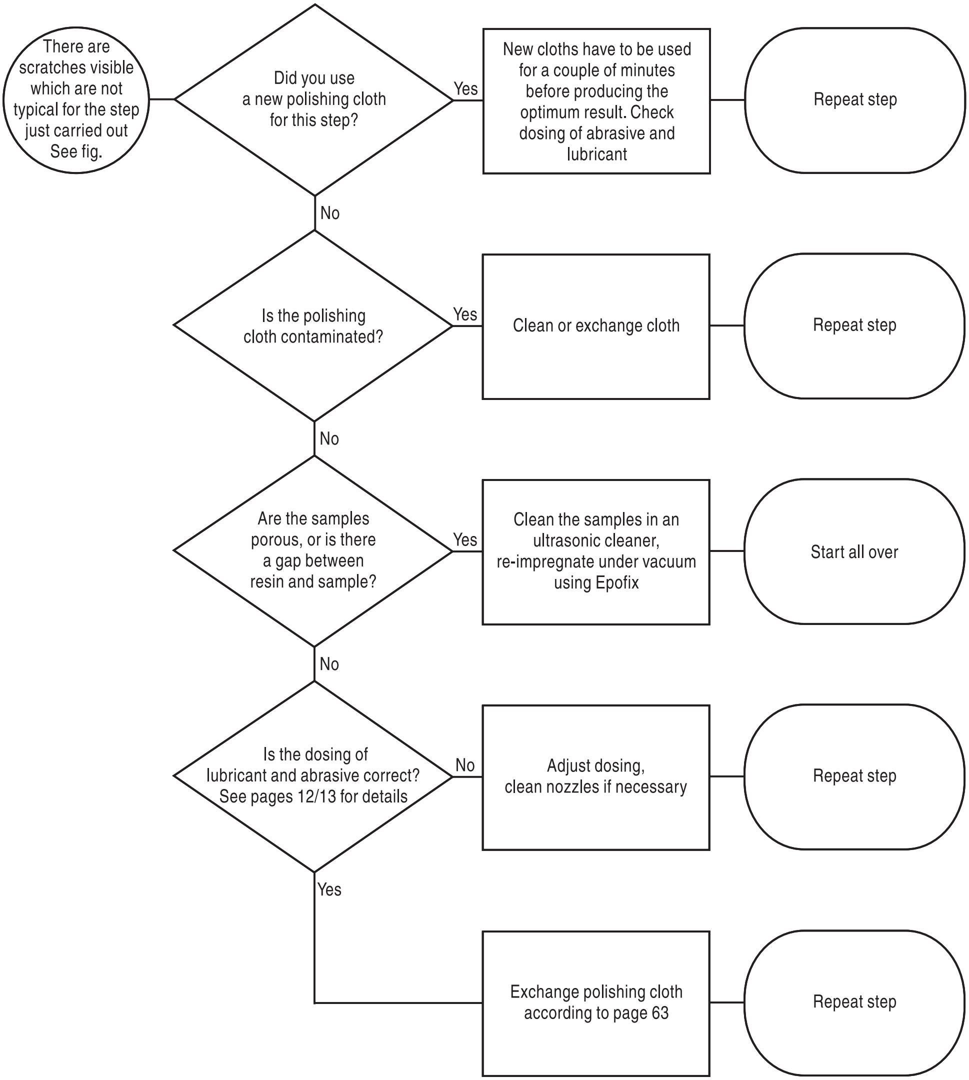
- *Make sure that after PG the surface of all samples in the specimen holder shows the same uniform scratch-pattern over the whole surface.*
- *Repeat PG if necessary.*
- *Clean the samples and sample holder carefully after every step, to avoid contamination of the grinding/polishing surface through large abrasive particles from a previous step.*
- *If there are still scratches left over from the previous step after finishing the current step, increase the preparation time by 25 to 50% as a first measure. If that does not help, use the Expert System.*



Continued on page 67

Metalog Master

After diamond polishing, scratches from FG still remain.
The very deep vertical scratch might even be left over from PG
Mag: 200x



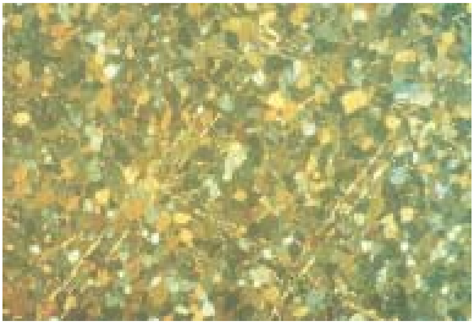
Metalog Master

Deformation

There are two types of deformation, elastic and plastic. Elastic deformation disappears when the applied load is removed. Plastic deformation may also be referred to as cold work. It can result in subsurface defects after grinding, lapping or polishing. Remaining plastic deformation can first be seen after etching.
Only deformation introduced during the preparation is covered here.
All other types from previous operations like bending, drawing and stretching are not considered, because it cannot be changed or improved by changing the preparation method.

1. Short deformation lines, restricted to single grains. Mag: 100 x, DIC

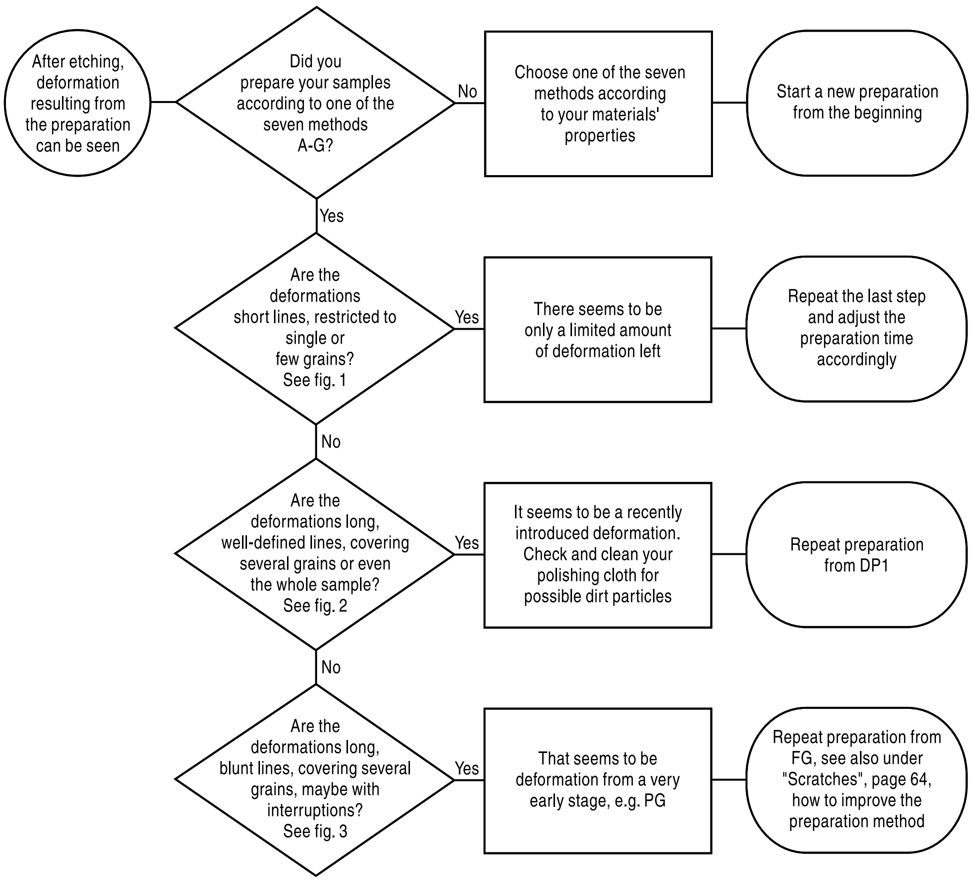
2. Well-defined, sharp deformation lines Mag: 200 x, DIC



3. Blunt deformation lines, interrupted Mag: 500 x, Polarized light

Deformation

- *Deformations are artifacts which first show up after etching (chemical, physical or also optical etching).*
- *If a supposed deformation line also is visible in brightfield in unetched condition, please see first under scratches on how to improve the preparation method.*



Smearing

The plastic deformation of larger sample areas is called smearing.

1. Smearing on soft, ductile steel
Mag: 15 x, DIC

2. Smearing on soft, ductile steel
Mag: 25 x, DIC

Smearing

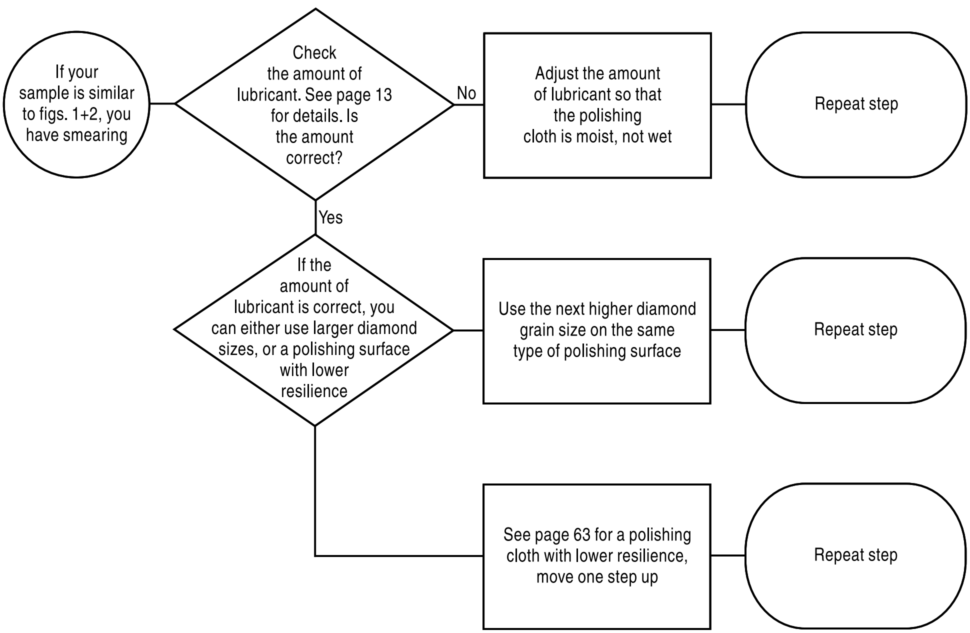
Instead of being cut, the material is pushed, moved across the surface.

The reason is an incorrect application of abrasive, lubricant or polishing cloth, or a combination of these, which makes the abrasive act as if it was blunt.
There are three possibilities to avoid smearing:

1. Lubricant: check the amount of lubricant, smearing often occurs at too low a lubricant level. If necessary, increase the amount of lubricant.

2. Polishing cloth: due to high resilience of the cloth the abrasive can be pressed too deep into the cloth and cannot cut.
Change to a cloth with lower resilience, see table on page 63.

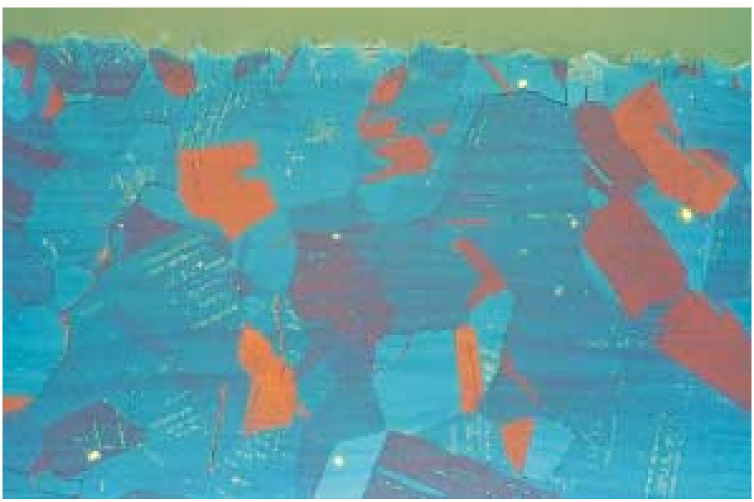
3. Abrasive: the diamond grain size might be too small. The particles cannot penetrate into the material and because of that, cannot cut.
Use a larger grain size.



