



SURFACE PREPARATION FOR STRAIN GAGE BONDING

Application Note B-129-8

1.0 Introduction

Strain gages can be satisfactorily bonded to almost any solid material if the material surface is *properly* prepared. While a properly prepared surface can be achieved in more than one way, the specific procedures and techniques described here offer a number of advantages. To begin with, they constitute a carefully developed and thoroughly proven system; and, when the instructions are followed precisely (along with those for gage and adhesive handling), the consistent result will be strong stable bonds. The procedures are simple to learn, easy to perform, and readily reproducible.

Furthermore, the surface preparation materials used in these procedures are, unless otherwise noted, generally low in toxicity, and do not require special ventilation systems or other stringent safety measures. Of course, as with any materials containing solvents or producing vapors, adequate ventilation is necessary.

The importance of attention to detail, and precise adherence to instructions, cannot be overstressed in surface preparation for strain gage bonding. Less thorough, or even casual, approaches to surface preparation may sometimes yield satisfactory gage installations; but for *consistent* success in achieving high-quality bonds, the methods given here can be recommended without qualification. Fundamental to the Vishay Micro-Measurements system of surface preparation is an understanding of *cleanliness* and *contamination*. All open surfaces not thoroughly and freshly cleaned must be considered contaminated, and require cleaning immediately prior to gage bonding. Similarly, it is imperative that the materials used in the surface preparation be fresh, clean, and uncontaminated. It is worth noting that strain gages as received from Vishay Micro-Measurements are chemically clean, and specially treated on the underside to promote adhesion. Simply touching the gages with the fingers (which are always contaminated) can be detrimental to bond quality.

The Vishay Micro-Measurements system of surface preparation includes five basic operations. These are, in the usual order of execution:

1. Solvent degreasing
2. Abrading (dry and wet)
3. Application of gage layout lines
4. Conditioning
5. Neutralizing

These five operations are varied and modified for compatibility with different test material properties, and exceptions

are introduced as appropriate for certain special materials and situations.

The surface preparation operations are described individually in *Section 2.0*, following a summary of the general principles applicable to the entire process. *Section 3.0* discusses special precautions and considerations which should be borne in mind when working with unusual materials and/or surface conditions.

The various surface preparation and installation accessories referred to throughout this Application Note are Vishay Micro-Measurements Accessories, listed in Catalog A-110 and available directly from Vishay Micro-Measurements.

As a convenience to the gage installer in quickly determining the specific surface preparation steps applicable to any particular test material, *Section 4.0* includes a chart listing approximately 75 common (and uncommon) materials and the corresponding surface preparation treatments.

2.0 Basic Surface Preparation Operations and Techniques

2.1 General Principles of Surface Preparation for Strain Gage Bonding

The purpose of surface preparation is to develop a chemically clean surface having a roughness appropriate to the gage installation requirements, a surface alkalinity corresponding to a pH of 7 or so, and visible gage layout lines for locating and orienting the strain gage. It is toward this purpose that the operations described here are directed.

As noted earlier, cleanliness is vital throughout the surface preparation process. It is also important to guard against recontamination of a once-cleaned surface. Following are several examples of surface recontamination to be avoided:

- a. Touching the cleaned surface with the fingers.
- b. Wiping back and forth with a gauze sponge, or reusing a once-used surface of the sponge (or of a cotton swab).
- c. Dragging contaminants into the cleaned area from the uncleaned boundary of that area.
- d. Allowing a cleaning solution to evaporate on the surface.
- e. Allowing a cleaned surface to sit for more than a few minutes before gage installation, or allowing a partially prepared surface to sit between steps in the cleaning procedure.



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Beyond the above, it is good practice to approach the surface preparation task with freshly washed hands, and to wash hands as needed during the procedure.

2.2 Solvent Degreasing

Degreasing is performed to remove oils, greases, organic contaminants, and soluble chemical residues. Degreasing should always be the first operation. This is to avoid having subsequent abrading operations drive surface contaminants into the surface material. Porous materials such as titanium, cast iron, and cast aluminum may require heating to drive off absorbed hydrocarbons or other liquids.

