

# Raman Spectroscopic Study of Counterfeit Electronic Components

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*Abstract:* The paper deals with the potential of Raman spectroscopy as an analytical method for the authenticity assessment of electronic components. Electronic components are an integral part of the devices that people use in their daily activities. Incidence of counterfeit electronic components is an increasingly common phenomenon in our modern world that may compromise reliability, functionality and other related purposes of the devices. As the Raman spectroscopy provides detailed information on the material used, the focus of the Raman spectroscopic study of selected original components was given especially on materials of polymer-based and ceramic-based packages and markings. Knowledge of this information can help to distinguish between genuine and counterfeit component. The non-original component was revealed using other methods used in our workplace. Raman spectroscopy also confirmed the differences in materials of counterfeits compared to the original.

*Key-Words:* - Electronic, components, Raman spectroscopy, counterfeit, non-destructive, authenticity assessment.

## 1 Introduction

In today's world, people are surrounded by diverse electronic devices. Their integral parts are electronic components. In recent years, an increasing incidence of counterfeit electronic components has appeared [1] which may compromise reliability, functionality and other related purposes.

Counterfeit products can be found at different levels and in different product commodities. In the field of electronics, it is not only fakes of complex products of established companies, but also the number of counterfeits of electronic components themselves that are growing dramatically. These are both, passive components (e.g. capacitors, precision resistors) as well as active components (integrated circuits of various complexity, transistors, etc.) [2].

There are several factors influencing the penetration of counterfeit components into product sets. However, accessibility and price play an important role. Several types of counterfeit electronic components are on the market to a lesser extent empty cases without any functionality, and on the contrary sophisticated counterfeits that are hardly recognizable from the original [3]. The largest part, however, consists of the scrap-starter circuits, where they are picked from the discarded electronics and then cleaned or even overwritten. The vast majority of these devices come from uncontrolled waste dumps of electronics in various

locations in the world. Counterfeit electronic components are most prevalent in mainland China [4]. Types of counterfeit can be classified into several categories, such as recycled, remarked, defective, cloned, etc. [5]

The danger of counterfeit electronic component lies in the fact that they do not have to meet the technical requirements and reliability guaranteed by the original components. In the case of penetration of counterfeits of electronic components into critical industries such as aviation, aerospace or healthcare, the consequences of failure can be very costly or tragic. In another fields counterfeits negatively impact the innovation, economic growth, employment [6].

## 2 Problem Formulation

The main objectives of the study is to prove the ability to measure Raman spectra of materials used for packages and markings of electrical components and subsequently, based on the obtained spectroscopic data, verify the possibility for further authentication procedure.

## 3 Methods for counterfeit detection

The detection of counterfeit components is a multilateral issue because of wide range of defects,

anomalies and degradation in performance. Therefore, a number of methods can be used for counterfeit detection. The suitability depends on the kind of defect (exterior, interior, physical, electrical, etc.) [6]. The methods of testing the originality of electronic components can be divided into destructive and non-destructive. Destructive methods require special equipment, for example, to open the component case, to see if the component's peripheral system originates and looks in accordance with the designation of the component case. Non-destructive methods may include expensive analytical devices such as special X-rays, ultrasound microscopes, and more. For most of these methods, a reference sample of the original component is necessary to detect differences [4, 5, 7].

The methods used for this purpose, with which we have experience in our department are especially [3, 7]

### 3.1 Analogue Signature Analysis curve tracing

Analogue Signature Analysis curve tracing uses Counterfeit IC detector. This method uses multichannel counterfeit detectors with several measuring modes and voltage patterns applied sequentially to selected pairs of component outlets. The specific voltamper characteristics of the exemplary component are stored in the instrument memory and the real characteristics of the analyzed components then compared with the stored pattern.

### 3.2 X-ray diagnostics

The X-ray device is mainly focused on the internal non-destructive analysis of electronic components encapsulated in non-hermetic plastic cases to study the geometry of the chip with respect to the axis of the case. This method also significantly complements to fiber laser to allow more accurate focus on the position of the chip in the case prior to laser ablation.