Edge rounding

Using a polishing surface with high resilience will result in material removal from both the sample surface and around the sides. The effect of this is edge rounding. With mounted specimens, this effect can be seen, if the wear rate of the resin is higher than that of the sample material.
See also page 87 on polishing dynamics.

1. Due to a gap between resin and sample the edge is rounded. Stainless steel. Mag: 500 x Etchant: Beraha I

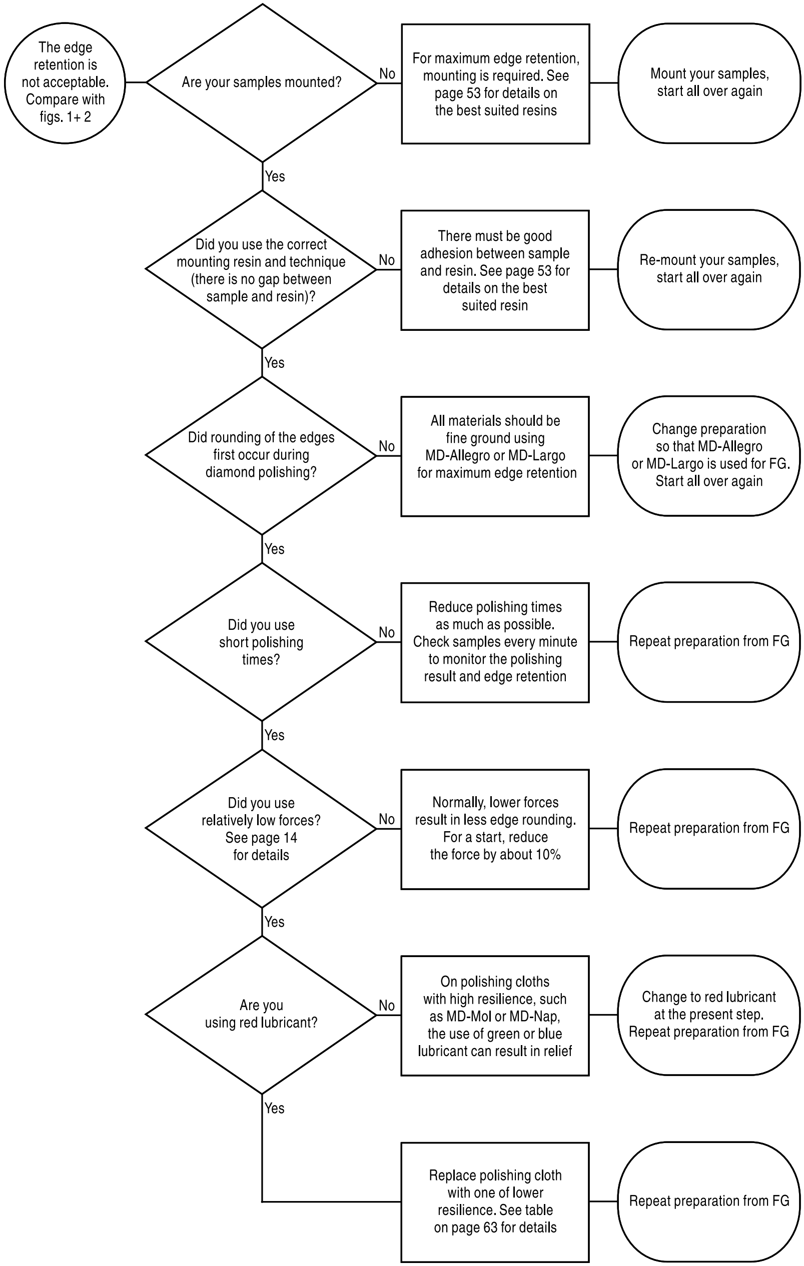


2. Good edge retention, stainless steel Mag: 500 x Etchant: Beraha I

Edge rounding

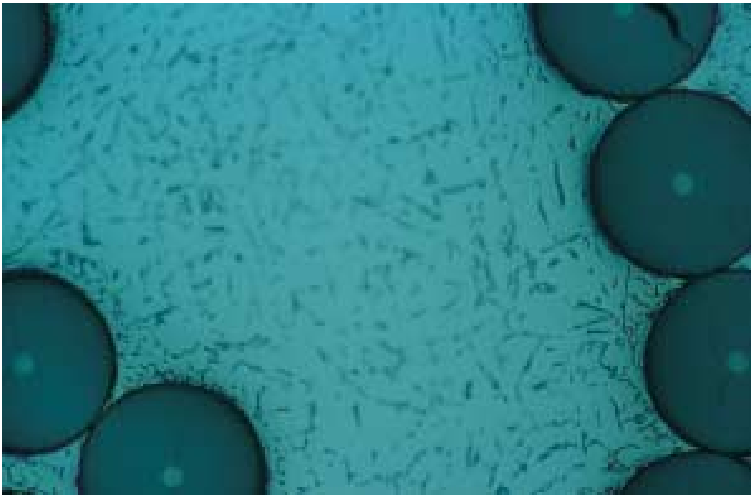
Please check your samples after every preparation step to see when the fault occurs.

If, for some reason, your samples cannot be mounted, some of the following hints can still be used to improve the edge retention.

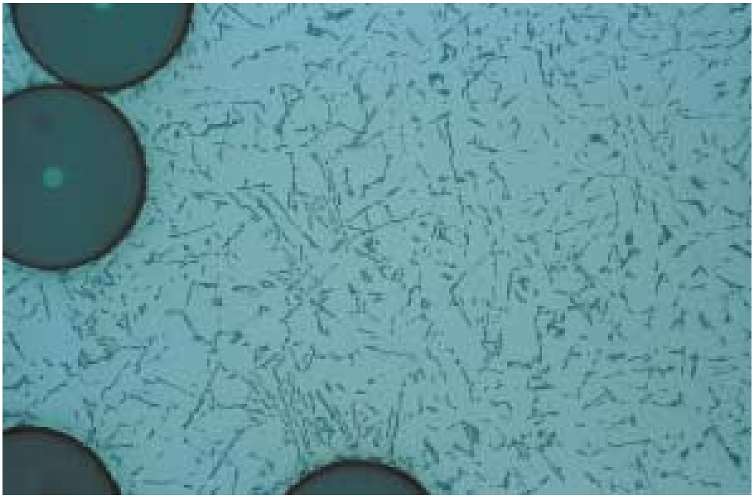


Relief

Material from different phases is removed at different rates, due to varying hardness or wear rate of the individual phases.



1. B_4C fibres in AlSi, relief between fibres and base material Mag: 200 x



2. Same as fig. 1 but without relief Mag: 200 x

Relief

Relief does normally first occur during polishing. However, for the best possible starting conditions, MD-Largo should be used for fine grinding of materials with a hardness below 150 HV, and MD-Allegro should be used for fine grinding of materials with a hardness of 150 HV and higher.

MD-Largo and MD-Allegro will provide the best possible planeness.

The most important parameters to avoid relief are the ***preparation time*** *and* ***polishing cloths*** *used.*

The preparation time should be kept as short as possible. When developing a new method, the samples have to be checked at short intervals, 1-2 min.

The polishing cloths have a strong influence on the planeness of the samples. A polishing cloth with low resilience produces samples with less relief than a cloth with high resilience.

See under "Edge Rounding" on page 72 for the correct way to change preparation parameters.

To avoid relief with layers and coatings, mounting may help to improve the result. See under "Mounting" in chapter 4, Metalog Process.

Metalog Master

Pull-outs

Pull-outs are the cavities left after grains or particles that are torn out of the sample surface during abrasion. They are found in hard and brittle materials, and in materials with inclusions. Hard or brittle materials cannot be deformed plastically, so small parts of the surface material shatter and may fall out or be pulled out by the polishing cloth.

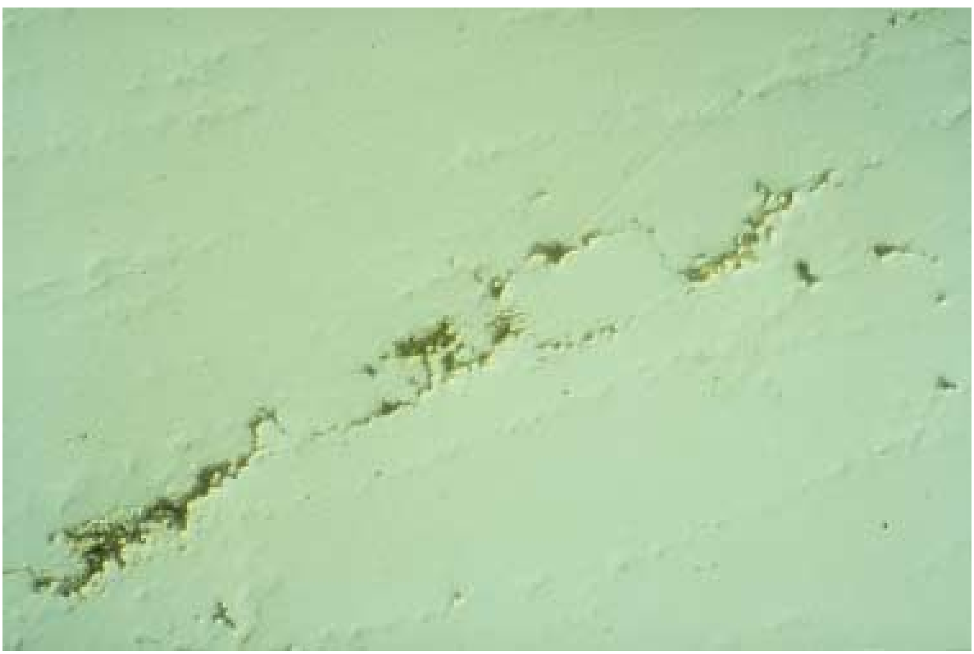
See under "False Porosity" on pages 82-85 for advice.

Inclusions may also be brittle or have other thermal expansion values than the matrix. In this case, the relatively loose or broken inclusions can be pulled out by a long napped polishing cloth.

Graphite can also be pulled out or "plucked" during preparation if a long napped cloth is used.

