Morgan Burgess and Marci Jefcoat Burton
Conservation of Archaeological and Ethnographic Materials, University of California, Los Angeles

An American Icon in Plastic: The Technical Analysis, Study, & Treatment of a First Edition 1959 Barbie™

Advisor: Ellen Pearlstein

This study focuses on a privately owned, autographed, first edition (c. 1959) Barbie™ doll made from poly(vinyl chloride) (PVC) plastic. Contrary to the more frequently encountered condition that collectors might refer to as "sticky leg syndrome", where plasticizer migrates from the PVC and deposits on the surface as a tacky liquid, this doll exhibits what is often described as a bloom, efflorescence, or exudate of a fugitive, waxy white solid on the legs from the mid-thighs to the ankles (Figures 1). In addition, the doll was autographed by Ruth Handler, the designer of Barbie™ and a cofounder of the Mattel Corporation (Figure 2). Her signature and the date are now barely legible, as the once sharp lines of ink have migrated within the PVC plastic.

Figure 1: c.1959 Barbie, before treatment**.** a (left): front. b (right): back.

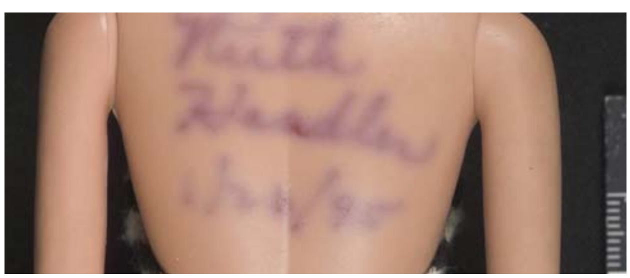

Figure 2: Back of Barbie, detail of faded signature from Ruth Handler, creator of Barbie. Signed as “ Ruth Handler, 1/25/95”.

In the summer of 2015, an uncharacteristically hot Los Angeles summer, the Barbie doll was stored in an environment lacking climate control, and subsequently exposed to periods of heat that reached over 90℉ over an extended period of time. It was after this exposure that the efflorescence was observed (Figure 3). Before considering removal of the efflorescence, it was important to determine whether the exuded compound was integral to the plastic composition or an additive to assist the manufacturing process. Once identified, the decision to remove the bloom could be rationalized. To understand the efflorescence exhibited on Barbie's legs, an investigation into the history of Barbie, her production, plastic formulation, and material composition was performed with collaboration with the Smithsonian's Museum Conservation Institute (MCI), the Smithsonian National Museum of Natural History and the x-radiography lab at the Getty Villa Antiquities Conservation.

Figure 3: Photomicrograph detail of the efflorescence on the proper right leg of the 1959 doll shows the needle-like structure of the exudate.

Multi-spectral imaging and x-radiography were performed on the doll to non-invasively and non-destructively examine the plastic and gain an understanding of the manufacturing procedures. In addition, computed tomography, X-ray fluorescence spectroscopy, Fourier transform Infrared spectroscopy, and Raman spectroscopy data were collected on the plastic components of the Barbie^{TM} doll. The results collected from the analysis provided insight into the process of manufacture, material composition and structural integrity of the doll, assisting in determination of the agents of degradation and identification of the waxy bloom compound.

The early edition Barbie was made using an injection rotational molding technique where the molten plastic mixture is added in predetermined quantities to a mold. X-radiography was performed on the c.1959 Barbie, and for comparison, two Barbies produced in the 1960s and one from the 1990s (Figure 4). The x-radiograph reveals manufacturing changes were made with the intention of producing a doll with less material, making them cheaper to produce and lighter-weight, as well as improving the injection mold process to reduce the occurrence of bubbles and defects in the formed plastic. The gradual decrease in bubbles within the plastic is evident with later dolls. Lubricants are added to a plastic melt for injection molding to aid the flow of the plastic through the mold, and to facilitate the release of the cured plastic. Lubricants are not intended to become integrated into the processed material.