### 3.3 Fiber laser ablation

Fiber laser material of package ablation. This method uses fiber laser on the principle of optical fiber enriched with ytterbium atoms. The laser operates in IR region at wavelength 1060 nm with a maximum output power of 10 W. Laser enables to remove parts of the case material according to diagnostic intention.

### 3.4 Final wet etching

Final wet etching. Method of chemical removal of the relevant part of the plastic case by etching acids. This process is usually carried out in automatic devices with a controlled mixing ratio of the suitable acids and dosing [8].

### 3.5 Raman spectroscopy

Raman spectroscopy is an effective vibrational spectroscopic method with a potential to answer a number of questions related to chemical details on molecular level. This fundamental fact makes this technique suitable for material identification [9]. Method is based on inelastic scattering of incident monochromatic light on the matter. Raman spectroscopy seems to be very promising analytical tool in recent years in number of scientific areas such as chemistry, material science, nanoscience, arts; it is also used for forensic and security purposes [10] and other.

Raman spectroscopy brings many benefits as the method is non-destructive, contactless, highly sensitive, relatively rapid, usable for measuring through transparent glass or polymeric covering layers, applicable to all states of matter and different forms, without special requirements for sample preparation, usable as in situ analysis.

However, inconvenience in measurement can occur when luminescence emerges. Luminescence as a stronger quantum phenomenon can partially mask or even overlap the less intense Raman signal.

Raman spectroscopy has a great potential in non-destructive material analysis. This experience we already have with other type of surveyed materials [11-13]. Therefore its application on electronic components is being studied to extend the range of methods for deviation detection from original electronic components.

## 4 Experimental part

The experimental part was realized firstly on selected samples of electrical component using Raman microscope to obtain characteristic Raman spectra of used materials. Secondly of a pair of genuine and non-original component. Samples, instrumentation and measurement procedure is described in this section.

### 4.1 Samples

Ten different samples of electrical components (see Fig. 8), were chosen for the preliminary study of spectroscopic vibrational response of used material. The specifications of the components are listed in Table 1. There are three solo components (no. 1, 2, 3) among the samples and two groups of

three (no. 4, 5, 6) and two (no. 7, 8) samples of the same kind and same producer. Two more samples are used for comparison of original component and its counterfeit.

Table 1. Assignment of analyzed electronic components

No.	Assignment	Type
1	B110D-Semicon	Integrated bipolar comparators with a differential input and a low impedance output compatible with all logic forms for universal application
2	F9601DC	Retriggerable One Shot CDIP14
3	AM27C128	Ultraviolet erasable programmable read-only memory.
4	ATMEL AT89C55 WD (7) Batch:0309	Low-power, high-performance CMOS 8-bit microcontroller with 20K bytes of Flash proramable read only memory and 256 bytes of RAM.
5	ATMEL AT89C55 WD (8) Batch:0309	Low-power, high-performance CMOS 8-bit microcontroller with 20K bytes of Flash programmable read only memory and 256 bytes of RAM.
6	ATMEL AT89C55 WD (9) Batch:0248	Low-power, high-performance CMOS 8-bit microcontroller with 20K bytes of Flash programmable read only memory and 256 bytes of RAM.
7	TESLA MDAC565	Integrated circuit: monolithic digital-to-analog converters with current output
8	TESLA MHB1504	Approximation register

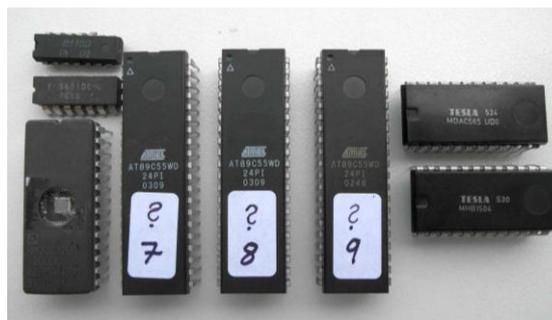


Fig. 1. Samples of electrical components.

## 4.2 Instrumentation

InVia Basis Raman microscope by Renishaw was performed for measuring all samples. The source of radiation was NIR diode laser with excitation wavelength 785 nm with maximum output power 300 mW. A Leica DM 2500 confocal microscope with the resolution 2 $\mu$ m was coupled to the Raman spectrometer. The used total magnifications were 200x and 500x.