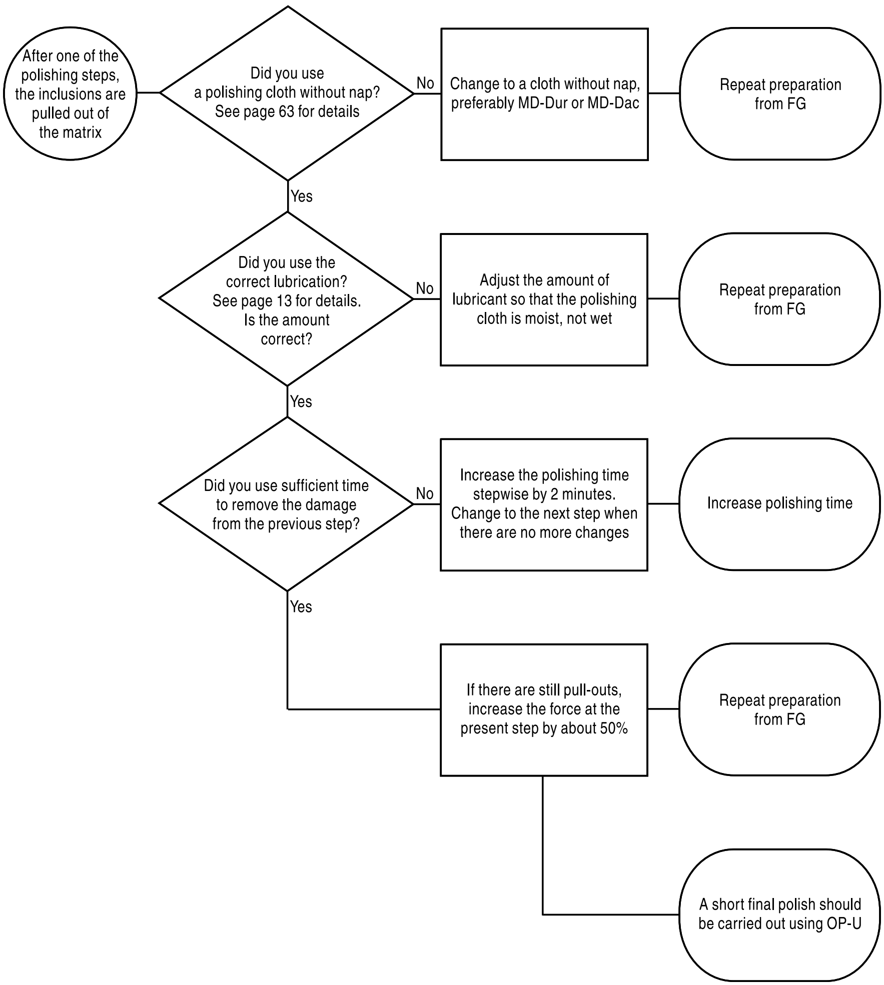
See also "Polishing Dynamics" page 87.

Inclusions pulled out. Scratches originating from the pulled out inclusions can be seen. Mag; 500 x, DIC



Pull-outs

- *On the surface of the sample dark spots or holes are visible after the preparation. See fig. (see also under "False Porosity" on pages 82-85).*
- *Be careful, already during cutting and mounting, not to introduce excessive stress that could damage the specimens.*
- *Do not use high forces or coarse abrasives for Plane Grinding or Fine Grinding.*
- *MD-Largo is less aggressive than MD-Allegro and should be used to avoid pull-outs.*
- *The margins between each grain size should not be too large, as that would prolong the preparation time unnecessarily.*
- *A napless polishing cloth should be used, as it does not tend to "pluck" particles out of the matrix. Also most of the napless cloths have a lower resilience, thus providing higher removal rates.*
- *Every step has to remove the damage from the previous one, and has to introduce as little damage as possible of its own.*
- *Check the samples after every step, to find out when pull-outs do occur.*

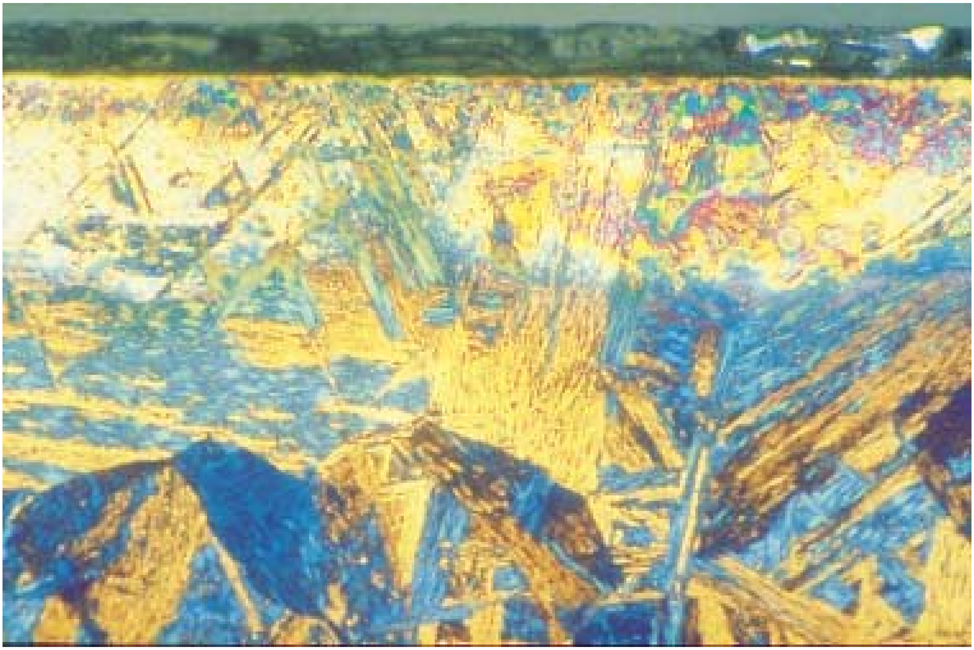


Metalog Master

Gaps

Gaps are voids between the mounting resin and sample material.

Gap between resin and sample. The etching has failed due to contamination of the sample. Also note the particles in the gap. Mag: 100x



Gaps

When examining samples under the microscope, it is possible to see if there is a gap between the resin and the sample. See fig.

This gap can result in a variety of preparation faults:

- *Edge rounding (see pages 72-73 for details)*
- *Contamination of polishing cloth*
- *Problems when etching*
- *Staining (see pages 94-95 for details)*

If a gap cannot be tolerated, see the table on page 53 for the correct choice of resin.

Vacuum impregnation using Epoxy will provide the best result.

The samples should always be cleaned and degreased to improve the adhesion of the resin to the sample.

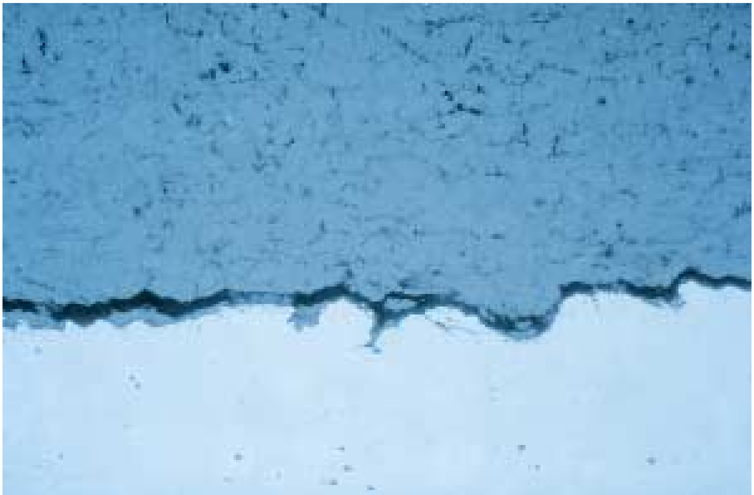
Hot mounting: choose the correct resin and cool the sample in the press under pressure to avoid gaps.

Cold mounting: avoid too high curing temperatures. For large mounts, ≥40 mm, use a stream of cold air for cooling if necessary.

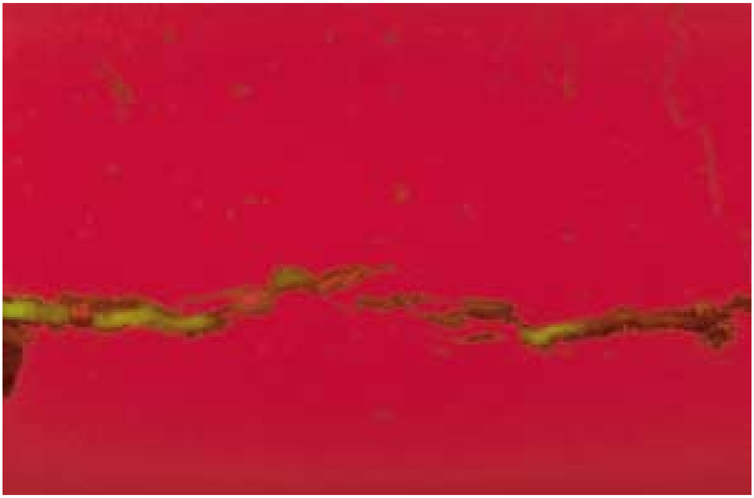
To save a sample with a gap, it is sometimes possible to reimpregnate it with Epoxy under vacuum. Clean and dry the sample carefully, put it into the vacuum chamber and use a small amount of Epoxy to fill the gap. The preparation has to be started all over again, to remove any excess epoxy on the sample surface.

Cracks

Cracks are fractures in brittle materials and materials with different phases. The energy used to machine the sample is greater than can be absorbed. The surplus energy results in the cracks.



Crack between a plasma spray coating and the substrate. The crack originates from cutting
Mag: 500 x



Sample mounted with Epofix and EpoDye under vacuum. The crack is filled with fluorescent dye, proving that the crack was in the material before mounting
Mag: 500 x
Fluorescent light

Cracks

Cracks do occur in brittle materials and samples with layers. Care has to be taken throughout the complete preparation process.

This section does not deal with cracks in ductile materials, as these are not caused by the preparation but are already present in the sample prior to preparation.

Cutting: the appropriate cut-off wheel has to be chosen, see page 44, and low feed rate should be used.

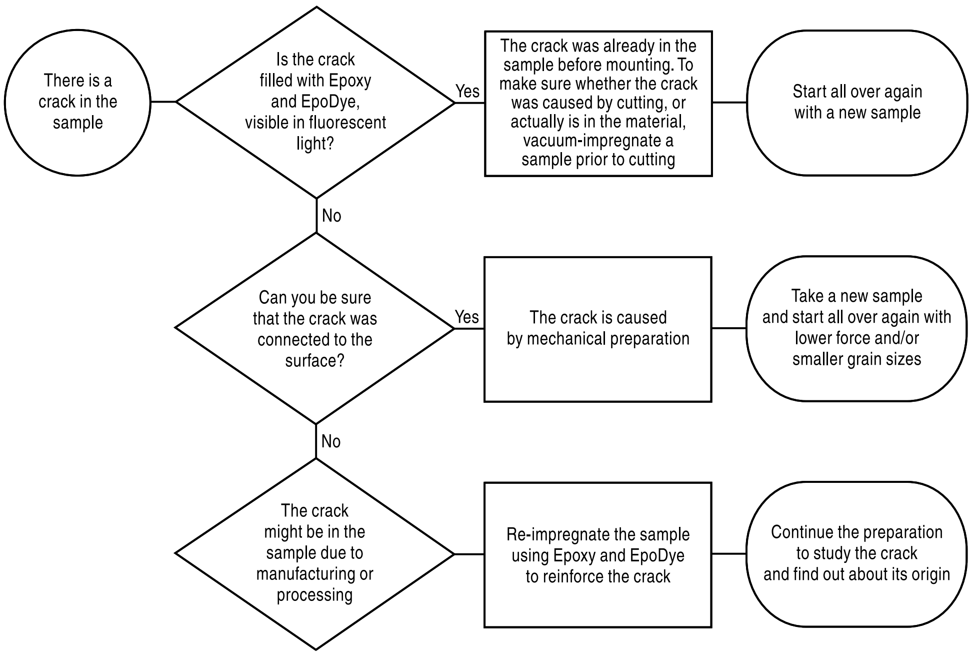
When cutting coated samples, the wheel should pass through the layer(s) first, so that the base material can act as support.

Clamping of the sample should be carried out in a way that no damage can occur. If necessary, soft packing between sample and clamp has to be used.