Degreasing can be accomplished using a hot vapor degreaser, an ultrasonically agitated liquid bath, aerosol type spray cans of CSM-2 Degreaser, or wiping with GC-6 Isopropyl Alcohol. One-way applicators, such as the aerosol type, of cleaning solvents are always preferable because dissolved contaminants cannot be carried back into the parent solvent. Whenever possible, the entire test piece should be degreased. In the case of large bulky objects which cannot be completely degreased, an area covering 4 to 6 in [100 to 150 mm] on all sides of the gage area should be cleaned. This will minimize the chance of recontamination in subsequent operations, and will provide an area adequately large for applying protective coatings in the final stage of gage installation.

2.3 Surface Abrading

General — In preparation for gage installation, the surface is abraded to remove any loosely bonded adherents (scale, rust, paint, galvanized coatings, oxides, etc.), and to develop a surface texture suitable for bonding. The abrading operation can be performed in a variety of ways, depending upon the initial condition of the surface and the desired finish for gage installation. For rough or coarse surfaces, it may be necessary to start with a grinder, disc sander, or file. (*Note: Before performing any abrading operations, see Section 3.1 for safety precautions.*) Finish abrading is done with silicon-carbide paper of the appropriate grit, and recommended grit sizes for specific materials are given in **Section 4.0**.

If grit blasting is used instead of abrading, either clean alumina or silica (100 to 400 grit) is satisfactory. In any case, the air supply should be well filtered to remove oil and other contaminant vapors coming from the air compressor. The grit used in blasting should not be recycled or used again in surface preparation for bonding strain gages.

The optimum surface finish for gage bonding depends somewhat upon the nature and purpose of the installation. For general stress analysis applications, a relatively smooth surface (in the order of 100 μin [2.5 μm] rms) is suitable, and has the advantage over rougher surfaces that it can be cleaned more easily and thoroughly. Smoother surfaces, compatible with the thin “gluelines” required for minimum creep, are used for transducer installations. In contrast, when very high

elongations must be measured, a rougher (and preferably cross-hatched) surface should be prepared. The recommended surface finishes for several classes of gage installations are summarized in Table I, below.

TABLE I

CLASS OF INSTALLATION	SURFACE FINISH, rms	
	μin	μm
General stress analysis	63 – 125	1.6 – 3.2
High elongation	>250	>6.4
	cross-hatched	
Transducers	16 – 63	0.4 – 1.6

Wet Abrading — Whenever *M-Prep* Conditioner A is compatible with the test material (see **Section 4.0**), the abrading should be done while keeping the surface wet with this solution, if physically practicable. Conditioner A is a mildly acidic solution which generally accelerates the cleaning process and, on some materials, acts as a gentle etchant. It is not recommended for use on magnesium, synthetic rubber, or wood.

2.4 Gage-Location Layout Lines

The normal method of accurately locating and orienting a strain gage on the test surface is to first mark the surface with a pair of crossed reference lines at the point where the strain measurement is to be made. The lines are made perpendicular to one another, with one line oriented in the direction of strain measurement. The gage is then installed so that the triangular index marks defining the longitudinal and transverse axes of the grid are aligned with the reference lines on the test surface.

The reference, or layout, lines should be made with a tool that *burnishes*, rather than scores or scribes, the surface. A scribed line may raise a burr or create a stress concentration. In either case, such a line can be detrimental to strain gage performance and to the fatigue life of the test part. On aluminum and most other nonferrous alloys, a 4H drafting pencil is a satisfactory and convenient burnishing tool. However, graphite pencils should never be used on high-temperature alloys, where the operating temperature might cause a carbon embrittlement problem. On these and other hard alloys, burnished alignment marks can be made with a ballpoint pen or a round-pointed brass rod. Layout lines are ordinarily applied following the abrading operation and before final cleaning. All residue from the burnishing operation should be removed by scrubbing with Conditioner A as described in the following section.

