
MAN-MADE JEWELRY MALACHITE

By V. S. Balitsky, T. M. Bublikova, S. L. Sorokina, L. V. Balitskaya, and A. S. Shteinberg

Jewelry-quality synthetic malachite is now being manufactured in the USSR. The texture, structure, and physical and physico-chemical properties of this synthetic malachite are reported. Three textural types have been identified: banded, silky, and bud-like. The malachite is composed of closely adjacent spherulitic aggregates, the generation and growth of which are controlled by the crystallization conditions. In chemistry, color, density, hardness, optical properties, and X-ray diffraction, the synthetic malachite proved virtually identical to the natural material. Only in the thermograms were significant differences noted. Therefore, the man-made malachite holds much promise for use in stone cutting and the jewelry trade.

One of the major advances in gemstone synthesis over the past few years has been the production of jewelry-quality synthetic malachite. The synthesis was accomplished at three institutions in the USSR at approximately the same time: Leningrad State University (LGU; Petrov et al., 1985); the All-Union Institute for the Synthesis of Mineral Raw Materials (VNIISIMS), in the Ministry of Geology of the USSR (Balitsky, 1983; Timokhina et al., 1983); and the Institute for Experimental Mineralogy (IEM, USSR Academy of Sciences; Balitsky et al., 1985). These institutions have devised several original methods which allow nearly all textural varieties found in natural malachite to be synthesized under chosen conditions (figures 1–5).

The methods currently used to synthesize malachite are based on its crystallization from aqueous solutions. Specimens produced thus far range from 0.5 kg to several kilograms. At the international exhibition held during the 27th International Geological Congress (Moscow, 1984), vases cut from synthetic malachite pillars weighing as much as 8 kg (and manufactured at the VNIISIMS) were on display. In fact, synthetic malachite is now being produced on a commercial level. For example, the "Uralskije samotsvety" plant (at Sverdlovsk, in the Urals) both produces synthetic malachite and mounts it in a wide

variety of jewelry (Petrov et al., 1985). The authors do not know if this material is being distributed outside the Soviet Union.

This article briefly describes the three most attractive varieties of the jewelry-quality synthetic malachite produced using the methods of the present authors (Balitsky, 1983; Balitsky et al., 1985): banded, silky, and bud-like. The authors then discuss the properties of the synthetic malachite and tests conducted to see how it can be separated from the natural material.

MAJOR TYPES OF SYNTHETIC MALACHITE

Banded. The banded synthetic malachite is very similar in appearance to the malachite from Zaire. Banding is formed by alternating parallel zones that range in color from light to very dark green, almost black. The width of the zones varies from a few tenths of a millimeter to 3–4 mm. The zone boundaries are straight, weakly undulating (see figure 2), or intricately curved. The bulk of the sample is composed of closely adjoining spherulitic aggregates of acicular or plate-like crystals. Both the spherulites and the crystals of which they are made become larger as a result of geometric selection during growth. The samples with contrast banding display recurrent (multilayer) generation of spherulites at the boundaries of particular zones. Where the banding is less contrasting, the development of new zones involves no interruptions in the formation of spherulites. Rather, in this case the spherulite crystals acquire a sub-parallel orientation (figure 3).

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Figure 1. These samples of synthetic jewelry-quality malachite, representing a mixture of banded and bud-like types, strongly resemble their natural counterparts. The largest specimen shown here is 100 × 90 mm.

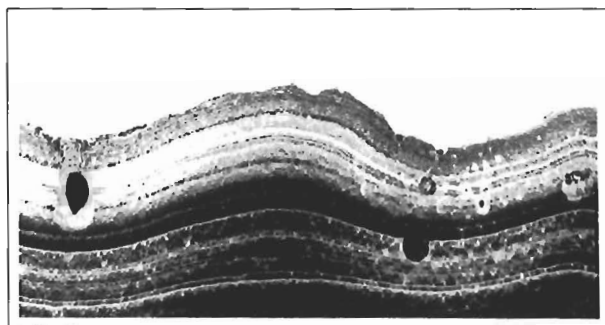


Figure 2. Undulating growth boundaries can be seen in this section of synthetic malachite with the banded texture. The cut is parallel to the growth direction. Maximum length and width, 100 × 28 mm.