***Mounting**: for fragile materials, hot compression mounting should be avoided and cold mounting, preferably vacuum impregnation, should be used instead. The only exception is thermoplastic SpeciFast, which can be used in ProntoPress-10/-20, where the resin can be pre-heated and softened without applying pressure.*

***Note**: vacuum impregnation will only fill cracks and cavities connected with the surface.*

Be careful not to use mounting materials with high shrinkage. They might pull layers away from the base material.



False porosity

Some materials have natural porosity, e.g. cast metals, spray coatings or ceramics. It is important to get the correct values, and not wrong readings because of preparation faults.

Soft/Ductile materials

1. Superalloy after 5 min. polishing on MD-Dur, 3 µm. Mag: 500 x

2. Same as 1 but after an additional polishing for 1 min. on MD-Dur, 1 µm

3. Same as 2 after an additional 1 min. on MD-Dur, 1 µm

4. Same as 3 after an additional 1 min. on MD-Dur, 1 µm. Correct result

False porosity

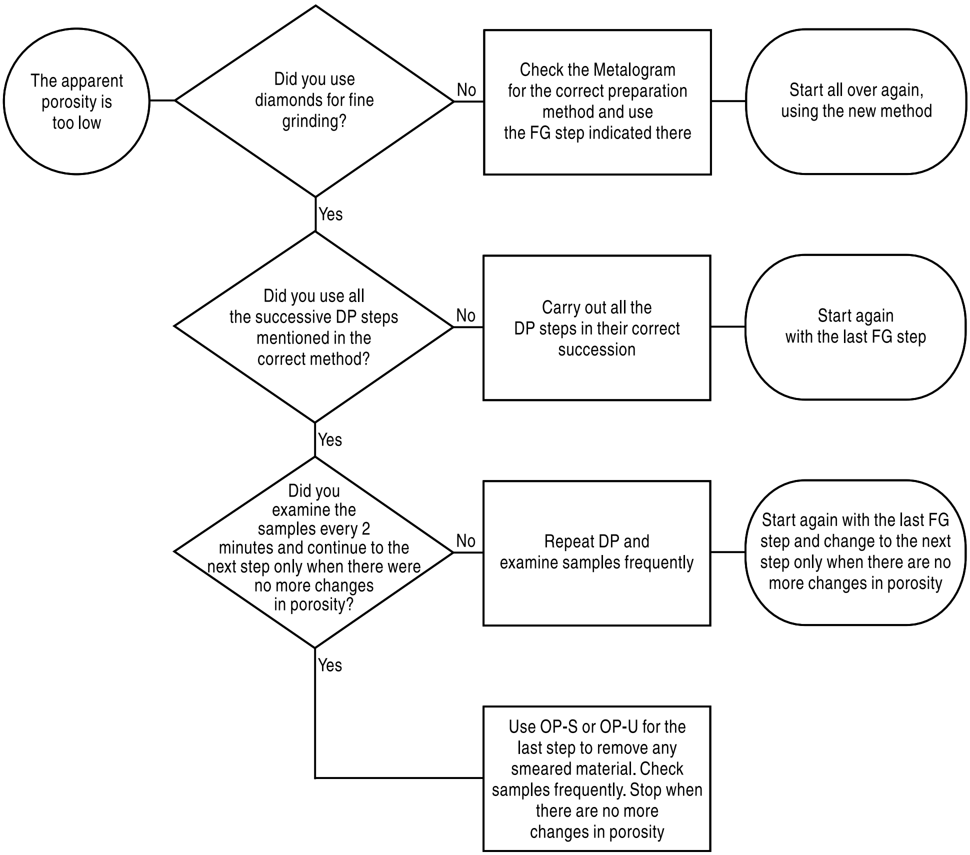
Depending on the properties of a material, two contrary effects regarding porosity can be seen.

Soft and ductile materials can be deformed easily. Therefore pores can be covered by smeared material. An examination might show readings which are too low.

Hard, brittle materials often get fractured at the surface during the first mechanical preparation steps. (See also under "Pull-outs" on pages 76-77). The surface might show a porosity higher than the real one.

Contrary to the ductile material, where the initial porosity seems to be low and pores have to be opened, brittle materials seem to have a high porosity. The apparent fracturing of the surface has to be removed.

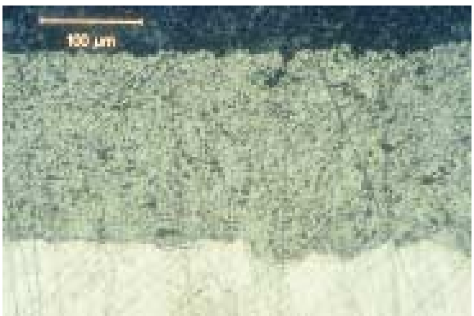
See next page



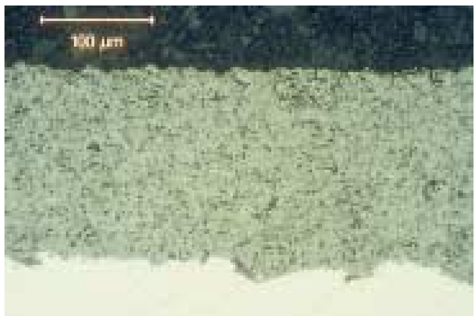
Metalog Master

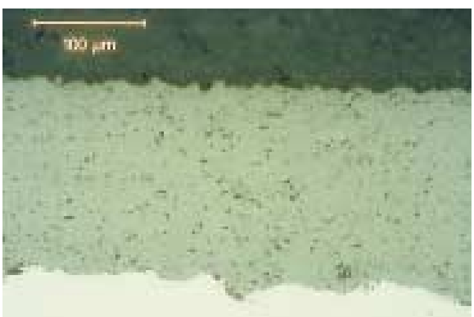
Hard/brittle materials

1. Cr_2O_3 plasma spray coating after FG step



2. Same as 1 after 3 min, 6 µm polishing





3. Same as 2 after additional polishing on MD-Nap, 1 µm. Correct result

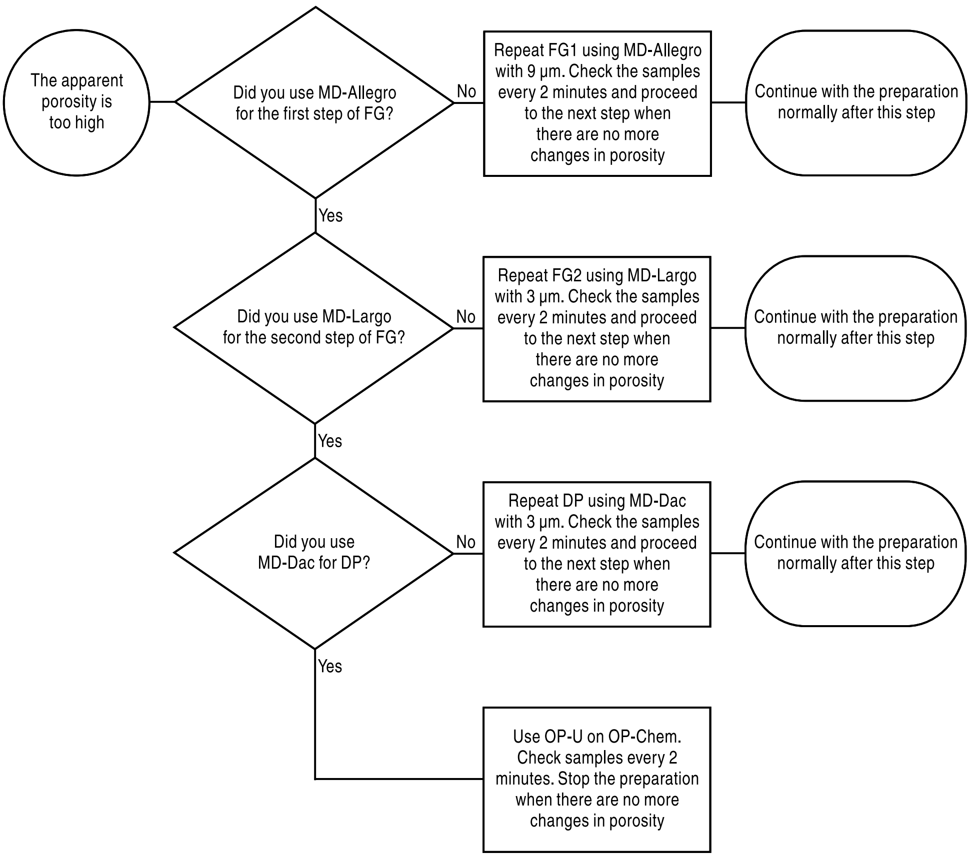
Continued from page 83

For both types of materials, method F should be used to reach the correct amount of porosity.

Polishing with diamonds has to be used, and the specimens have to be examined every two minutes under the microscope. The same area should be inspected, to clearly see possible changes. One way of doing this is to mark an area with a hardness indentation. (For brittle materials, care has to be taken not to introduce further stress).

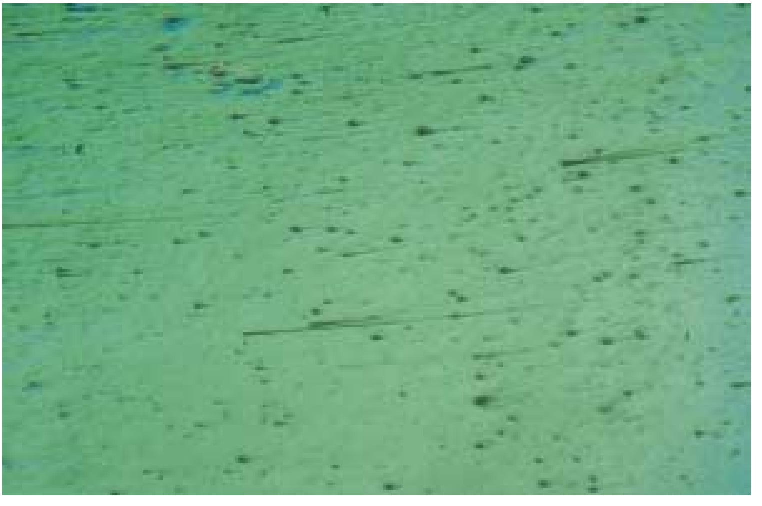
A change to the next polishing step must first be done when there are no more changes in porosity level at the step just carried out.

The last step should be an oxide polishing with either OP-U or OP-S, because both these media remove material slowly, without introducing any new deformation at all.



Comet tails

Comet tails occur adjacent to inclusions or pores, when the motion between sample and polishing disc is unidirectional. Their characteristic shape earns the name “comet tails”. A key factor in avoiding comet tails is the polishing dynamics.



1. Comet tails
Mag: 20 x, DIC

2. Comet tails
Mag: 200 x, DIC

Polishing Dynamics

There are many variables in the materialographic polishing process. The most commonly recognized are items such as cloths and abrasives. While these have a great effect on the polishing process, other critical parameters are often neglected. These parameters are the polishing dynamics. The dynamics or speed of the specimen in relation to the cloth plays an important role in the final outcome of the polishing process. Artifacts such as comet tails, pullouts, and edge rounding can be attributed to an imbalance in the dynamics.

Struers polishers have been designed to “optimize” the dynamics of the polishing process. Through this optimization it is possible to produce a very uniform, nondirectional polish on any material. To assist in the visualization of the polishing process, a mathematical model (computer program) was developed. This program calculates the relative velocity between the specimen and polishing cloth. These results are then plotted on a polar coordinate graph. This graph is a simple method for “seeing” the dynamics of the polishing process. In addition to calculating the relative velocity, the program calculates the velocity variance (in 5 mm increments) across the face of the specimen itself. This variance is very important with respect to specimen quality and is often overlooked.

