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PRECIOUS METAL MECHANICAL CLAD VS. ELECTROPLATE: DISTINCT DIFFERENCES

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ABSTRACT
More than two and a half centuries ago the first precious metal clad was invented and immediately found its use in making ornaments and jewelry (now known, for example, as gold filled jewelry). A century later the improvements in precious metal electroplating technology raised serious competition to clad metal. Today, both precious metal clad and electroplating are still being used for making jewelry, each offering different features and benefits, and each serving different purposes. Equating clad and electroplate appears to be misleading to a consumer. This paper presents the work on developing the recommendations to the Federal Trade Commission that LeachGarner carried out on behalf the Jewelers Vigilance Committee. It clearly identifies the fundamental practical differences between clad and electroplate using mechanical wear tests.

BACKGROUND
Precious metal cladding and electroplating have been a traditional part of manufacturing jewelry, ornaments, utensils and tableware for more than two centuries. The first clad metal of silver on copper (known as "Old Sheffield Plate") was accidently discovered by British cutler Thomas Boulsover[1] in 1743. This discovery led to a rapidly growing industry of precious metal cladding as it offered a significant material cost savings without compromising the aesthetic appearance of the final product. The first clad of gold on base metal was produced in Great Britain in 1817 by John Turner[2] resulting in the emergence of gold filled and rolled gold plate raw materials such as sheet, wire and tubing. All these early clad metals employed a thin layer of silver or gold alloy that was mechanically affixed to a base metal by means of pressure, heat and brazing – the processes that stayed basically the same as we know it today. The electroplating was discovered by Italian chemist Luigi Brugnatelli[3] in 1803. Remarkably, his first experiments were carried out on electroplating gold. By 1840 electroplating became a substantial industry that imposed serious competition to cladding. Often, both techniques were used in combination to produce relatively inexpensive precious metal articles of fairly complex and intricate shapes.

The fundamental differences between clad and electroplate were recognized and unambiguously defined by international agreement after the First World War[4]. The history of government involvement in regulating the precious metal and jewelry industries goes back to as early as the end of the 13th - beginning of the 14th centuries. The regulations were intended to achieve two objectives: **consumer protection against fraud and deception,** and **trader protection against unfair competition**. With these objectives in mind, the National Gold and Silver Stamping Act[5] was introduced by the United States Government in 1906. Gold filled, rolled gold plate and electroplate were separately defined and regulated there besides establishing the legal definitions for karat golds. In 1957 the Federal Trade Commission (FTC, formed in 1914) enacted the Guides for the Jewelry, Precious Metals and Pewter Industries. The Guides were last revised in 1996 (see also reference 7). The Stamping Act and the Guides have become the basic laws that regulate the jewelry industry in the U.S. The Jewelers Vigilance Committee (JVC, established in 1912) published The Essential Guide to the U.S. Trade in Gold and Silver Jewelry" to ensure a greater understanding of these laws so that they can be properly applied to the trade practice in this area and, therefore, to provide clear, accurate consumer information".

According to the current law, 0.3% tolerance is allowed in the gold content of karat golds, and 0.7% tolerance is acceptable when solder is used. The gold filled and rolled gold plate are defined as mechanically applied karat golds of a certain weight fraction: minimum 1/20 by weight for gold filled (GF) and minimum 1/40 by weight for rolled gold plate (RGP). The gold content tolerances are the same as for the solid karat golds. In contrast, the electroplated gold is regulated not by the weight fraction, but by the thickness of the plated layer. For example, "heavy gold electroplate" should have the minimum thickness of 100 micro-inches (1 micro-inch = 10^{-6} inches or 1 mil), "gold plate" should be a minimum of 20 micro-inches thick, and "gold wash" must be 7 micro-inches minimum.

Apparently, the current laws are not perfect, as they do not reflect recent developments some of which are driven by the volatile precious metal markets and European regulations:

- Low gold alloys below 10K became commercially attractive.
- Almost all commercial palladium containing white golds require rhodium plating.
- Palladium and platinum electroplates also require regulations in addition to rhodium.
- Numerous different composite materials combining low and high precious metal containing alloys are now being offered to the market.
- Platinum and palladium clads similar to gold filled also need regulations.