Silky. When cut parallel to the growth direction, banded synthetic malachite displays chatoyancy and appears silky. Individual crystals in the silky aggregates are 0.01–0.1 mm thick and several millimeters long. In some samples with complex banding, the chatoyancy is particularly attractive. Distinct areas appear light in cuts parallel to the crystal elongation and almost black in cuts per-

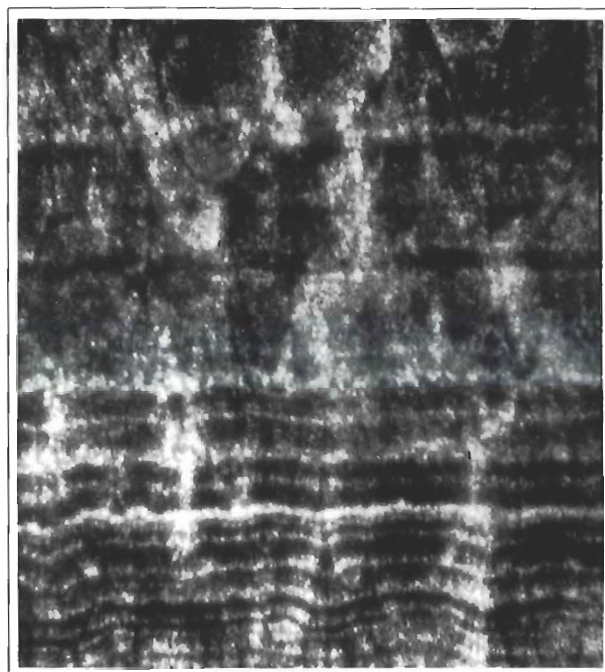


Figure 3. This finely banded sample of synthetic malachite shows the many-tier nucleation of spherulites. The cut is parallel to the growth direction. Magnified 30×.



Figure 4. A bud-like texture is evident in this sample of synthetic malachite, which is cut parallel to the growth direction. Maximum length and width, 30 × 12 mm.

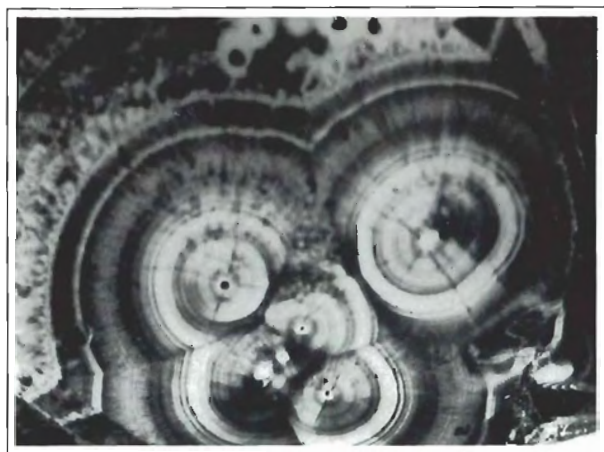


Figure 5. In this close-up view of a sample of bud-like synthetic malachite, the concentric zones of which the buds are comprised are readily evident. The cut is perpendicular to the growth direction. The buds range in diameter from 5 to 10 mm.

pendicular to it. The silky material is, however, the least desirable for jewelry use.

Bud-like. The bud-like synthetic malachite is of a higher jewelry quality than the banded material (see figure 4). It is similar in appearance to the famous Ural malachite. Individual buds in synthetic specimens range from 2–5 to 10–15 mm across. They are formed as a result of the growth of

particular spherulites and develop either a radiated or a concentric zonal structure. In the former type, the crystals in the buds are arranged radially relative to the center of the spherulite nucleus. On cut surfaces, such buds display a gradual color change from almost black at the center to light green toward the edges. The coloration depends on the pattern of relative orientation of the crystal axis and the cut plane. In addition, the tones and intensity of the color can vary with the viewing angle or with the angle of light incidence.