Figures one and two show graphically the dynamics of two commercially available polishing machines. Figure one is from a Struers machine and represents the “ideal” or “optimal” dynamic conditions. This graph shows that the relative velocity of the specimen is constant, regardless of its position on the polishing cloth. Also, there is no variance in velocity across the face of the specimen as noted by the tight bandwidth of the graph.

Figure two illustrates the effects of deviating from established dynamic conditions. In this situation, the relative velocity varies tremendously (0.25 - 1.70 m/s) as the specimen moves from the inside to the outside of the polishing cloth. The cause of this variation is related to the difference in specimen holder speed (24 rpm) and polishing cloth speed (125 rpm). Additionally, the relative velocity across the face of the specimen varies significantly depending on location.

In order to establish “optimal” dynamic conditions the following must be observed:

- rotate the specimen holder and polishing cloth in the same direction

and

- rotate the specimen holder and polishing cloth at the same speed.

By utilizing the “optimal” dynamic conditions for polishing, one can be assured of consistent, high quality microstructures that are free from dynamically induced preparation artifacts, such as comet tails, pull-outs and edge rounding.

(The above is quoted from “A Study in the Dynamics and Wear of Rigid Disc Systems” by S. D. Glancy and M. J. Damgaard, Structure 25, 3-7, 1992).

Fig. 1

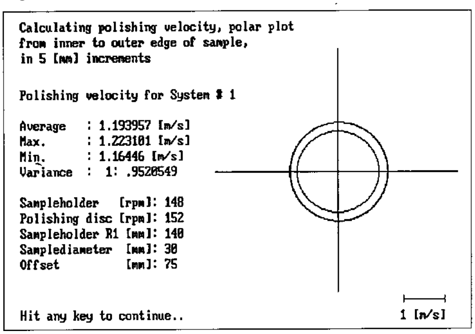
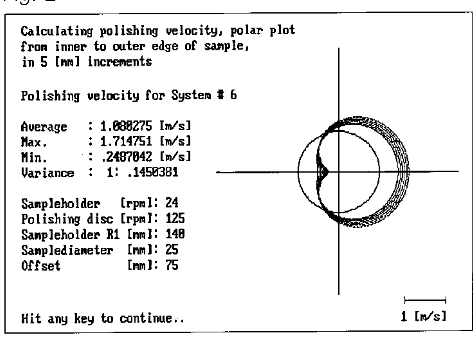


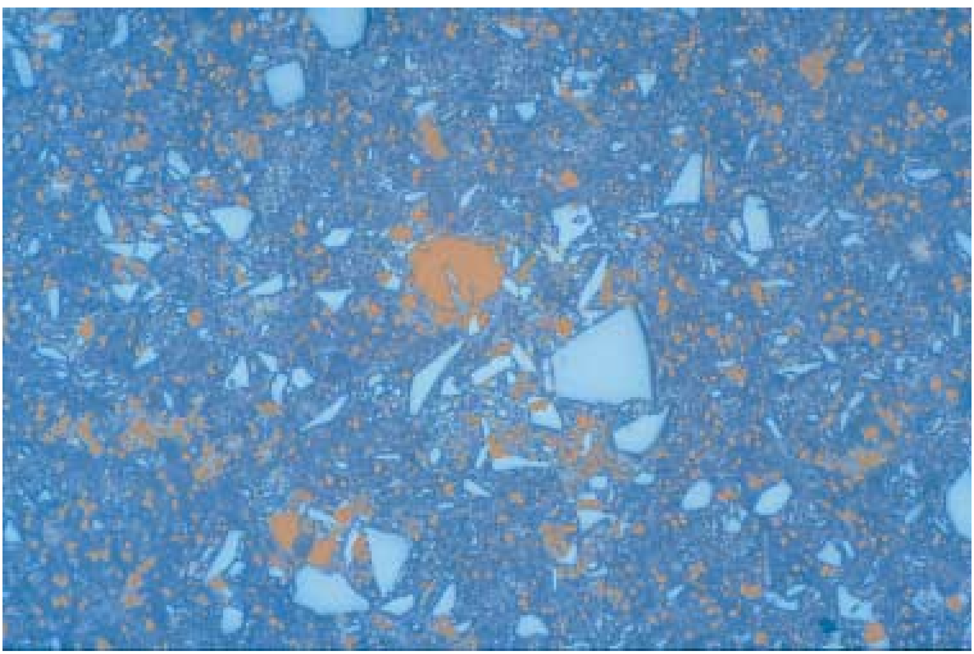
Fig. 2



Contamination

Material from a source other than the sample itself, which is deposited on the sample surface during mechanical grinding or polishing, is called contamination.

Copper from a previous preparation is deposited on the surface of the sample. Due to slight relief between the B_4C particles and the aluminium matrix the copper is picked up. Mag: 200 x



Contamination

Contamination can occur on all types of materials.

During polishing, possible dirt particles or material removed during a previous step can be deposited on the specimen.

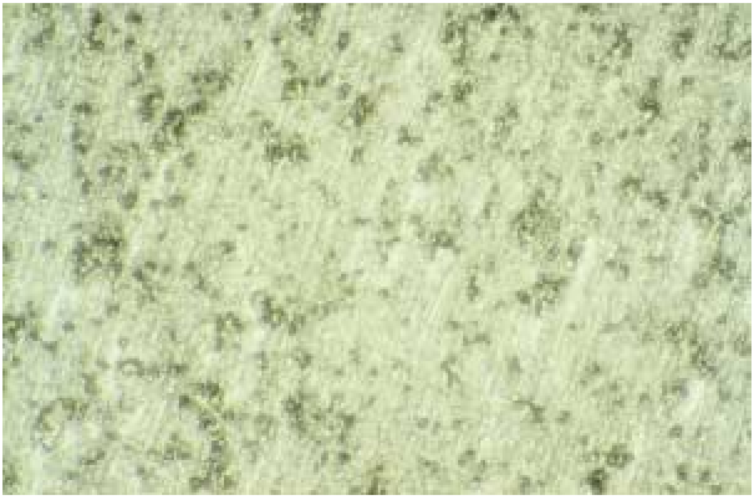
Microscopic examination can show "inclusions" or parts of a structure which should not actually be there.

Be sure always to store your polishing discs in a dustproof cabinet to avoid foreign particles being brought onto the disc.

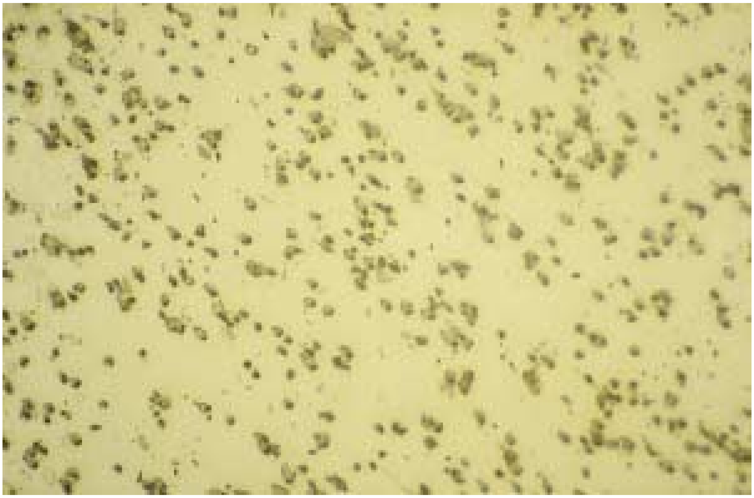
Should there be any doubt if a phase or particle belongs to a certain sample, please clean or change the polishing cloth and repeat the preparation from the fine grinding step.

Embedded abrasive

Loose abrasive particles pressed into the surface of the sample.



1. Aluminium, ground with 3 µm diamond, using a cloth with low resilience. Numerous diamonds are embedded in the sample Mag: 500x



2. Same as above, after final polishing. Most of the diamonds are still left in the sample Mag: 500x

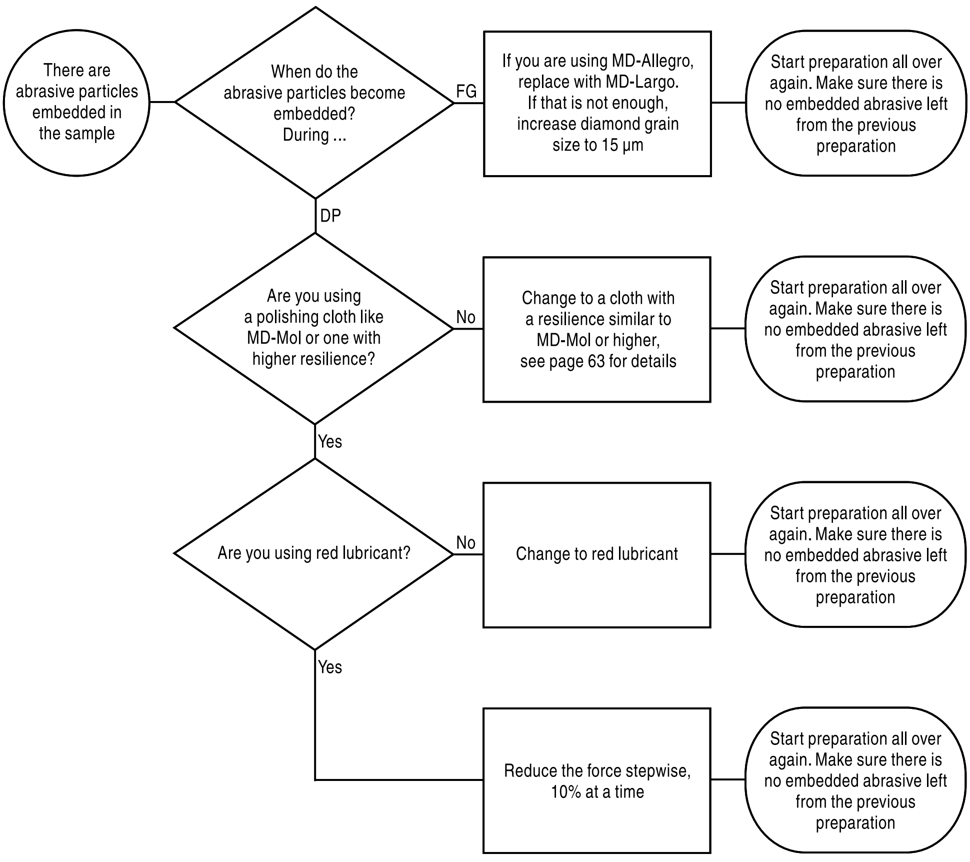
Embedded abrasive

With soft materials, abrasive particles can become embedded.

That can happen because of these reasons:

Too small abrasive particle size, disc / cloth used for grinding or polishing with too low resilience or a lubricant with too low a viscosity. Often a combination of these reasons takes place.

- *When plane grinding on MD-Primo 120, abrasive particles can become embedded in soft materials. Continue with MD-Primo 220 as a second plane grinding step and MD-Largo for fine grinding. Embedded particles should be removed after the fine grinding step.*
- *MD-Allegro should not be used for materials with a hardness lower than 150 HV. The abrasive particles will, instead of being pressed into the disc, be pressed into the sample and stay there, firmly embedded. Use the MD-Largo instead of MD-Allegro.*
- *When polishing soft materials, grain sizes of 3 µm and smaller should only be used on cloths with high resilience, see table on page 63.*
- *For the last polishing steps of soft materials, where fine abrasive particles are used, red lubricant, a lubricant with high viscosity, has to be used.*



Lapping tracks

These are indentations on the sample surface made by abrasive particles moving freely on a hard surface. There are no scratches, like from a cutting action. Instead, there are the distinct tracks of particles tumbling over the surface without removing material.