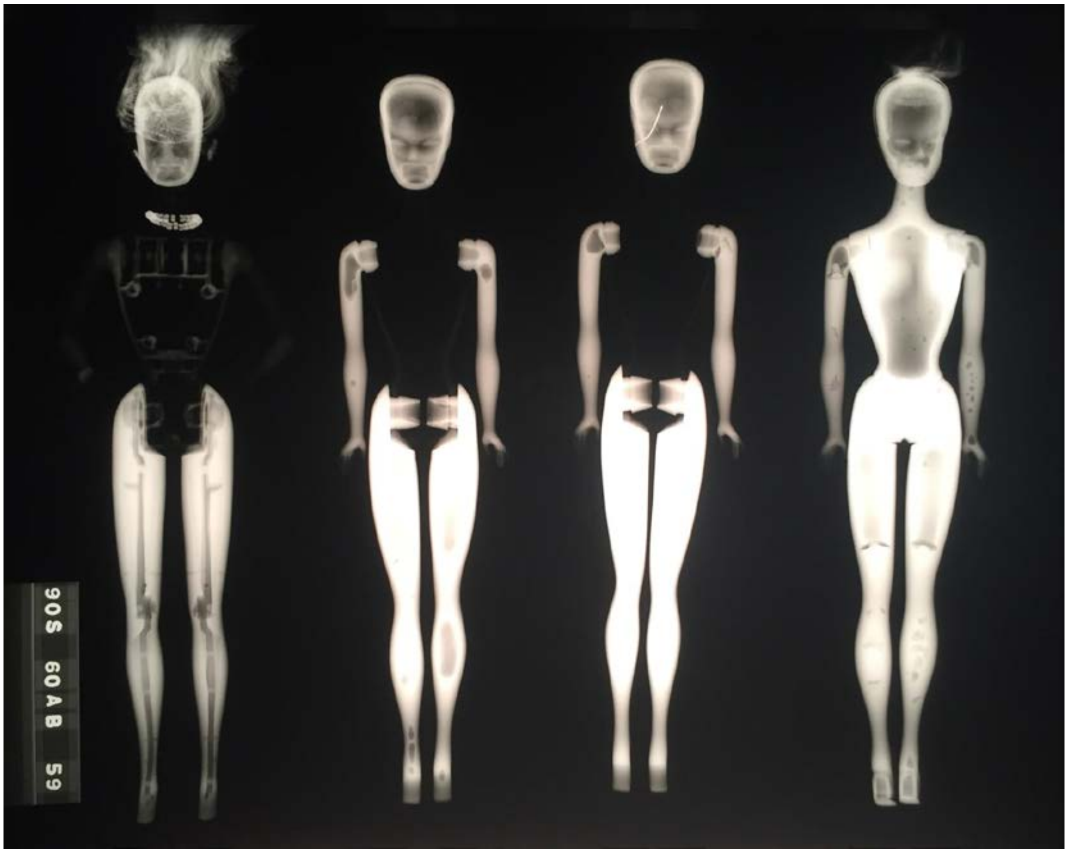

Figure 4: X-Radiography image of the c.1959 doll (far right). For comparative purposes, two dolls from the 1960s (middle), and one doll from the 1990s (far left) were also examined. X-rays collected at 35 kV, current of 6.85 µA for 120 seconds with a focal distance of 1 meter and a focal spot of 2.5 mm.

Computed Tomography (CT) was performed on the first edition 1959 Barbie with Dr. David Hunt at the Smithsonian National Museum of Natural History in Washington, DC. The CT-scan provided clear information on the flaws of the injection molding process, the joints between the limbs and torso, and the variations in plastic density and thickness throughout the doll (Figure 5). A vertical cross section through the doll reveals the densest locations of the body, the area from the mid-thigh to the feet. This solid interior correlates with the area associated with the bloom.