2.5 Surface Conditioning

After the layout lines are marked, Conditioner A should be applied repeatedly, and the surface scrubbed with cotton-tipped applicators until a clean tip is no longer discolored by the scrubbing. During this process the surface should be kept

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constantly wet with Conditioner A until the cleaning is completed. *Cleaning solutions should never be allowed to dry on the surface.* When clean, the surface should be dried by wiping through the cleaned area with a *single* slow stroke of a gauze sponge. The stroke should begin inside the cleaned area to avoid dragging contaminants in from the boundary of the area. Then, with a fresh sponge, a *single* slow stroke is made in the opposite direction. The sponge should never be wiped back and forth, since this may redeposit the contaminants on the cleaned surface.

2.6 Neutralizing

The final step in surface preparation is to bring the surface condition back to an optimum alkalinity of 7.0 to 7.5 pH, which is suitable for all Vishay Micro-Measurements strain gage adhesive systems. This should be done by liberally applying *M-Prep Neutralizer 5A* to the cleaned surface, and scrubbing the surface with a clean cotton-tipped applicator. The cleaned surface should be kept completely wet with Neutralizer 5A throughout this operation. When neutralized, the surface should be dried by wiping through the cleaned area with a *single* slow stroke of a clean gauze sponge. With a fresh sponge, a *single* stroke should then be made in the opposite direction, beginning with the cleaned area to avoid recontamination from the uncleaned boundary.

If the foregoing instructions are followed precisely, the surface is now properly prepared for gage bonding, and the gage or gages should be installed as soon as possible.

3.0 Special Precautions and Considerations

3.1 Safety Precautions

As in any technical activity, safety should always be a prime consideration in surface preparation for strain gage bonding. For example, when grinding, disc sanding, or filing, the operator should wear safety glasses and take such other safety precautions as specified by his organization or by the Occupational Safety and Health Administration (OSHA).

When dealing with toxic materials such as beryllium, lead, uranium, plutonium, etc., all procedures and safety measures should be approved by the safety officer of the establishment before commencing surface preparation.

3.2 Surfaces Requiring Special Treatment

Concrete — Concrete surfaces are usually uneven, rough, and porous. In order to develop a proper substrate for gage bonding, it is necessary to apply a leveling and sealing precoat of epoxy adhesive to the concrete. Before applying the precoat, the concrete surface must be prepared by a procedure which accounts for the porosity of this material.

Contamination from oils, greases, plant growth, and other soils should be removed by vigorous scrubbing with a stiff-bristled brush and a mild detergent solution. The surface is then rinsed

with clean water. Surface irregularities can be removed by wire brushing, disc sanding, or grit blasting, after which all loose dust should be blown or brushed from the surface.

The next step is to apply Conditioner A generously to the surface in and around the gaging area, and scrub the area with a stiff-bristled brush. Contaminated Conditioner A should be blotted with gauze sponges, and then the surface should be rinsed thoroughly with clean water. Following the water rinse, the surface acidity must be reduced by scrubbing with Neutralizer 5A, blotting with gauze sponges, and rinsing with water. A final thorough rinse with distilled water is useful to remove the residual traces of water-soluble cleaning solutions. Before precoating, the cleaned surface must be thoroughly dried. Warming the surface gently with a propane torch or electric heat gun will hasten evaporation.

Vishay Micro-Measurements M-Bond AE-10 room-temperature-curing epoxy adhesive is an ideal material for precoating the concrete. For those cases in which the test temperature may exceed the specified maximum operating temperature of AE-10 (+200°F [+95°C]), it will be necessary to fill the surface with a higher temperature resin system such as M-Bond GA-61.

In applying the coating to the porous material, the adhesive should be worked into any voids, and leveled to form a smooth surface. When the adhesive is completely cured, it should be abraded until the base material begins to be exposed again. Following this, the epoxy surface is cleaned and prepared conventionally, according to the procedure specified in *Section 4.0* for bonding gages to epoxies.