1. Lapping tracks on Zirkalloy: The tumbling track of abrasive particles, following the rotation of the disc can clearly be seen Mag: 200 x

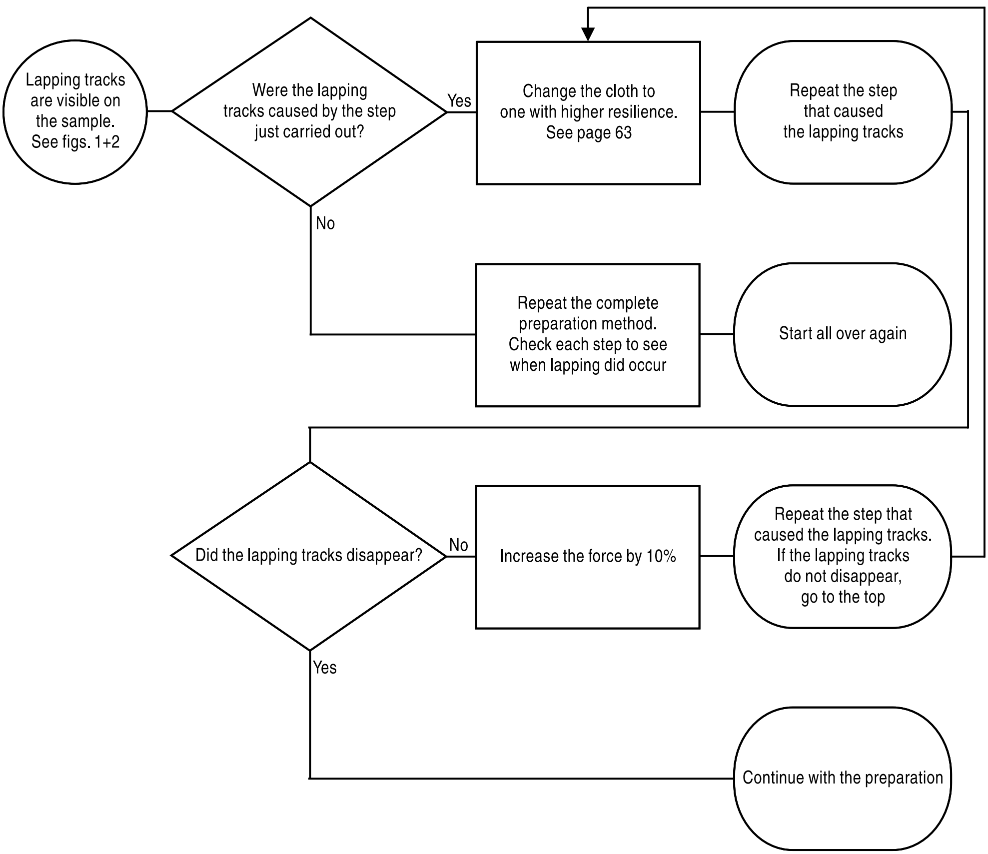
2. Lapping tracks after final polishing. The very deep indentations can still be seen. Also visible is the underlying deformation following the lapping track. Pure Tantalum Mag: 500 x, DIC

Lapping tracks

If an abrasive particle is not held in a fixed position while the sample is passing over it, it will start rolling. Instead of removing, cutting, chips of material, the grain is forced into the sample material, creating deep deformation, and only pounding small particles out of the sample surface. (See detailed explanation on page 96).

Lapping tracks can be produced during both grinding and polishing.

The causes are: wrong disc/cloth surfaces for the actual operation or the wrong force.
Also combinations of these faults can cause lapping.

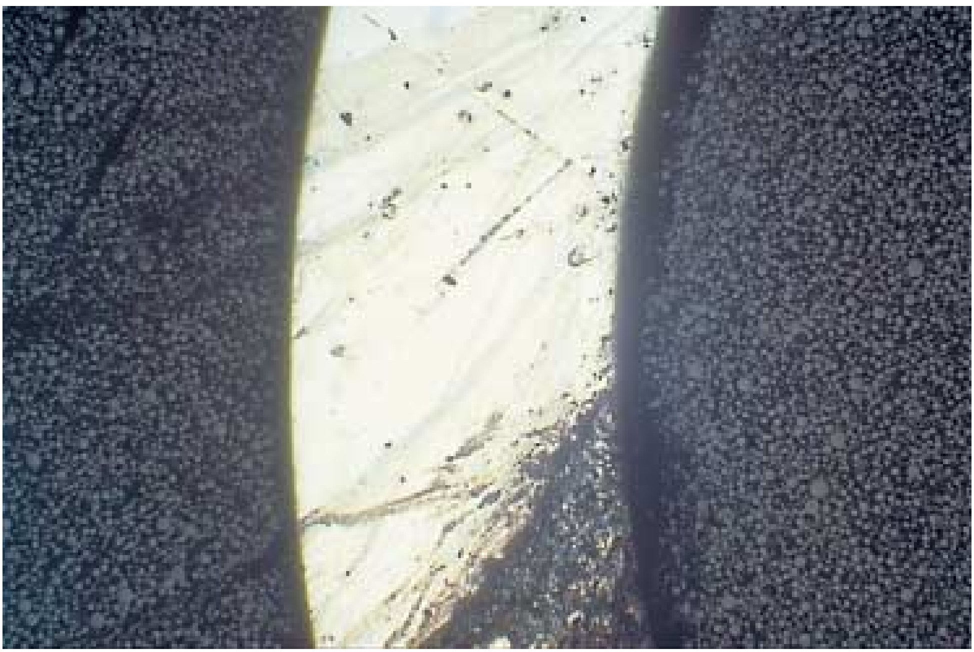


Metalog Master

Staining

Staining is a discoloration of the sample surface, typically because of contact with a foreign body.

Staining of sample due to gap between resin and sample
Mag: 20 x



Staining

Staining is often seen after cleaning or etching samples.

- *When there is a gap (see pages 78-79) between sample and resin, water, alcohol or etchant can bleed out of the gap during drying or even on the microscope. Areas on the sample surface can be discolored, and make the examination difficult or even impossible.*

Choose a mounting resin without shrinkage on page 53.

- *Clean and dry your samples immediately after each preparation step.*
- *Avoid the use of compressed air when drying your samples after final polishing, because compressed air can contain oil or water.*
- *OP polishing can result in a white film left on the sample surface if the cleaning is not carried out correctly.*

During the last 10 seconds of OP polishing, flush the polishing cloth with water to clean both samples and polishing cloth.

- *Do not use hot water for cleaning samples, as hot water is more aggressive than cold water, and subsequent etching will be intensified.*
- *Never leave samples in normal room conditions, as humidity might attack the sample. Always store samples in a desiccator if you want to keep them.*

The Process of Mechanical Preparation

The basic process of mechanical sample preparation is material removal, using abrasives.
There are three mechanisms of removing material, listed here according to their ability to introduce deformation.
1. Lapping
2. Grinding
3. Polishing

In the following section we shall analyse the action of these mechanisms and their influence on the sample surface.

Lapping

In lapping, the abrasive is applied in a suspension onto a hard surface. The particles cannot be pressed into that surface and secured there, so they roll and move freely in all directions. They hammer small particles out of the sample surface, introducing deep deformations.
This takes place because the free moving abrasive particle is not able to produce a real "chip" of the sample surface, (see below).
For this reason the removal rate (the amount of material removed in a certain period of time) is very low during lapping, giving very long process times.
With soft materials, the abrasive particles are often pressed into the sample surface, becoming firmly embedded.
Both the **deep deformations** and **embedded grains** are extremely undesirable in materialographic sample preparation.
Because of the reasons described above, lapping is only used for the preparation of very hard, brittle materials, like ceramics and mineralogical samples.

Lapping
Three positions of an abrasive grain passing the sample surface in a rolling fashion.
Position 1: *Grain is entering the sample surface.*
Position 2: *Grain rolls over and hammers a piece of the sample material out.*
Because of the "hammering effect" strong deformations arise in the sample material.
Position 3: *Grain rolls on without touching the sample surface. When the grain passes the sample again a smaller or bigger piece is hammered out, according to the shape of the grain*

Grinding

Grinding is material removal using fixed abrasive particles which produce chips of the sample material, (see below).
The process of making chips with a sharp abrasive grain produces the lowest amount of deformation in the sample while giving the highest removal rate.
Polishing basically uses the same mechanism as grinding, see below.

The Grinding (Polishing) Process

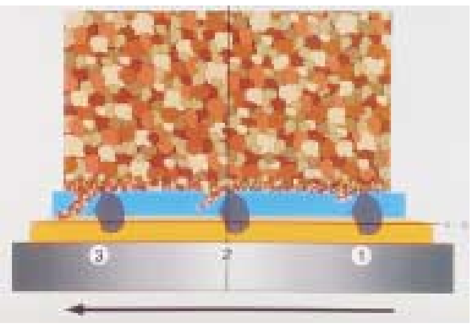
Grinding (Polishing) requires certain conditions:

1. Cutting force
The specific pressure between sample surface and abrasive grain must be high enough to generate a cutting force able to produce a chip, (see below).

2. Horizontally fixed grain
The abrasive grain must be fixed horizontally while the sample is passing over it to obtain sufficient cutting force, (see below).

3. Vertical penetration
The abrasive grain must be supported vertically to obtain the desired chip size. The chip size and the material removal rate are closely related.

Plane Grinding, PG: To obtain a high material removal rate, totally fixed grains with a relatively large grain size are preferred. MD-Primo or MD-Piano are used for plane grinding. They provide perfectly plane specimens thus reducing the preparation time on the following fine grinding step. In addition, MD-Primo and MD-Piano provide a very high edge retention. MD-Primo contains SiC and is used for grinding of soft materials with a hardness below 150 HV. MD-Piano contains diamonds and is used for materials with a hardness of 150 HV or higher. MD-Primo and MD-Piano are based on abrasive particles in a resin bond. During wear new abrasive grains are revealed ensuring a consistant material removal.



***Grinding** (Polishing)*
Three positions of an abrasive grain passing the sample surface in a fixed state.
***Position 1:** Grain is entering the sample surface. The grain is totally fixed in the X-direction; in the Y-direction a certain movement (resilience) can take place. The chip is started when the grain enters into the sample material.*
***Position 2:** Grain is halfway through, the chip is growing.*
***Position 3:** Grain passes out of sample surface, leaving a scratch in the surface with relatively little deformation in the sample material*

Fine Grinding, FG: A high removal rate is obtained by using grain sizes of 15, 9 or 6 µm. This is done on the fine grinding discs MD-Largo or MD-Allegro, or on hard “cloths” with low resilience, MD-Plan, MD-Pan and MD-Dur. MD-Largo and MD-Allegro are hard composite discs (rigid discs) with a surface of a special composite material allowing the diamond grains, which are continuously supplied, to embed in the disc surface, providing a fine grinding action. MD-Largo and MD-Allegro provide the highest material removal, a very plane sample surface, and ensure a high edge retention.
The force on the sample should be relatively high during grinding to obtain a large chip size.

Polishing, DP: During polishing, a smaller chip size is desirable to ultimately achieve a sample surface without scratches and deformation. More resilient cloths, like MD-Mol or MD-Nap, are used, along with smaller grain sizes, such as 3 or 1 µm, to obtain a chip size approaching zero. A lower force on the samples will also reduce the chip size during polishing.