In the second type of structure, the buds are composed of concentric zones that vary in color from light to dark green (figures 4 and 5). Each zone has the spherulitic structure, the spherulites being 0.01–3 mm in size. The zones composed of small spherulites are lighter than those composed of large ones. Every new zone normally gives rise to a new generation of spherulites, but occasionally earlier spherulites are inherited by the later ones.

In addition to the above textural types, several intermediate varieties of synthetic malachite—representing a mixture of two or all three of these types—are also possible (again, see figure 1).

PROPERTIES OF SYNTHETIC MALACHITE

The chemical composition (table 1) and principal physical and physico-chemical properties (table 2) of the scores of synthetic malachite samples examined for this study were compared with the data available on natural samples from the Urals, Ka-

TABLE 1. Mean chemical compositions for natural and synthetic malachite.^a

Components (wt.%)	Natural (locality)	Synthetic (mfr.)	
	Kazakhstan	IEM ^b	VNIISIMS
CuO	71.77	70.22	71.90
MgO	0.001	0.017	nd ^c
CaO	0.003	0.014	nd
H ₂ O	8.52	9.31	—
CO ₂	19.65	19.94	—
H ₂ O + CO ₂	—	—	28.35
Total	99.94	99.50	100.25

^aAt least 20 samples of each type were analyzed. All analyses were performed by the authors using a combination of wet chemical and spectrophotometric methods.

^bFor the samples from Kazakhstan and IEM, FeO, SiO₂, TiO₂, Al₂O₃, and Fe₂O₃ were also determined but not detected
^cnd = not determined.

TABLE 2. Gemological properties of natural and synthetic malachite.^a

Property	Natural (locality)		IEM	Synthetic (mfr.)	
	Zaire	Kazakhstan		LGU	VNIISIMS
Color	Light green to dark green	Green	Light green to dark green	Almost black to light green with pale bluish tint	Almost black to light green
Refractive indices					
α	1.907	1.909	1.908	1.907	1.911
β	1.874	1.875	1.876	1.875	1.877
γ	1.653	1.655	1.657	1.654	1.658
Density, g/cm ³	4.0	4.1	4.0	3.95	3.90
Hardness (Mohs scale)	4.4	4.2	4.2	4.5	3.5
Endothermal effect, °C (peak center)	342	340	270, 300	272, 301	275, 305

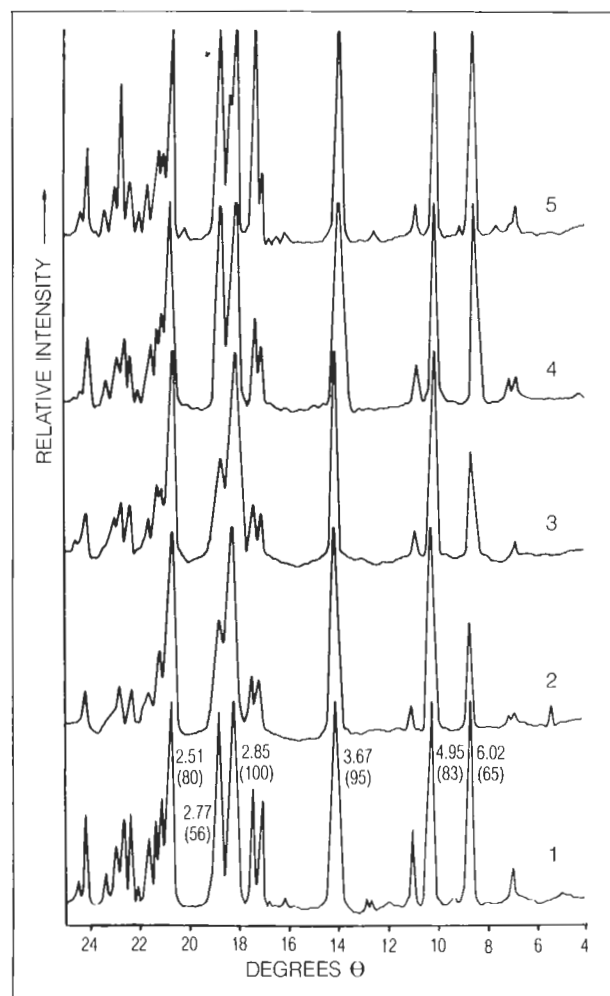
^aAt least five samples of each type were examined.