Plated Surfaces — In general, plated surfaces are detrimental to strain gage stability, and it is preferable to remove the plating at the gage location, if this is permissible. Cadmium and nickel plating are particularly subject to creep, and even harder platings may creep because of the imperfect bond between the plating and the base metal. When it is not permissible to remove the plating, the surface should be prepared according to the procedure given in *Section 4.0* for the specific plating involved. Note that it may be necessary to adjust testing procedures to minimize the effects of creep.

Use of Solvents on Plastics — Plastics vary widely in their reactivity to solvents such as those employed in the surface preparation procedures described here. Before applying a solvent to any plastic, *Section 4.0*, which includes most common plastics, should be referred to for the recommended compatible solvent. For plastics not listed in *Section 4.0*, the manufacturer of the material should be consulted, or tests should be performed to verify nonreactivity between the solvent and the plastic.

Dimensional or Mechanical Changes Due to Surface Preparation — For most materials, strain measurement results are usually not significantly changed by the surface preparation procedures described in this Application



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Note. Even with appreciable material removal, effects on the static mechanical properties of the test part are generally negligible compared to other error sources in the experiment. It should be understood, however, that removal of a plated or hardened surface layer, or of a surface layer with significant residual stresses, may noticeably affect the fatigue life or the wear characteristics of the part when operated under dynamic service conditions.

Silicone Contamination —The properties of silicones which make them excellent lubricants and mold-release agents also make them the enemies of adhesion, and therefore potentially the most serious of contaminants to be encountered in the practice of bonding strain gages. The problem is compounded by the high natural affinity of the silicones for most materials, and by their tendency to migrate. Furthermore, since silicones are relatively inert chemically, and unaffected by most solvents, they are among the most difficult surface contaminants to remove.

The best practice is to keep the gage-bonding area free of silicones. This may not be as easy as it sounds, since the widely used silicones can be introduced from a variety of sources. For instance, many hand creams and cosmetics contain silicones, and these should not be used by persons involved in gage installation. Some of the machining lubricants also contain silicones, and such lubricants should be avoided when machining parts that are to have strain gages installed. Similarly, silicone-saturated cleaning tissues for eyeglasses should not be used in the gage-bonding area or by gage-installation personnel.

Regardless of efforts to avoid silicones, contamination may still occur. Light contamination can sometimes be removed by cleaning with Conditioner A, preferably heated to +200°F [+95°C]. More severe cases may require special cleaning solutions and procedures, recommendations for which should be obtained from the manufacturer of the silicone compound involved in the contamination.

4.0 Index of Test Materials and Surface Preparation Procedures

In this section, the specific step-by-step surface preparation procedures are given for approximately 75 different materials. For compactness, and convenient, quick access to the procedure for any particular material, the information is presented in chart form in Table II. The test materials are listed alphabetically, from ABS Plastics to Zirconium; and the complete procedure for each material is defined by one or more digits in each of the applicable operations columns of the table. Each digit identifies the required operation and specifies the step number for that operation in the complete procedure.

For example, assume that the necessity arises for bonding one or more strain gages to a brass test specimen. Reading down the *Specimen Material* column of Table II to Brass, and following that row across the table to the right, the first step in

surface preparation consists of degreasing the specimen with CSM-2 Degreaser. The symbol (1) in the *Isopropyl Alcohol* column indicates that this is a suitable substitute degreasing operation. Continuing across the row, the second operation calls for abrading the specimen surface with 320-grit silicon-carbide paper. In the third operation the specimen is reabraded with 400-grit silicon-carbide paper, wet lapping with Conditioner A if feasible. The fourth and fifth operations consist of applying layout lines for locating the gages, and scrubbing the surface clean with Conditioner A. Cleaning with isopropyl alcohol is the final operation in the procedure.