In 2013 the FTC announced a roundtable discussion on the revision of the current Guides. Historically, the word "plate" is used interchangeably to describe both clad and electroplate. This leads to some confusion, and as a result, there is an attempt now to equate clad and electroplate in the new FTC Guides by identifying both just as "coating". This appears to be misleading to a consumer as clad and electroplate are distinctively different products, each offering different features, and serving different purposes[4]. Some fundamental differences between GF/RGP clad metals and electroplate are listed below:

GF/RGP:

- Jewelry clad material is designed to maintain certain substantial precious metal content. The precious metal content is independent of size and shape of the jewelry article.
- Jewelry clad is made with a wide variety of commercial karat gold jewelry alloys of different colors.
- Karat gold alloy is mechanically affixed to the base metal substrate (usually brass). The bond is strong so that the jewelry article may be formed into complicated shapes. Therefore, clad is a workable manufacturing material.
- Jewelry clad does not require the presence of an interliner between base metal substrate and gold alloy.
- The jewelry article that is made with clad material appears and feels as an article made with the solid jewelry alloy.
- The thickness of the clad is significant and unlimited, normally around 600 mils.

Electroplate:

- The precious metal content of electroplated jewelry is practically negligible. It also varies with the surface area and the overall volume.
- Electroplate is mainly used to deposit single elements such as gold, silver rhodium, etc., as well as some limited alloys the composition of which differs significantly from that of common jewelry alloys.
- The forming operations are not practical for electroplated material as the bond is not as strong and the plated layer may flake or peel off. The plating is always carried out as a final operation on the finished article as a decorative or protective coating.
- Electroplate requires the presence of an interliner, such as a pre-plated layer of nickel or palladium, or both, to condition the surface of the substrate.
- The plating has a distinct specific appearance that differs from that of solid karat gold jewelry.
- Electroplate thickness is relatively small as it has certain limitations related to porosity. Normally, the thickness may vary between several mils (for Rh) and 200 mils (for Ag).

OBJECTIVE and APPROACH

In the attempt to prevent equating clad and electroplate the objective of this work was to illustrate the fundamental differences between clad and electroplate for the FTC roundtable discussion by carrying out the abrasive wear test to reiterate the fact that different clads and electroplates show different reaction to exposure to abrasive media. The test was also expected to reveal the wear limitations of different clads and electroplates. The results of this study have eventually become a part of JVC recommendations to the FTC on new Guides.

SAMPLE PREPARATION

Electroplating was done by Tanury Industries in Lincoln, RI using annealed brass discs approximately 0.020" thick and 1.5" OD. The discs were pre-plated with the interliner containing either nickel or palladium, or both, and then plated with four precious metals: rhodium (Rh), palladium (Pd), gold (Au) and silver (Ag).

The same OD discs with approximately the same thickness were cut out from the sheet strips of 10K/20 and 14K/20 gold filled material, double-sided 14K/40x14K/40 rolled gold plate, and 1/10 sterling silver clad on brass. 14K and sterling clad sheet strips were annealed, whereas 10K/20 material was selected in hard as rolled condition to see the potential effect of hardness on wear resistance. Vickers hardness at 50 gram load was measured for all the samples. Table 1 lists the sample description and measured hardness values. This is not unusual that the hardness of the electroplated pure metals exceeds that of the same pure metals in the annealed condition. Naturally, the hardness values of karat gold and sterling silver clads are in line with the corresponding values for the solid alloys.

Table 1. Hardness data on clads and electroplates.

Sample	Vickers Hardness
Rhodium electroplate 5 mils nominal	255
Palladium electroplate 10 mils nominal	150
Gold electroplate 50 mils nominal	170
Silver electroplate 200 mils nominal	140
1/10 sterling silver clad	75
10K/20 gold filled	220
14K/20 gold filled	110
14K/40x14K/40 rolled gold plate (RGP)	110

EXPERIMENTAL PROCEDURE, RESULTS and DISCUSSION

The wear test was conducted using Otec mass finishing equipment shown in Figure 1. The disc samples were placed inside the bowl filled with walnut shells mixed with moderately abrasive paste. The spinning of such an abrasive media in the bowl as shown in Figure 2 provided slow and graduate removal of disc surface layers with time.