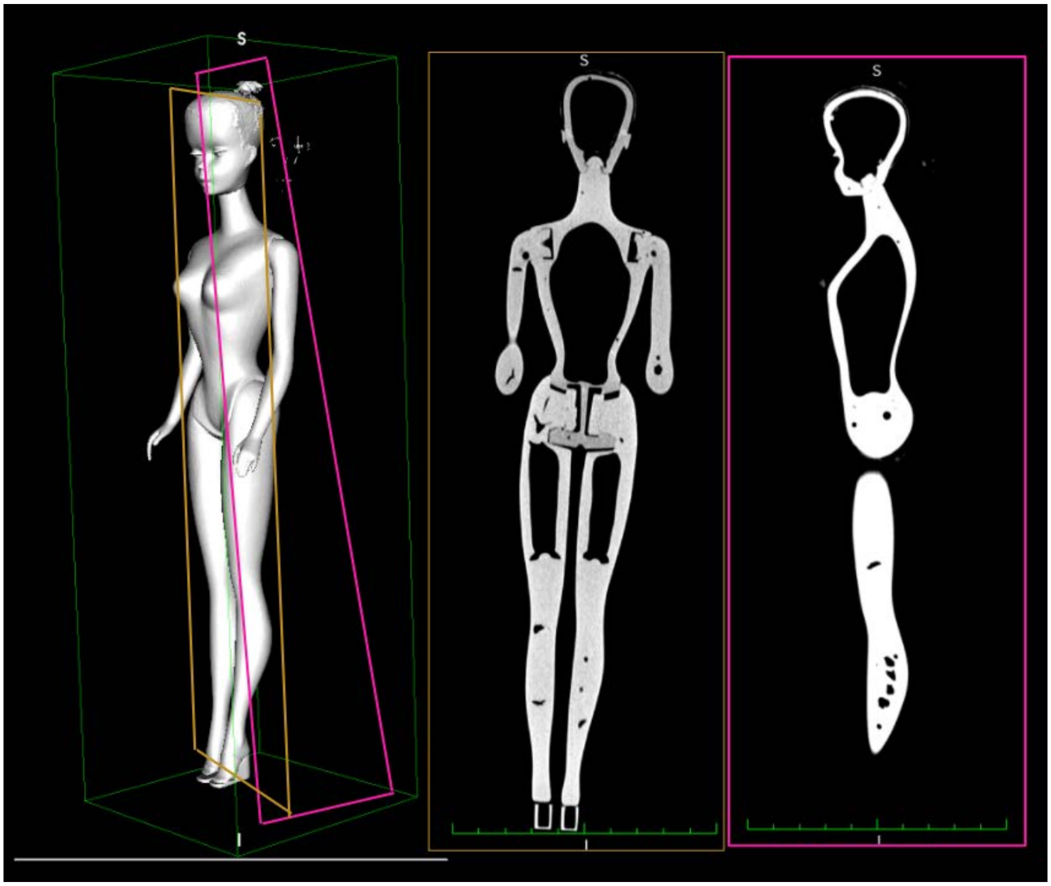

Figure 5: Computed Tomography was performed on the first edition doll. The left figure depicts where the cross-sections are being captured. The middle and right figures show hollow areas, bubbles created in production, and give clear information on how the doll is held together at the neck, arm, and leg joints.

Attenuated Total Reflectance Fourier Transform Infrared Spectroscopy (ATR- FTIR) was performed on Barbie's proper right foot and a sample of the white efflorescence collected from the doll's leg (Figure 6). The spectrum collected was compared with a spectral database and matched to polyvinyl chloride (PVC), diethyl hexyl phthalate (DEHP), and stearic acid (or similar). Through a thorough literature search it was found that diethyl hexyl phthalate (DEHP) is a common PVC plasticizer used worldwide since the 1950s. Since DEHP is used as a solvent in many paints and inks, Handler's now fuzzy signature on Barbie can be explained: the plasticizer likely solubilized the ink which then migrated through the open PVC polymer network.