## 4.3 Measurements

To reach the best quality spectra, various combinations of measurement parameters were tested. Finally, the spectra were collected with exposure time from 1 to 10 seconds, with 20 or 100 accumulations and with laser power from 1.5 mW to 300 mW, according to kind of a sample. Raman spectra were acquired in two specific domains: (100 – 1300)  $\text{cm}^{-1}$  and (800 – 1900)  $\text{cm}^{-1}$ . All spectra were measured in the dark environment to avoid any interference.

## 5 Results and discussion

For the material identification based on Raman spectra, the layout of the bands according to x-axis (Raman shift) is crucial. This layout is connected to specific vibration of chemical bonding in the structure of material, caused by the incident laser radiation. The intensity of single bands inform about quantity of vibrating bonds of the same chemical composition, i.e. how much of the specific bonding (C-C, C-H, etc.) is in the material.

Each chemical compound or its modification has a unique Raman spectrum. This feature brings the benefit of recognition different materials. If the counterfeit package is fabricated from different material compared to original, it is recognizable from Raman spectra. The materials of the samples are usually known only partly from the datasheet, if this information is available at all.

## 5.1 Packages

The colours of all the packages are dark grey to black, what is rather a disadvantage for Raman spectroscopic measurement due to high absorption of radiation by a sample. Hence, spectra with higher noise are obtained. However, some of specific bands are recognizable in Raman spectra. Materials of packages are polymer-based (no. 1, 4-8) and ceramic-based (no. 2, 3). The difference in material response of polymer package of sample 1 and ceramic package of sample 2 is demonstrated in Fig. 2.

The measurement repeatability was successfully tested on all samples. Raman spectra of samples no. 4, 5, 6 from the same producer ATMEL are displayed in Fig. 3. Spectra from all three samples show compliance.

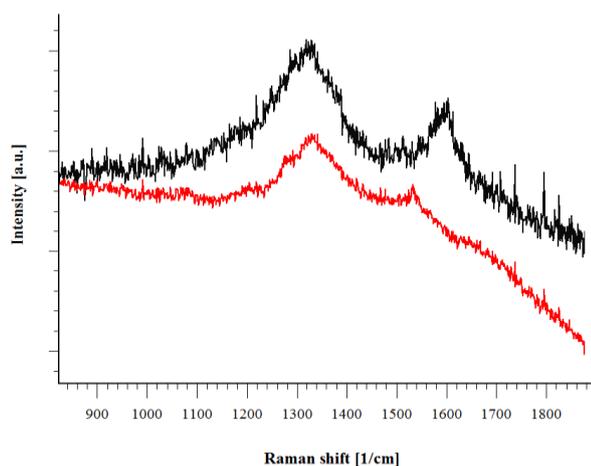


Fig. 2. Samples of electrical components, sample no. 1 (upper), sample 2 (lower).

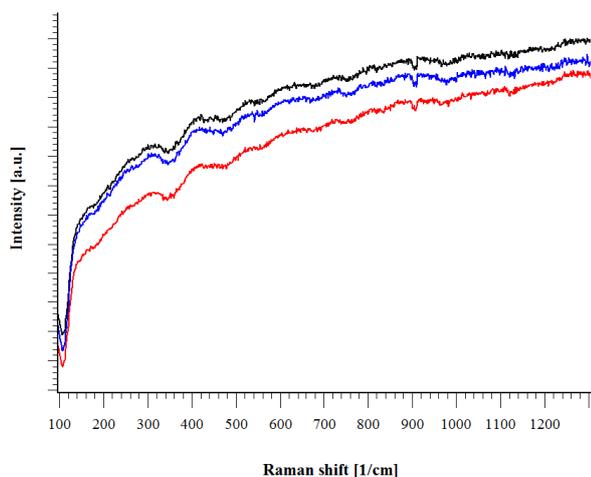


Fig. 3. Raman spectra of packages of samples no. 4, 5, 6. (from the top).