In the *Remarks* column, it is recommended that the gages be installed within 20 minutes after completing the surface preparation, because the freshly bared brass surface tends to oxidize rapidly. In addition, in the *Grit Blast* column, the gage installer is specifically advised not to substitute grit blasting for other surface abrading methods, in order to avoid significantly altering the surface condition of this relatively soft material. Surface preparation procedures for other materials are defined similarly in the table, and, in many cases, accompanied by special warnings or recommendations in the *Remarks* column. When an operation not included in the first ten column headings is required, it is indexed in the *Other* column, with an arrow pointing to the *Remarks* column where the operation is specified.

Additional References

For additional information, refer to Instruction Bulletins listed below:

B-127, “Strain Gage Installations with M-Bond 200 Adhesive”.

B-130, “Strain Gage Installations with M-Bond 43-B, 600, and 610 Adhesives”.

B-137, “Strain Gage Applications with M-Bond AE-10, AE-15, and GA-2 Adhesive Systems”.

Important Notice

The procedures, operations, and chemical agents recommended in this Application Note are, to the best knowledge of Vishay Micro-Measurements, reliable and fit for the purposes for which recommended. This information on surface preparation for strain gage bonding is presented in good faith as an aid to the strain gage installer; but no warranty, expressed or implied, is given, nor shall Vishay Micro-Measurements be liable for any injury, loss, or damage, direct or consequential, connected with the use of the information. Before applying the procedures to any material, the user is urged to carefully review the application with respect to human health and safety, and to environmental quality.



TABLE II
Index of Test Materials and
Surface Preparation Procedures
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SPECIMEN MATERIAL	See Section						REMARKS
	2.2	2.2	2.3	2.4	2.5	2.6	
	CSM-2 DEGREASER	G-6 ISOPROPYL ALCOHOL	GRT-BLAST	220-GRT ABRASIVE PAPER	320-GRT ABRASIVE PAPER	400-GRT ABRASIVE PAPER	
			GAGE LOCATION LAYOUT	CONDITIONER A (SCRUB)	NEUTRALIZER 5A	OTHER	
ENAMEL PAINTS				4	1	Paint is normally removed for gage installation. Baked enamels may be left on surface if essential to test.	
EPOXIES	1 (1)		2	3	4	Surface may require several initial cleanings with Conditioner A if silicones are present.	
FIBERGLASS LAMINATES	1		2	3	4	Coarser abrasive may be necessary in Step 2 to remove all surface gloss.	
GRAPHITE AND GRAPHITE COMPOSITES	1,3,5*		2	4	5*		
GLASS	1 (1)	No		2	3	Abrasion not usually necessary. Engineering approval for abrading is generally required.	
GOLD	1 (1)			2	3		
INCONEL	1	2 (2a) (2b)		3	4	Repeat Steps 4 and 5 if gages cannot be installed within 45 min.	
INDIUM	1			2	3		
INVAR	1	2 (2a) (2b)		3	4	Repeat Steps 4 and 5 if gages cannot be installed within 45 min.	
IRON, CAST, OR WROUGHT	1*	2 (2a) (2b)		3	4	Repeat Steps 2 through 5 if gages cannot be installed within 30 min.	
ISOELASTIC	1	No	2	3	4	Repeat Steps 4 and 5 if gages cannot be installed within 45 min.	
KAPTON	1 (1)	(2)		2	3		
LEAD		1	No	2	3		
MAGNESIUM	1 (1)			3	No	Do not abrade magnesium (i.e., avoid producing fine particles). Scrape gage site with deburring knife or file. Do not use Conditioner A on magnesium.	
MANGANIN	1 (1),5			2	3		
MASONRY	1,4*			3	5	Wire-brush or disc-sand, and remove dust with dry paintbrush. Fill and seal surface with epoxy adhesive, such as AE-10, and sand smooth after adhesive is cured.	
MODELTECH® (aluminum-filled cast epoxy)	1			2	3		
MOLYBDENUM	1 (1)		2	3	4		
MONEL	1 (1)		2	3	4		
MYLAR	1	(2)		2	3		
NICHROME	1 (1)	(2)		2	3		
NICKEL AND NICKEL PLATE	1 (1)		2	3	4	If permissible, nickel plating should be removed at gage installation site.	
NI-SPAN C	1 (1)	(2)		2	3		
NYLON	1	(2)		2	3		
PHENOLIC COMPOSITES	1,5*			2	3		
PHOSPHOR BRONZE	1 (6**)		2	3	4	Step 2 may require coarser abrasive to remove all surface gloss.	
PLATINUM				2	3		