Figure 1.
Otec mass finishing equipment.

Figure 2.
Spinning walnut shells.

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The thickness measurements of electroplates and clads were performed on the cross sectioned segments of each disc sample using Scanning Electron Microscope (SEM). As examples, Figures 3 and 4, 5 and 6, and 7 and 8 respectively show the SEM micrographs of the gold and silver electroplated layers and 14K/40 RGP layer before the abrasive test and after the extended abrasive test exposure. The original magnification is 1000X for all the photographs, and the scale bar is 10 microns (approximately 400 mils).

The thicknesses of the clad and the electroplated layers were measured prior to the test, and then after 2.5, 8.5 and 26.5 hours. Along with the thickness measurements the X-ray spectrum of the surface of each disc sample was also collected to confirm the presence and the integrity of top layers. As an example, Figures 9, 10 and 11 respectively show the X-ray spectra of the original surface of the rhodium-plated disc, the same surface after 2.5 and after 8.5 hours of test. The original surface shows only a rhodium peak. The same surface after 2.5 hours also shows a palladium peak that belongs to the pre-plated interliner – this is an indication that a significant portion of the rhodium layer has been removed. The surface after 8.5 hours shows no rhodium and only a palladium peak – this is an indication that the entire rhodium layer has been removed.

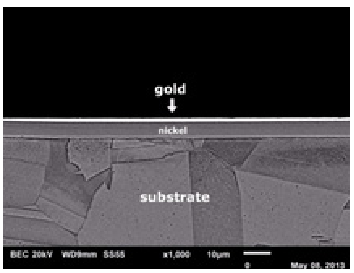

Figure 3.
Au electroplate
before abrasive test.

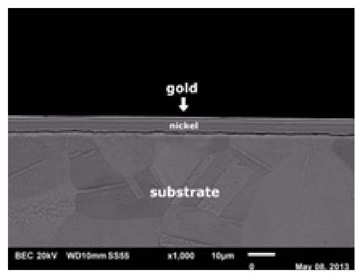

Figure 4.
Remaining Au electroplate
after extended abrasive test
exposure.

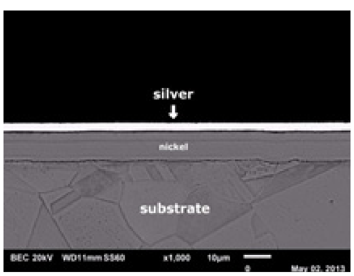

Figure 5.
Ag electroplate
before abrasive test.

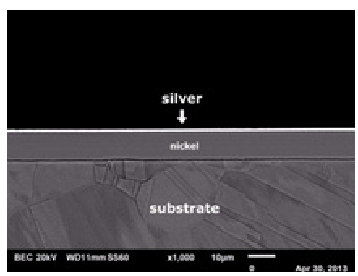

Figure 6.
Remaining Ag electroplate
after extended abrasive test
exposure

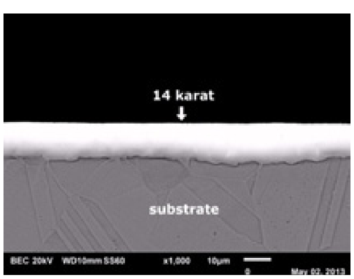

Figure 7.
14K/40 RGP
before abrasive test.

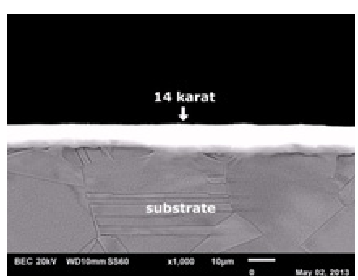

Figure 8.
14K/40 RGP
after extended abrasive test
exposure.