4. Supply of abrasive

It is very important that the right amount of diamond abrasive is present during the process.
If the diamond particles are applied in large amounts at large intervals, like with DP-Paste or DP-Stick, the process will vary with the number of particles available. In order to best control the process, abrasive should be added in the smallest possible amounts at the shortest possible intervals. It is therefore recommended to use the DP-Suspension which can be supplied automatically during the process, so there are always new, sharp, fresh cutting grains available. This ensures a constant, reproducible process at the lowest cost per sample.

5. Lubrication

Sufficient lubrication between the sample surface and the grinding/polishing surface is necessary for three reasons:

Enhancement of cutting: The correct lubricant improves the cutting process and yields the smallest scratch depth and the lowest deformation.

Reduce friction: The friction between the sample and the surface must be correct; too little lubricant will cause overheating, too much lubricant will decrease the cutting action by washing away abrasive particles and creating a hydro-planing condition.

Cooling: The ideal conditions for optimal grinding/polishing will create frictional heat. This is kept low by using the correct lubricant.

Attention: The ideal conditions require the abrasive particles to be supplied independently from the lubricant. The optimal process may need **more abrasive and less lubricant or more lubricant without adding more abrasive.**

Polishing

Polishing as a process is described along with Grinding above. Polishing includes the last steps of the preparation process. By using successively smaller grain sizes and cloths with higher resilience, polishing can remove all the deformations and scratches from fine grinding.

The risk with polishing is the creation of relief and rounding of edges because of the resilience of the cloths. These drawbacks are reduced by keeping the polishing times as short as possible.

Abrasives

The removal rate is very closely related to the abrasives used.

Diamond is the "king" of abrasives. It has the highest hardness of any known material, about 8,000 HV. That means it can easily cut through all materials and phases.

Different types of diamond are available.

Tests have shown that the high material removal, together with a shallow scratch depth, is obtained because of the many small cutting edges of polycrystalline diamonds.

SiC, silicon carbide, with a hardness of about 2,500 HV, is a widely used abrasive for grinding papers and cut-off wheels, mainly for non-ferrous metals.

Al_2O_3, aluminium oxide, with a hardness of about 2,000 HV, is used primarily as an abrasive in grinding stones and cut-off wheels. It is used mainly for the preparation of ferrous metals. It was also once extensively used as a polishing medium, but has, since the introduction of diamond products for this purpose, largely lost its usefulness.

Note: According to Samuels*, the hardness of abrasive grains must be about 2.5 to 3 times the hardness of the material to be prepared. Neither SiC nor Al_2O_3 can be used for either grinding or polishing of materials like ceramics or sintered carbides.

Metalog Master

**L. E. Samuels:*
Metallographic Polishing by Mechanical Methods,
3rd Edition, see page 107

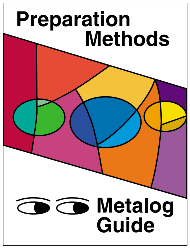
6. Consumables Specification

Consumables for Metalog Methods

All consumables used in the Metalog Methods are listed in this chapter. All these consumables are marked with a special label, see below, indicating that the consumable belongs to a Metalog Method. The chapter also contains alternative consumables from Struers.

Metalog Consumables – Your Assurance

The combination of Metalog Methods and Metalog Consumables assures that the correct result is obtained. Also reproducibility, the correct preparation process repeated over time, is secured.



Metalog Guide label

Cut-off Wheels

Application	Cut-off Wheel diameter i mm						
	Shaft diameter 32 mm				Shaft dia. 22 mm	Shaft diameter 12.7 mm	
	432 x 3.0	350 x 2.5	300 x 2.0	250 x 1.5	235 x 1.5	125 x 0.5	150 x 0.5
Plastic, very soft metals						370SA 125 x 0.6	
Non-ferrous soft metals	106MA	86EXO	56UNI	36TRE	06TRE	357CA 355CA*	459CA
Very ductile metal (Titanium)		90EXO	56UNI	40TRE	10TRE	357CA	459CA
Soft ferrous metals	104MA	84EXO 8UEXO	54UNI	35TRE		357CA 355CA*	457CA
Medium soft ferrous metals	104MA	84EXO 8UEXO	54UNI	34TRE 37TRE	04TRE	357CA 355CA*	457CA 45UCA
Medium hard ferrous metals	102MA 202MA	83EXO 8UEXO	53UNI	33TRE	03TRE	457CA 355CA*	456CA
Hard ferrous metals	102MA	81EXO	51UNI	32TRE	02TRE	356CA 355CA*	456CA
Very hard ferrous metals	101MA	81EXO	51UNI	31TRE	01TRE	355CA*	
Extremely hard ferrous metals				38TRE		355CA*	
Sintered carbides Hard ceramics		26EXO 350 x 1.5	25EXO 305 x 1.8	24TRE 252 x 1.1	23TRE 202 X 1.01	352CA 127 X 0.6	452CA 152 x 0.8
Minerals and ceramics				25TRE 250 x 1.1	20TRE 202 x 1.1	330CA 127 x 0.3	430CA 150 x 0.4

**355CA: CBN, 127 x 0.6 mm*

Mounting Materials

Hot Mounting	1 kg	2.5 kg	7.5 kg	25 kg	Dia. 25 mm 10 kg	Dia. 30 mm 10 kg	Dia. 40 mm 10 kg
	Code	Code	Code	Code	Code	Code	Code
ConduFast	RESFE	-	-	-	-	-	-
SpeciFast	RESTH	-	RESYV	RESFA		-	-
PolyFast	FAPSA	-	FAPME	-	-	-	-
IsoFast	RESDI	-	RESTY	-	-	-	-
DuroFast	RESIF	-	RESEN	-	-	-	-
MultiFast	-	RESRU	RESUK	RESLA	-	-	-
MultiFast Grün	-	FAGSA	FAGME	-	-	-	-
MultiFast Braun	-	FABSA	FABME	FABLA	-	-	-
Bakelit	-	-	-	-	RESUN	RESGI	RESAM

Cold Mounting	Small Kit	Resin	Hardner	Powder	Liquid
	Code	Code	Code	Code	Code
SpeciFix-20	EPO20	1 l EPOIN	½ l EHA20	-	-
SpeciFix-40	EPO40	1 l EPOIN	1 l EHA40	-	-
Epofix	EPOFI	1 l EPOES	½ l EPOAR	-	-
Caldofix	CALDO	1 l CALRE	½ l CALAR	-	-
MetaFix-20	MET20	-	-	3 kg MEP20	1 l METLI
Citofix	CIFIM	-	-	3 kg CIFRE	1 l CIFHA
Durofix-2	DUFIM	-	-	3 kg DUFRE	1 l CIFHA
Acryfix	ACRYF	-	-	3 kg ACRES	1 l ACHAR
Triofix-2	TRIKI	-	-	-	-
Serifix	FIXMA	1 l FIXRE	½ l FIXAR	-	-

Accessories: Mounting cups	Dia. 25 mm	Dia. 30 mm	Dia. 40 mm	Dia. 1¼"	Dia. 1½"
	Code	Code	Code	Code	Code
Flexiform	SILMO	SILTE	SILPY	SILQU	SILHA
Multiform	EFOMO	EFOTE	EFOPY	-	-
Seriform	SPEMO	SPETE	SPEPY	-	-

Accessories: Clips	6 mm 100 pcs.	9 mm 100 pcs.	50 pcs.
	Code	Code	Code
Metal clip	CLIMO	CLIPS	-
Plastic clip	-	-	CLIPE

Accessories:	
Fluorescent Dye	Code
EpoDye	EPOLU
Colouring Dye	Code
AcryDye	METAD

Consumables

Surfaces for Plane Grinding

MD-Primo				Disc dia. 350 mm (14")	Disc dia 300 mm (12")	Disc dia. 250 mm (10")	Disc dia. 200 mm (8")
Application		HV	Abrasive/Bond	Code	Code	Code	Code
Soft Materials	MD-Primo 120	< 150	SiC/Resin	MAROB	MARXA	MARFI	MAROT
	MD-Primo 220	< 150	SiC/Resin	MARBO	MARAX	MARIF	MARTO

MD-Piano				Disc dia. 350 mm (14")	Disc dia 300 mm (12")	Disc dia. 250 mm (10")	Disc dia. 200 mm (8")
Application		HV	Abrasive/Bond	Code	Code	Code	Code
All Materials	MD-Piano 80	> 150	Diamond/Resin	MANPX	MANPA	MANPI	MANPO
	MD-Piano 120	> 150	Diamond/Resin	-	MANAX	MANIF	MANTO
	MD-Piano 220	> 150	Diamond/Resin	MANOX	MANXA	MANFI	MANOT

MD-Forte				Disc dia. 300 mm (12")	Disc dia. 250 mm (10")	Disc dia. 200 mm (8")
Application		HV	Abrasive/Bond	Code	Code	Code
All Materials	MD-Forte 120	> 40	Diamond/Metal	MAFAX	MAFIF	MAFTO

Grinding Wheel				MAPS / Abraplan	Prepamatic-2
Application	HV	Abrasive	Grit size	Code	Code
Soft and ductile metals	< 250	Al_2O_3	# 600	ABGOF	
Harder metals	> 250	Al_2O_3	# 150	ABGAL	PAMST*
Ceramics and sintered carbides	< 800	Diamond	# 120	ABWEE	

SiC Paper				Disc dia. 305 mm (12")	Disc dia. 250 mm (10")	Disc dia. 230 mm (9")	Disc dia. 200 mm (8")
Application	HV	Abrasive	Grit size	Code non-PSA/PSA	Code non-PSA/PSA	Code non-PSA/PSA	Code non-PSA/PSA
All Materials	30-800	SiC	# 80	ROTUS/PAPPE	VARUS/PAPFI	ROTAR/PAPRO	PAPER/PAPNO
			# 120				
			# 180				
			# 220				

** For Prepamatic and Prepamatic-2 (PAMTA) position 1*

Surfaces for Fine Grinding

MD-Largo				Disc dia. 350 mm (14”)	Disc dia 300 mm (12”)	Disc dia. 250 mm (10”)	Disc dia. 200 mm (8”)
Application	HV	Abrasive	Grain size	Code	Code	Code	Code
All Materials	< 150	*	From 15 to 3 µm	MALBO	MALAX	MALIF	MALTO

MD-Allegro				Disc dia. 350 mm (14”)	Disc dia 300 mm (12”)	Disc dia. 250 mm (10”)	Disc dia. 200 mm (8”)
Application	HV	Abrasive	Grain size	Code	Code	Code	
All Materials	> 150	*	From 15 to 6 µm	MADBO	MADAX	MADIF	MADTO

MD-Piano				Disc dia.300 mm (12”)	Disc dia. 250 mm (10”)	Disc dia. 200 mm (8”)
Application		HV	Abrasive/Bond	Code	Code	Code
All Materials	MD-Piano 1200	> 150	Diamond/Resin	MANLE	MANLI	MANLO
	MD-Piano 600	> 150	Diamond/Resin	MANEL	MANIL	MANOL

MD-Fuga		Disc dia. 300 mm (12”)	Disc dia. 250 mm (10”)	Disc dia. 200 mm (8”)
Application	Adhesive disc for SiC-paper	Code	Code	Code
All Materials	SiC-paper with plain backing	MUGMA	MAGFI	MUGTO

MD-Rondo		Disc dia. 350 mm (14”)	Disc dia 300 mm (12”)	Disc dia. 250 mm (10”)	Disc dia. 200 mm (8”)
Application	Adaptor for use of self-adhesive comsumables with the MD-System	Code	Code	Code	Code
All Materials	Consumables with PSA backing	RONBO	RONAL	RONIF	RONLA