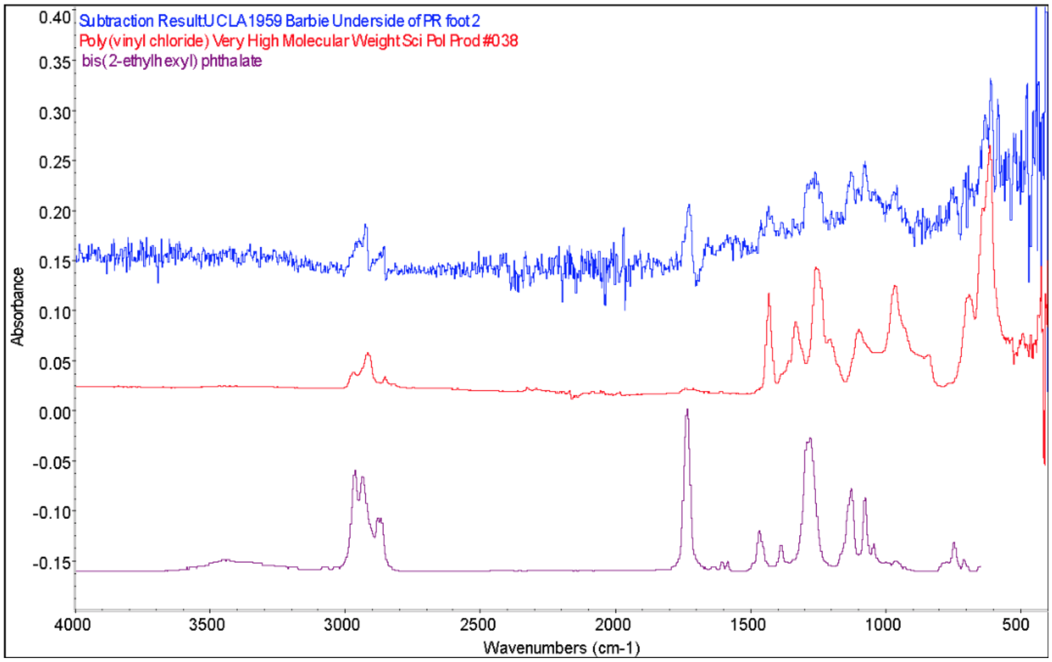

Figure 6: ATR-FTIR spectra of the c.1959 Barbie doll's proper right foot (blue spectrum) matched to poly(vinyl chloride) (PVC) base polymer (red spectrum) and bis(2-ethylhexyl) phthalate (DEHP) plasticizer (purple spectrum).

Dispersive Raman spectroscopy collected on the white efflorescence showed that the white bloom was an 80 percent match to sodium stearate, indicating it is likely stearic acid or a stearate derivative (Figure 7).