Table 2 lists the measured sample thicknesses as a function of the wear test duration. The data shows that within the first 2.5 hours of the test the regular 14K layer loses about 120 mils of its thickness. This amounts to about 25 milligrams of material per square inch area. **This is a noticeable loss, as it can be measured by a conventional instrument such as a micrometer or a two-decimal place scale. In practice, such a loss of 14K material corresponds to a prolonged exposure to normal wear and handling.**

Table 2. Measured thickness values of electroplated and clad layers vs. time.

	Measured thickness (mils)							
Time (hrs.)	**Rh**	**Pd**	**Au**	**Ag**	**1/10 Stg.**	**10K/20**	**14K/20**	**14K/40**
0	7	17	68	176	1686	603	860	586
2.5	5	12	54	154	1560	546	737	474
8.5	0	10	39	105	1439	507	690	410
26.5	0	0	16	38	1170	456	563	273

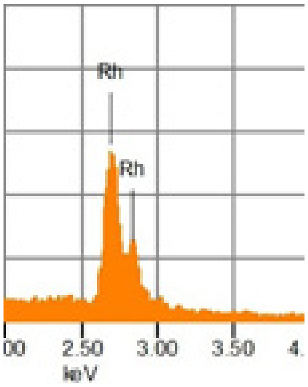

Figure 9.
X-ray spectrum of original rhodium-plated surface.

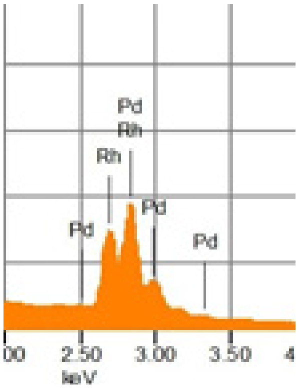

Figure 10.
X-ray spectrum of rhodium-plated surface after 2.5 hours

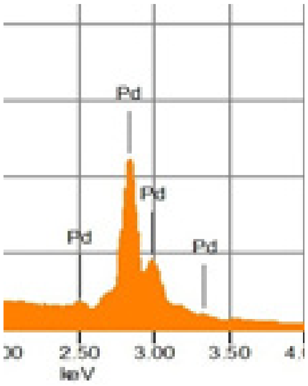

Figure11.
X-ray spectrum of rhodium-plated after 8.5 hours.

This data also shows that within 2.5 hours (or under prolonged exposure to normal wear and handling) rhodium loses 2 mils and palladium loses 5 mils. With some safety factor for rhodium (as 2 mils is an extremely low thickness) one may conclude that at least 3 mils for rhodium and 5 mils for palladium are reasonable minimum limits.

Our data also indicates that after 2.5 hours the gold loss is about 14 mils. It is not unreasonable to conclude, therefore, that at least 15 mils should be a minimum thickness to withstand prolonged normal wear and handling. It is not unusual, however, for the industry current practice to electroplate 7 mils of gold. According to our data the silver minimum limit may be reduced to 50 mils with a good safety factor.

Data presented in Table 2 is plotted in two different diagrams shown in Figures 12 and 13 separately for electroplates and clads. It is evident that under the same conditions even though the rhodium electroplate shows the highest hardness, it wears off between 2.5 and 8.5 hours of testing because of an extremely low thickness. Palladium wears off between 8.5 and 26.5 hours. By the time both rhodium and palladium are completely removed, gold and silver still retain about 20% of the original thickness. At the same time, clad samples including rolled gold plate retain between 50%-70% of their original thickness. The extrapolation of these plots indicates that a complete removal of electroplated gold and silver should take place in about 35 - 40 hours of the test while clads may still retain a significant portion of the original thickness. Also, as anticipated, the clad thickness curve for hard as rolled gold filled material shows the lowest slope indicating higher resistance to wear as opposed to the annealed material.

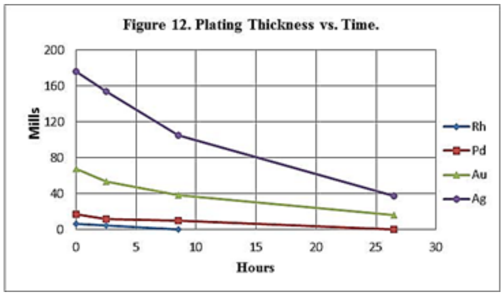

Figure 12. Plating Thickness vs. Time.