SPECIAL NOTES

- * Heating specimen will help drive out oils, moisture, and solvent.
- ** Rinse with distilled water, and wipe dry.
- † Use clean (filtered), dry air. Do not recycle alumina or silica grits.
- ‡ Wet lap with Conditioner A when compatibility is indicated by "Conditioner A (Scrub)" column.
- () Parentheses indicate alternate step(s).

REMARKS



SPECIAL NOTES

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REMARKS

SPECIMEN MATERIAL	See Section										REMARKS			
	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2				
	GC-6 DEGREASER	GRT-BLAST	220-GRIT ABRASIVE PAPER	320-GRIT ABRASIVE PAPER	400-GRIT ABRASIVE PAPER	CONDITIONER A (SCRUB)	NEUTRALIZER BA	OTHER	2.4	2.5	2.6			
PLUTONIUM	1								2	3	4	5	Should be electroplated with nickel before gage installation. Contact Vishay Micro-Measurements Applications Engineering Department for specific instructions.	
POLYCARBONATES	1	No								2	3	4	5	
POLYETHYLENE	1									(2)	3	No	4	2 → Scour with household cleanser and rinse with water, or flame-burnish surface.
POLYURETHANE	1									2	3		4	
POLYVINYL CHLORIDE	1									(2)	3		4	2 → Scour with household cleanser and rinse with water.
PORCELAIN	1											2	3	
QUARTZ	1											2	3	
RENE 41	1	(2)								2	3	4	5	
RUBBER, NATURAL OR SYNTHETIC	1									2			4	(2) → Scour with household cleanser and rinse with water.
SILVER	1									3			4	2 → Scrub with slurry of pumice powder and isopropyl alcohol.
SINTERED METALS	1									2	3	4	5*	(1) → Hot-vapor degrease.
STEEL (Carbon and Stainless)	1	(2a)	(2b)							3	4	5		Repeat Steps 4 and 5 if gages cannot be bonded within 45 min of final surface preparation.
STEEL, 4000 SERIES	1	(2)	2							3	No	4		Conditioner A tends to produce black residue on surface.
STEEL, SURFACE HARDENED	1									2	3,4	5		Removal of surface material may alter residual stress conditions and/or fatigue life and wear resistance.
STONE	2*										3	4		Wire-brush, grind, or disc-sand, and dust surface with dry paint brush. Fill and seal surface with epoxy adhesive, such as AE-10, and sand smooth after adhesive is cured.
TANTALUM	1	(1)								2	3	4	5	
TEFLON	1	(1)								3			4	2 → Etch surface with Tetra-Etch, rinse with isopropyl alcohol, then with water.
TIN	1	(1)								2	3	4	5	
TITANIUM	1	2	(2)							3	4	5		It may be necessary to heat-cycle the specimen two or three times to +350°F [+175°C] as initial step in surface preparation. Halogens should never be used for degreasing if the specimen is to be tested at temperatures above +700°F [+370°C]. Install gages within 10 min of final surface preparation.
TITANIUM SILICATE	1	(1)								2			5	
TUNGSTEN CARBIDE	1	(1)								2			5	
URANIUM	1	No											5	2 → Should be electroplated with nickel before gage installation. Contact Vishay Micro-Measurements Applications Engineering Department for specific instructions.
WOOD														1 → It may be necessary to kiln-dry wood of more than 20% moisture content. After abrasion, dust surface with dry paint brush.
ZINC	1	No								2			5	
ZIRCONIUM	1	(1)								2			5	It may be necessary to repeat Step 5 until proper surface pH is achieved.

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