## 5.2 Markings

There are two main types of markings on the packages of the surveyed samples. Either, the markings are burned by laser or the die is applied on the surface of the case. Laser markings usually show higher noise and worse signal in comparison to Raman spectrum of the package material as can be seen from spectra of sample no. 7 presented in Fig. 4.

An optical microscopy with high magnification serves for the visual survey of the irregularities on the surface. A detail of the paint marking on the sample no. 7 is depicted in Fig. 5. Using the database of Raman spectra, the results show a significant content of TiO<sub>2</sub>, as shown in Fig. 6.

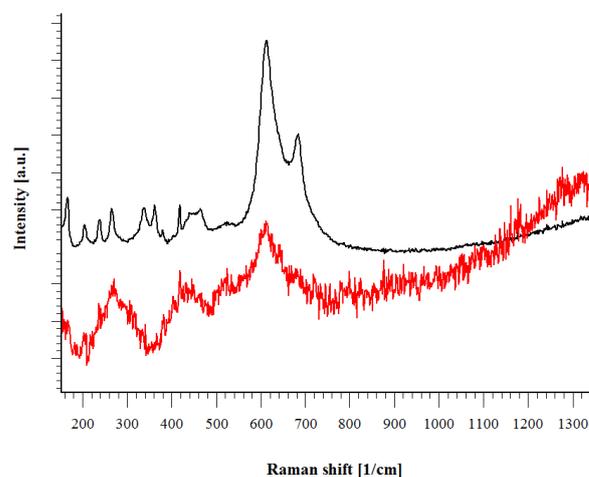


Fig. 4. Raman spectra: of package material (upper), focused on burned markings (lower), sample no. 2.

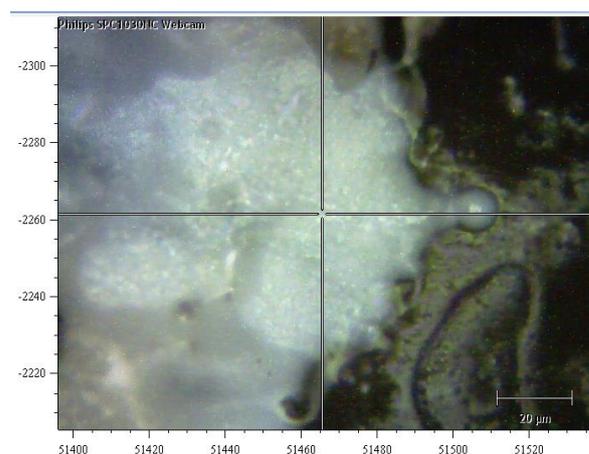


Fig. 5. Microscopic detail of the paint markings, sample no. 7.

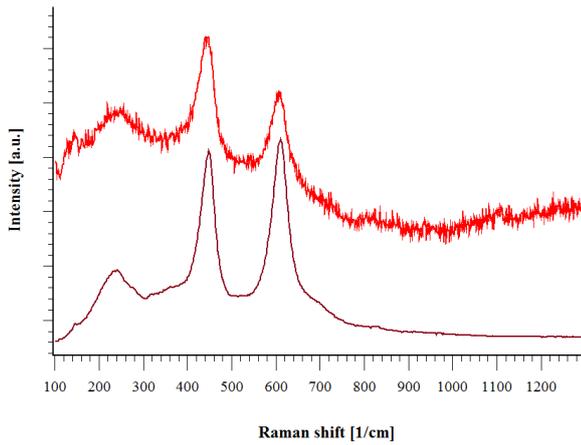


Fig. 6. Comparison of measured Raman spectra of marking material, samples no. 7 (upper) and pure rutile (TiO<sub>2</sub>) from the spectral database (lower).

### 5.3 Chips

The optical microscope coupled to Raman spectrometer enables a size of the target area up to the order of micrometers. The detail of chip of sample no.3 is in Fig. 7. Raman spectra confirm the content of pure silicon on chips (Fig. 8) - which is essential for their functionality.