zakhstan, and Zaire (Grigorjev, 1953; Vertushkov, 1975). The chemical composition of the synthetic malachite produced by IEM and VNIISIMS proved almost identical to that of the natural malachite found at Kazakhstan (table 1), although some natural malachite has a high cobalt and nickel content (Deliens et al., 1973; Tarte and Deliens, 1974). Both the natural and the synthetic malachite examined contained minor amounts (hundredths and thousandths of a percent) of impurities such as zinc, iron, silica, sulfur, calcium, and phosphorus. These impurities had only a very slight effect on the refractive indices of the synthetic malachite, which average $\alpha = 1.909 \pm 0.002$, $\beta = 1.876 \pm 0.001$, $\gamma = 1.656 \pm 0.002$.

The synthetic malachite was found to vary in density (as determined hydrostatically) from 3.9 to 4.0 g/cm³, and in hardness from 3.5 to 4.5 on the Mohs scale. The hardness is a little lower along the crystal elongation than perpendicular to it.

X-ray diffraction analysis of all the types of synthetic malachite produced thus far (DRON-2 diffractometer, CoK α radiation, filter Fe) detected no differences from natural malachite (figure 6).

Figure 6. No significant differences were observed in the X-ray powder diffraction curves of natural and synthetic malachite. Natural samples: 1—Kazakhstan, 2—Zaire. Synthetic samples: 3—IEM, 4—LGU, 5—VNIISIMS.