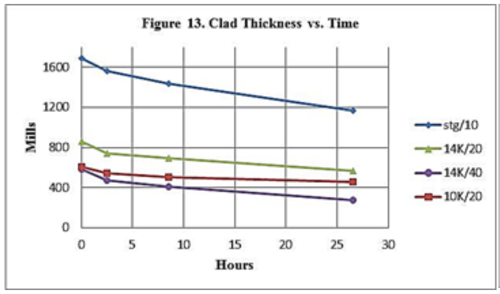

Figure 13. Clad Thickness vs. Time

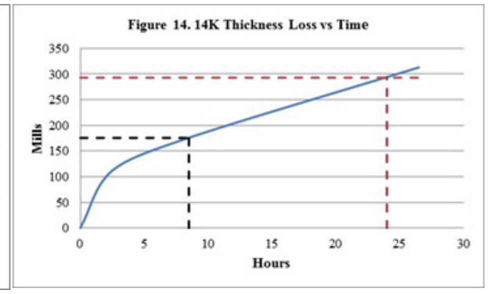

Figure 14. 14K Thickness Loss vs Time

The thickness of the precious metal layer depends on the total material thickness. 1/10 sterling silver clad, 1/20 gold filled and 1/40 rolled gold plate appear to exhibit reliable wear characteristics even at the total clad thickness below 0.020". For instance, 0.010" thick 14K/40 material has about 290 mils of 14K layer, and 0.006" thick material (which is the smallest practical size) has about 175 mils of 14K layer. Figure 14 shows the 14K gold layer thickness loss vs. time. It is evident that both 0.010 and 0.006 thick 14K/40 withstand 24 hrs. and 8 hrs. of wear testing respectively – this is way within the conditions of normal prolonged wear and handling. The materials with lower than 1/40 fractions of 14K, such as 1/60 and 1/80, may not show as high performance under similar conditions especially when the total material thickness is below 0.020".

CONCLUSIONS

1. In general, electroplates and clads are fundamentally different matters: Electroplates serve as decorative or protective coatings, whereas clads are suitable for working and forming just like solid metals.

2. The wear behavior of electroplates is significantly inferior to that of gold filled, rolled gold plate and sterling silver clads mainly due to inherent thickness limitations.

3. Presented data supports the justification for the following minimum thickness limits for electroplates:
   - 3 mils for rhodium,
   - 5 mils for palladium,
   - 15 mils for gold,
   - 50 mils for silver.

4. The results indicate that 1/10 sterling silver clad, 1/20 gold filled and 1/40 rolled gold plate withstand normal prolonged wear and handling at all practical total clad thicknesses.

5. The clad materials with lower than 1/40 fractions of gold alloy layer may not show adequate wear characteristics.

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2. Anselm Kuhn, "The Uses of Gold and its Technology as recorded in Early British Patents", Gold Bulletin, 32(2) (June 1999: 59-65.

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4. "Precious Metals Science and Technology", Edited by Dr. Linda S. Benner, at al, (International Precious Metal Institute 1991), p. 453.

5. http://www.gpo.gov/fdsys/pkg/USCODE-2009-title15/html/USCODE-2009-title15-chap8.htm

6. http://www.ftc.gov/sites/default/files/documents/federal_register_notices/16-cfr-part-23-guides-jewelry-precious-metals-and-pewter-industries-announcement-public-roundtable/130430jewelryguides.pdf

7. U.S. Department of Commerce / NBS (now NIST) Voluntary Product Standards (introduced in 1977 and withdrawn in 1984, but still referenced by FTC):
   - PS 68-76, Marking of Articles Made of Silver in Combination with Gold,
   - PS 70-76, Marking of Articles Made of Karat Gold,
   - PS 71-76, Marking of Jewelry and Novelties of Silver,
   - PS 67-76, Marking of Gold Filled and Rolled Gold Plate Articles Other than Watchcases,
   - PS 69-76, Marking of Articles Made Wholly or in Part of Platinum.