### 5.4 Comparison of original and counterfeit component

The component type processor in a package SOIC with 28-pin was recorded as malfunctioning after assembly into the module. Therefore, the processor was tested on the SentryCounterfeit IC Detector, which detected a malfunction on one of the pins, pin no.9. The component was subjected to additional analysis using CT micro-focal X-ray. The internal structure of the component was revealed. The Fig. 9.

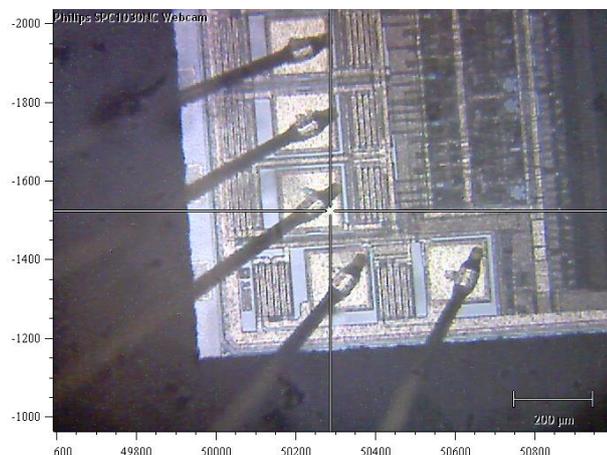


Fig. 7. Microscopic detail of the chip, sample no.3.

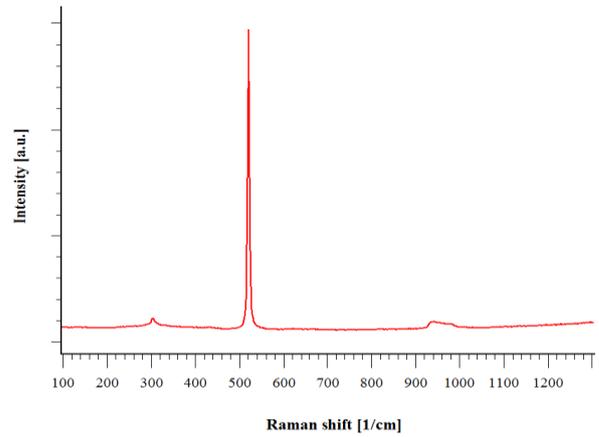


Fig. 8. Raman spectrum of the chip material.

shows the structure of the interconnection system and the chip of the non-original components, which differs significantly from the original component in the area of the contact field and connections of the chip to the pins. These tests have confirmed that the electronic component is not an original piece.

Raman spectroscopic measurements also indicated apparent differences in the spectra of both, material of packages and markings. Raman spectra are displayed in Fig. 10, the details of the spectral response can be seen in Fig. 11. TiO<sub>2</sub> markings are obvious for the original, not for counterfeit, as depicted in Fig 12.

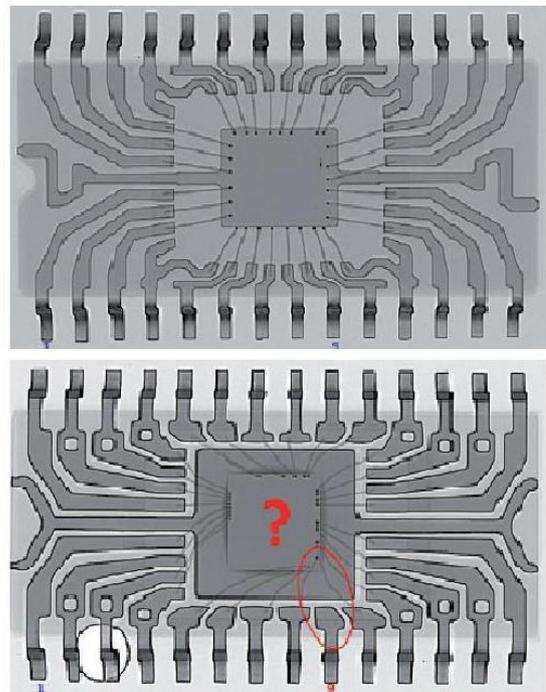


Fig. 9. X-rays of original (top) and non-original (bottom) components.