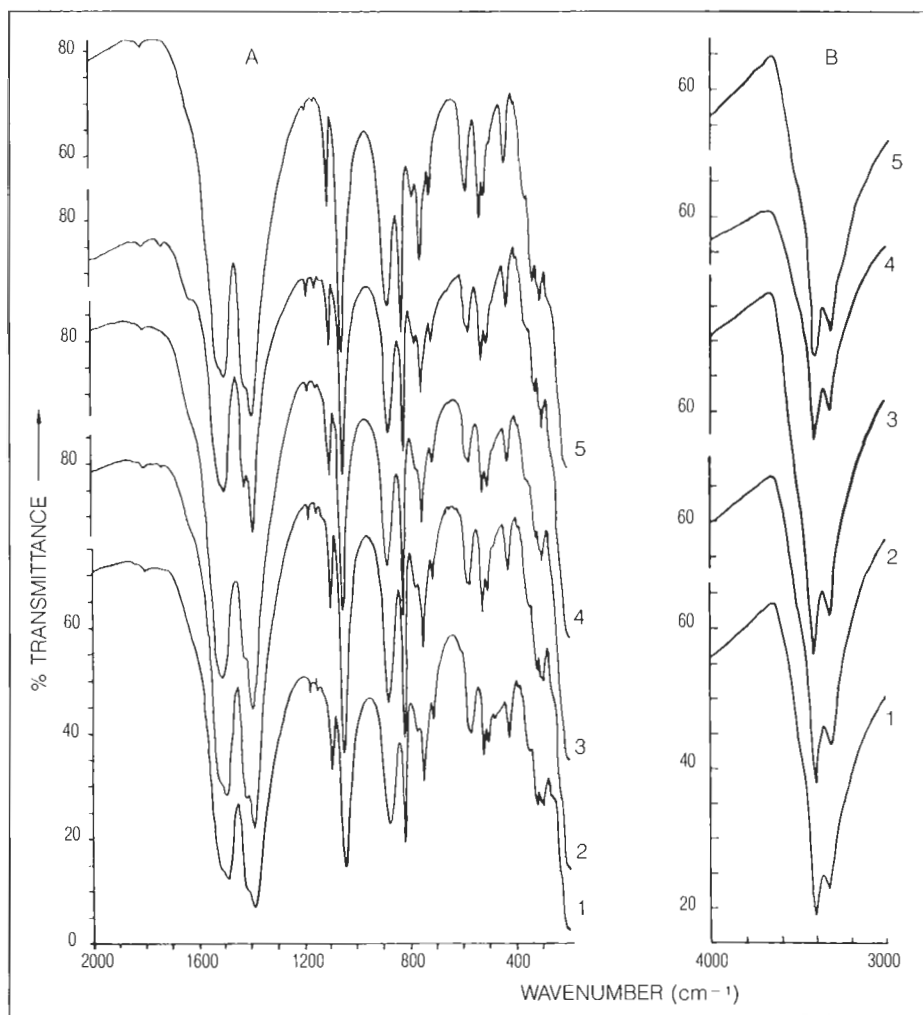


Figure 7. Examination of the infrared spectra of natural and synthetic malachite in the regions A=200–2000 cm^{-1} and B=3000–4000 cm^{-1} revealed no significant differences either. Natural samples: 1—Kazakhstan, 2—Zaire. Synthetic samples: 3—IEM, 4—LGU, 5—VNIISIMS.

As reported in 1983 by Timokhina et al., no differences in infrared spectra have been found for synthetic and natural malachite [either in the regions of stretching vibrations of Cu-O (400–600 cm^{-1}), C-O (1000–1100 and 1350–1550 cm^{-1}), and OH⁻ groups (3315–3410 cm^{-1}), or in the deformation vibration region O-C-O (700–900 cm^{-1})]. Figure 7 shows characteristic infrared spectra in the regions 200–2000 cm^{-1} and 3000–4000 cm^{-1} for different samples of natural and synthetic malachite.

Some difference between synthetic and natural malachite can be seen in the pattern of curves produced by differential thermal analysis and thermogravimetry (figure 8). Five samples of each were tested. As illustrated in figure 8, dehydration and decarbonation of natural malachite take place at one stage marked by a profound endothermal effect in the 310°–390°C range (the peak centers at 340°–345°C) and at a weight loss of 27.5–28 mass %. In the synthetic malachite (the banded

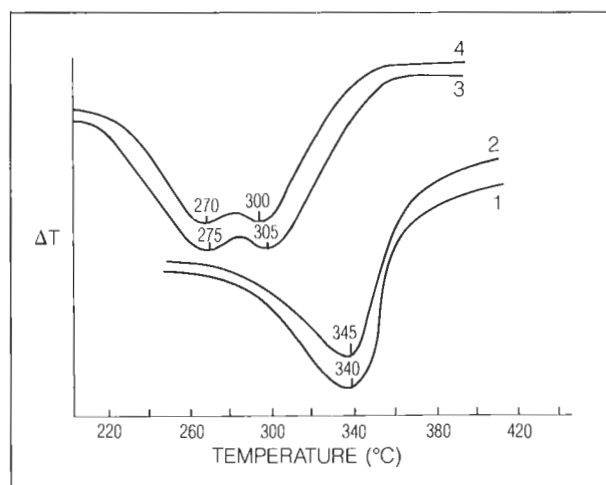


Figure 8. Only the thermograms revealed a clear distinction between the natural and synthetic malachite examined. Natural malachite from Kazakhstan (1) and the Urals (2); synthetic malachite with the banded (3) and bud-like (4) textures.



Figure 9. All of these polished samples of synthetic malachite show potential for use in jewelry, carving, or inlay. The cabochons range from 15 to 32 mm.

and bud-like varieties), the endothermal effect is displayed in a lower region, 230°–340°C, and the weight loss is 29–30 mass %. The thermograms of all the synthetic malachite tested always showed two weak minima (the first peak center is at 270°–275°C; the second is at 300°–305°C). The cause of these differences has not yet been determined. However, it does not appear that these differences have affected the mineral structure in any way.

CONCLUSION

The synthetic malachite currently being produced

in the USSR is virtually a complete analogue of natural jewelry-quality malachite with respect to physical appearance, chemistry, texture, structure, and principal physical properties (again, see table 2). Thus far, the only method that has proved effective in separating the natural from the synthetic material is differential thermal analysis. However, the fact that this test is destructive makes it impractical for gemological purposes. It appears, therefore, that there are unlimited possibilities for the man-made malachite to be used in stone cutting and for inlay, carvings, and cabochons in the jewelry trade (figure 9).

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