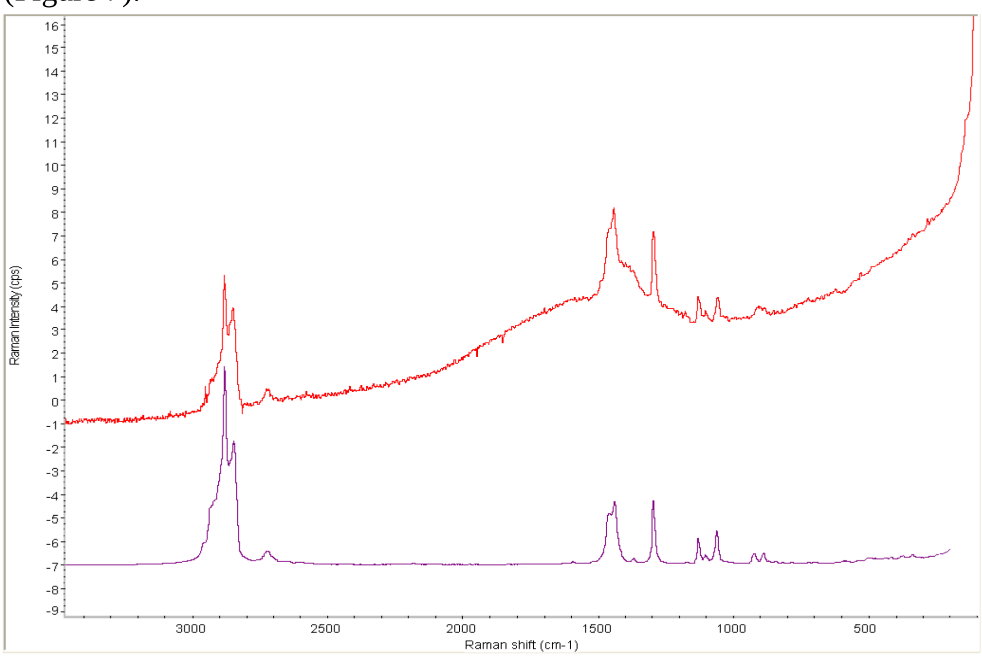

Figure 7: Dispersive Raman spectral overlay of the white efflorescence from the Barbie leg (red spectrum) matched 80% to the sodium stearate reference spectrum (purple spectrum).

Stearic acid and its derivatives have been used historically and are still widely used as lubricants in PVC plastics to reduce interactions between PVC molecules, lower the melt viscosity of the plastic and reduce adhesion of a plastic to metal surfaces such as extruders, molds and other processing equipment. Lubricants, such as stearic acid and stearate derivatives are selected for their low compatibility with PVC so a sufficient number of molecules migrate to the plastic surface to aid in removal from the mold.

The saturation concentration is the maximum amount of lubricant considered to be compatible with PVC. The use of internal lubricants with a lower concentration than the saturation point reduces the viscosity of the melt and ensures their permanence within the plastic. Concentrations higher than the saturation point lead to formation of lubricant pools between the voids in the polymer network. Increased temperature and/or time ensures the release of lubricants from these pools at the surface of the plastic. Various sources indicate that 1 percent or anywhere from 1 to 3 percent by weight of a lubricant may be added to plasticized PVC formulas. They are intended to exude from the melt during processing to facilitate flow and the release of the cured plastic object from the mold.

Unlike the plasticizer, which is imperative to the plastic mixture to increase flexibility and cohesion, the lubricant is not an integral part of the plastic formula, rather an additive used in manufacture. The removal of the bloom will not interfere with the PVC plastic integrity, but rather assist in the lubricant's initial purpose of migrating out of the doll. Similar blooms may continue to occur until there are negligible amounts of lubricant left.

The bloom was removed mechanically, with a process that minimized the risk of abrasion to the plastic surface (Figure 8). This was accomplished using a small, soft brush to gently lift and guide the waxy deposits away from the plastic. Locations where the bloom was more compact and stuck to the plastic surface were gently swabbed with dry cotton to agitate and lift the compound. Lastly, a clean piece of Vellux microfiber cloth was wiped over the legs to pick up residual efflorescence crystals on the plastic surface. Solvents were avoided for cleaning due to their risks of swelling, dissolving or extracting additives from plastic substrates.

Figure 8: Mechanical removal of the white efflorescence from the c. 1959 Barbie legs with a soft brush. The exudate was collected and stored in plastic vials for future study.

The stearate compound exuding from the plastic legs of the c. 1959 Barbie was successfully removed (Figure 9). This lubricant is exuding out of the plastic as a function of time and accelerated by increased temperature. As lubricants are modifiers added to the plastic for processing only, and do not affect the properties of the cured plastic, the removal of the bloom will not interfere with the PVC plastic integrity. This phenomenon could potentially occur on other parts of Barbie's body, such as her arms or may recur on her legs until the lubricant concentration has diminished.

Figure 9: a (left): c.1959 Barbie, before treatment, front. b (right): c.1959 Barbie, after treatment, front.

Acknowledgements

We'd like to especially thank Odile Madden for her collaboration on this project, Dr. David Hunt for his time and help with computed tomography, Jeffrey Maish for his assistance with x-radiography, and our advisor professor Ellen Pearlstein.