SiC Paper				Disc dia. 305 mm (12”)	Disc dia. 250 mm (10”)	Disc dia. 230 mm (9”)	Disc dia. 200 mm (8”)
Application	HV	Abrasive	Grit size	Code non-PSA/PSA	Code non-PSA/PSA	Code non-PSA/PSA	Code non-PSA/PSA
All materials	30-800	SiC	# 320	ROTUS/PAPPE	VARUS/PAPFI	ROTAR/PAPRO	PAPER/PAPNO
			# 500				
			# 800				
			# 1000				
			# 1200				
Soft materials	30-400	SiC	# 2400				
			# 4000				

** Abrasive has to be added*

Surfaces for Fine Grinding

MD-Cloths				Disc dia. 300 mm (12")	Disc dia. 250 mm (10")	Disc dia. 200 mm (8")
Name	Hardness / Resilience	Abrasive	Application	Code	Code	Code
MD-Plan	Hard / Very low	15, 9, 6 µm	Ceramics, sintered carbides, minerals	MEPLA	MUPLA	MAPLA
MD-Dur	Hard / Medium	15, 9 µm	Ferrous metals, non-ferrous coatings, platics	MEDUR	MUDUR	MADUR
MD-Dac	Hard / Medium	15, 9 µm	Ferrous metals, non-ferrous metals, coatings, plastics	MEDAC	MUDAC	MADAC

Polishing Surfaces

MD-Cloths				Disc dia. 300 mm (12")	Disc dia. 250 mm (10")	Disc dia. 200 mm (8")
Name	Hardness / Resilience	Abrasive	Application	Code	Code	Code
MD-Plan	Hard / Very low	9, 6, 3 µm	Ceramics, sintered carbides, minerals	MEPLA	MUPLA	MAPLA
MD-Dur	Hard / Medium	6, 3, 1 µm	Ferrous metals, non-ferrous metals, coatings, plastics	MEDUR	MUDUR	MADUR
MD-Dac	Hard / Medium	9, 6, 3, 1 µm	Ferrous metals, non-ferrous metals, coatings, plastics	MEDAC	MUDAC	MADAC
MD-Mol	Soft / High	6, 3, 1 µm	Ferrous metals, non-ferrous metals, final polishing	MEMOL	MUMOL	MAMOL
MD-Plus	Soft / High	3 µm	Ferrous metals, sintered carbides. One-step polishing	MEPLU	MUPLU	MAPLU
MD-Nap	Very soft / Very high	1 µm, ¼ µm OP-U, OP-S. OP-A	Final polishing of all materials. Oxide polishing	MENAP	MUNAP	MANAP
MD-Chem	Soft / High	OP-U, OP-S, OP-A and OP-S with additives	Final polishing of all materials.	MECHE	MUCHE	MACHE

Abrasives and Lubricants

Diamond Products		45 µm	25 µm	15 µm	9 µm	6 µm	3 µm	1 µm	¼ µm
Name		Code	Code	Code	Code	Code	Code	Code	Code
DP-Suspension, P	2,5 l			SPUFI	SPUNI	SPUEX	SPUTE	SPUON	SPUQU
DP-Suspension, P	250 ml			SAPFI	SAPNI	SAPEX	SAPTE	SAPNO	SAPUQ
DP-Suspension, P	125 ml*					SEPEX	SEPTE	SEPON	
DP-Suspension, A**	250 ml			SAKFI	SAKNI	SAKEX	SAKTE	SAKNO	SAKUQ
DP-Suspension, M	2,5 l			SMUFI	SMUNI	SMUEX	SMUTE	SMUON	
DP-Suspension, M	250 ml			SAMFI	SAMNI	SAMEX	SAMTE	SAMNO	
DP-Spray, P	150 ml	SPRIR	SPRAM	SPRUF	SPRAC	SPRIX	SPRET	SPRON	SPRYT
DP-Spray, M	150 ml			SMAUF	SMAAC	SMAIX	SMAET	SMAON	
DP-Stick, P	25 ml			KITIF	KITNI	KITEX	KITTE	KITON	KITQU
DP-Paste, P	10 g			DIFTE	DININ	DIATE	DEPOA	DEPOB	DEPOC
DP-Paste, M	10 g			SYNOT	SYNNI	SYNXI	SYNTE	SYNSU	SYNTY

Lubricant Products		Container of 1 ltr.	Container of 5 ltr.	Container of 10 ltr.
Name	Specification	Code	Code	Code
DP-Lubricant	Green	LUGON	LUGFI	LUGTE
	Blue	DEPTI	DEPIF	DEPTE
	Red	DEPPO	DEPPI	DEPPE
	Brown**	LUBON		
	Yellow**	LUYON		

Oxide Products	Container of 1 ltr.	Container of 5 ltr.	Container of 500 ml
Specification	Code	Code	Code
OP-A			OPAHA
OP-S	OPSOT	OPSIF	
OP-U	OPUNO	OPUFI	

** In pump bottles*

*** Recommended for water sensitive materials*

7. Miscellaneous

List of Literature

Books

A History of Metallography
C. St. Smith
The University of Chicago Press (1960)
A popular exposition of the history of metallography.

Metallographie
H. Schumann
VEB Verlag für Grundstoffindustrie, Leipzig (1967).
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George Vander Vort
Principle and Practice.
McGraw-Hill Book Company (1984).

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L. E. Samuels
3rd. Edition 1982, published by ASM
An exhaustive description of mechanical polishing with examples.

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A comprehensive collection of etching recipes.

Metallographisches Keramographisches Plastographisches Ätzen
G. Petzow
6. überarbeitete Auflage
Gebrüder Bornträger Verlag, Stuttgart (1994).
A comprehensive collection of etching recipes for all types of materials.

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A. Guy, Deutsche Bearbeitung
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Akademische Verlagsgesellschaft, Frankfurt a.M. (1970).
An elementary introduction to metallurgy with a particular view to metallography.

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IV: Recent Examination Methods in Metallography/The Metallography of Welds.
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Verlag Stahleisen GmbH. Düsseldorf (II)
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Various volumes.

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W. J. Huppmann, K. Dalal
Verlag Schmid GmbH, 1986.

Metallographie der Gusslegierungen
W. Jähnig
VEB Deutscher Verlag für Grundstoffindustrie, Leipzig 1971.
A collection of micrographs of castings.

Schweisstechnischer Gefügeatlas
V. Horn
VEB Verlag Technik, Berlin 1974.
An extended collection of micrographs of welding seams.

Metallographic Etching
G. Petzow
American Society for Metals.
Metals Park, Ohio 44073, 1978.

Elements of Ceramics
F. H. Norton 1972
Addison + Wesley.

Metallographische Anleitung zum Farbätzen nach dem Tauchverfahren
E. Weck, E. Leistner
Metallographic Instructions for color etching by immersion.
Part 1, 2 and 3.
Deutscher Verlag für Schweisstechnik1982.

ASM - Metal Reference Book
Second Edition
1983 ASM.

Präparative Metallographie
H. Waschull (1993)
Deutscher Verlag für Grundstoffindustrie
Leipzig - Stuttgart.

Periodicals

Praktische Metallographie/Practical Metallography
(Bilingual German-English/monthly).
Carl Hanser Verlag,
Kolbergerstrasse 22,
8000 München 80.

Metallography
(English/bimonthly).
American Elsevier Publishing Comp. Inc., New York/USA. 52 Vanderbilt Avenue.

Metallographische Arbeitsblätter
(German/quarterly)
Fachunterausschuss.
Metallographische Werkstoffprüfung der KTD,
3011 Marburg. Masenstr. 20.

Structure
(English, German, French editions - 2 times a year).
Struers A/S, Valhøjs Allé 176
DK-2610 Rødovre, Denmark.

Advanced Materials and Processes
English/monthly).
ASM, Materials Park, Ohio 44073, USA.

Zeitschrift für Metallkunde
(German/monthly)
Carl Hanser Verlag,
Kolbergerstrasse 22,
8000 München 80.

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(German/monthly)
Verlag Stahleisen, Düsseldorf.

Metall
(German/monthly)
Metall-Verlag GmbH.,
Berlin-Grünewald, Hubertusallee 18.

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Institute of Metals 1, Carlton House Terrace, London S. W. 1.

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(German/every 6 weeks).
Verlag Chemie GmbH. 694
Weinheim/Bergstr. Pappelallee 3.

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(English/monthly).
Elsevier Sequoia S.A. P.O. Box 851,
1001 Lausanne 1, Switzerland.

Materials Characterization
(English/monthly).
Elsevier Science Publishing Co. Inc.

Approximate equivalent hardness numbers

Vickers hardness	Brinell hardness 10 mm tungsten carbide ball	Rockwell hardness		
	Load 3000 kg	B scale 100 kg load	C scale 150 kg load	D scale 100 kg load
940			68.0	76.9
920			67.5	76.5
900			67.0	76.1
880	(767)		66.4	75.7
860	(757)		65.9	75.3
840	(745)		65.3	74.8
820	(733)		64.7	74.3
800	(722)		64.0	73.8
780	(710)		63.3	73.3
760	(698)		62.5	72.6
740	(684)		61.8	72.1
720	(670)		61.0	71.5
700	(656)		60.1	70.8
690	(647)		59.7	70.5
680	(638)		59.2	70.1
670	(630)		58.8	69.8
660	620		58.3	69.4
650	611		57.8	69.0
640	601		57.3	68.7
630	591		56.8	68.3
620	582		56.3	67.9
610	573		55.7	67.5
600	564		55.2	67.0
590	554		54.7	66.7
580	545		54.1	66.2
570	535		53.6	65.8
560	525		53.0	65.4
550	517		52.3	64.8
540	507		51.7	64.4
530	497		51.1	63.9
520	488		50.5	63.5
510	479		49.8	62.9
500	471		49.1	62.2
490	460		48.4	61.6
480	452		47.7	61.3
470	442		46.9	60.7
460	433		46.1	60.1
450	425		45.3	59.4
440	415		44.5	58.8
430	405		43.6	58.2
420	397		42.7	57.5
410	388		41.8	56.8

Vickers hardness	Brinell hardness 10 mm tungsten carbide ball	Rockwell hardness		
	Load 3000 kg	B scale 100 kg load	C scale 150 kg load	D scale 100 kg load
400	379		40.8	56.0
390	369		39.8	55.2
380	360	(110.0)	38.8	54.4
370	350		37.7	53.6
360	341	(109.0)	36.6	52.8
350	331		35.5	51.9
340	322	(108.0)	34.4	51.1
330	313		33.3	50.2
320	303	(107.0)	32.2	49.4
310	294		31.0	48.4
300	284	(105.5)	29.8	47.5
295	280		29.2	47.1
290	275	(104.5)	28.5	46.5
285	270		27.8	46.0
280	265	(103.5)	27.1	45.3
275	261		26.4	44.9
270	256	(102.0)	25.6	44.3
265	252		24.8	43.7
260	247	(101.0)	24.0	43.1
255	243		23.1	42.2
250	238	99.5	22.2	41.7
245	233		21.3	41.1
240	228	98.1	20.3	40.3
230	219	96.7	(18.0)	
220	209	95.0	(15.7)	
210	200	93.4	(13.4)	
200	190	91.5	(11.0)	
190	181	89.5	(8.5)	
180	171	87.1	(6.0)	
170	162	85.5	(3.0)	
160	152	81.7	(0.0)	
150	143	78.7		
140	133	75.0		
130	124	71.2		
120	114	66.7		
110	105	62.3		
100	95	56.2		
95	90	52.0		
90	86	48.0		
85	81	41.0		

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