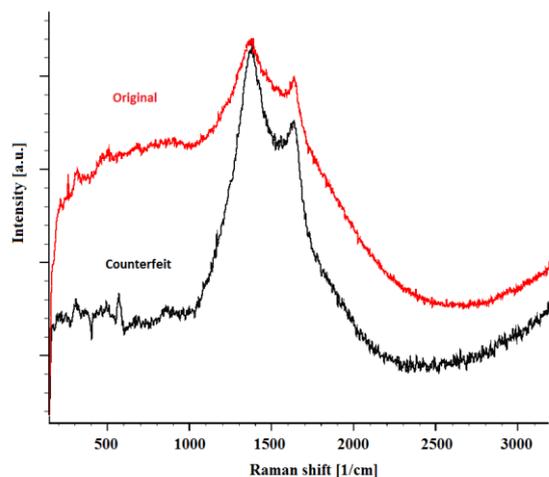


Fig. 10. Comparison of Raman spectra of packages of original and counterfeit component.

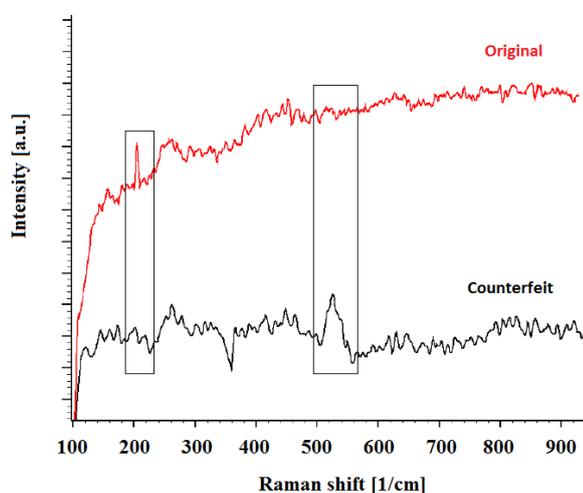


Fig. 11. Detail of Raman spectral range  $100\text{ cm}^{-1}$  -  $900\text{ cm}^{-1}$  of packages of original and counterfeit component

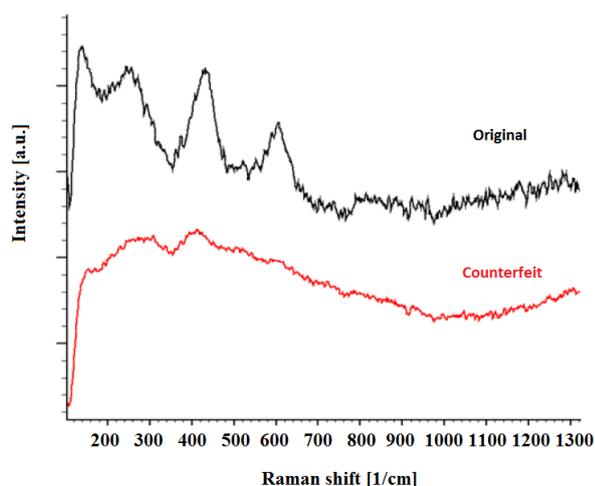


Fig. 12. Comparison of Raman spectra of markings of original and counterfeit component.

## 5.5 Further steps

There are two main aims for the further work. Firstly, measurement of larger number of components from reliable suppliers and verified by other methods. Secondly, to create a database based on the obtained spectral data for comparing with the questioned components. A thorough analysis and comparison of materials and their spectra acquired from different components is also expected.

## 6 Acknowledgement

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## 7 Conclusion

Currently, counterfeit electronic components can be revealed according to a number of characteristics – external, internal, functional, electrical, visual, etc. Raman spectroscopy was used as an innovative method for this purpose. The carried out study showed the potential of Raman spectroscopy for assessment of materials used on the electronic components. The main interest was focused on material of packages and the paint used for markings. Even if the Raman scattering from the packages is in many cases rather weak, Raman spectral data offer valuable information about the materials. The diversity of Raman spectra for genuine and counterfeit component was demonstrated. A prerequisite for a common use of Raman spectroscopy is creation of the spectral database of guaranteed electronic components. Raman spectroscopy has the potential to extend the range of non-destructive, fast and reliable methods for counterfeit electronic component detection.

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