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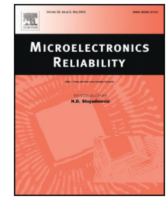


# Effect of roughness on electrical contact performance of electronic components

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This study investigated the effects of electrical contact resistance (ECR) on pogo pins used in mobile phones, chargers, digital cameras, Bluetooth headsets, medical equipment, and other electronic products with different surface roughness. Experimental results revealed that metallic wear debris is generated by fretting motion and formation of a third body on rough surfaces without removal by fretting motion, thus increasing ECR. Wear debris does not easily form the third body at contact areas of smooth surfaces and causes formation of metal–metal contact pattern. Results showed low ECR with fretting motion. 3D and 2D profiles of contact area verified the definition of contacting high spots, further explaining increases in ECR.



## 1. Introduction

Pogo pins are typically used as connectors in mobile phones, chargers, digital cameras, Bluetooth headsets, automotive parts, medical equipment, and other electronic products (Fig. 1) [1]. Maintenance of stable low-value electrical contact resistance (ECR) in electrical connectors and other contact-containing components is essential to protect circuits that contribute to degradation to facilitate correct selection of contact materials and component designs [2]. Unstable ECR values may lead to electrical degradation or temperature increment at contact areas and eventually result in circuit breaker or battery explosion [3]. ECR between pogo pins/plane contacts strongly depends on surface integrity of contact areas. For connectors subject to vibration, fretting is considered a primary degradation mechanism; it is a relative cyclic motion with small amplitude occurring between two oscillating surfaces. In another study, fretting was found to cause intermittent electrical contact, wear, and corrosion on contact materials and caused variations in results of ECR [4,5].

Although pogo pins feature low cost and convenience in manufacturing, they raise a major concern due to their high interfacial contact resistance (CR) caused by mechanical polishing of their surfaces. CR is generally governed by electrical properties of interface layer between contacting surfaces [6]. As a result of surface roughness at microscopic scale, current flows only through these asperities, which occupy a small fraction of areas of nominal contacting surfaces in theory. $Ra \leq 1$ μm is a processing requirement for surface roughness of commonly used electrical contact connectors [7,8]. ECR depends on materials, diffusion media, compression pressure, surface roughness of contacting materials, and other conditions used during measurements [9,10]. Clearly, studies should research and develop low-cost and reliable solutions for reducing ECR and improving performance of electrical connectors. Further studies must also determine the effects of ECR of pogo pins/plane contact burring by roughness.

Fig. 1 presents the common working state of pogo pins. Pre-tightening force usually exists between pogo pins/contactors. Contactors utilize copper as material. For this study, red copper was the preferred material for contact manufacturer owing to its unique combination of conductivity, strength, stiffness, formability, and low cost [11]. Red copper contacts are usually plated with noble metals to improve their electrical contact performance [12,13].

Pogo pin connectors are the most critical links of electronic and power systems and are needed to provide paths for electronic signals and/or power connections. ECR between pogo pins and copper plates in electronic components is governed by multi-scale surface topography of contacting pairs [14]. The roughness featured at contacting surfaces decreases actual contact areas, leading to a voltage drop across interface [15]. Assembling relationship between electrical components applies pressure at interfaces, leading to increases in contact areas between electrical components and subsequent decreases in ECR [9]. However, excessively large pre-tightening forces may cause difficulty in assembly and deformation of pogo pins [16,17]. Thus, an optimum clamping pressure exists and trades off between competing requirements.

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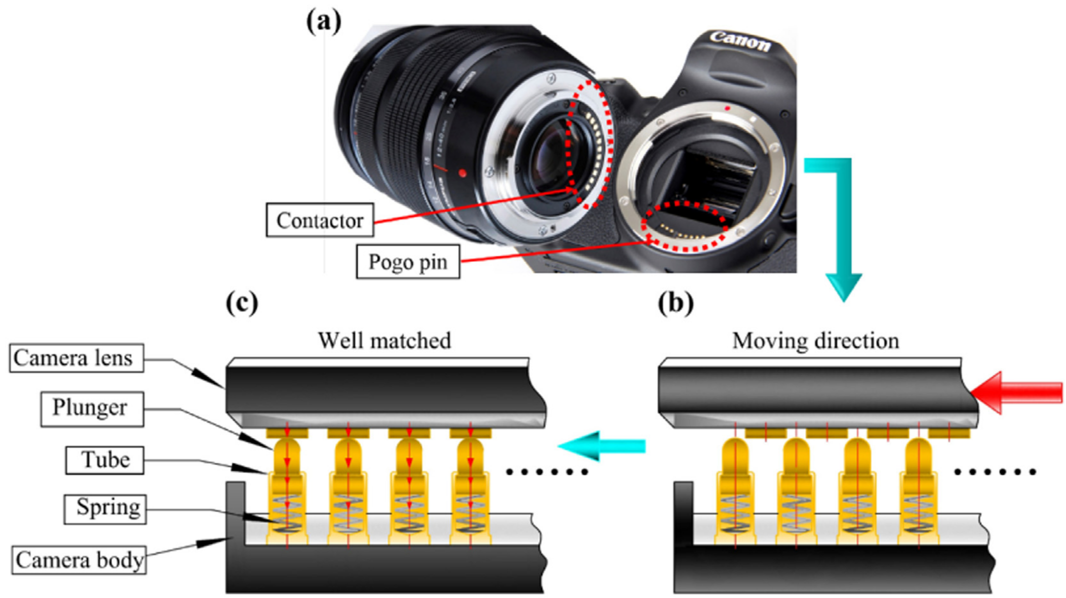


**Fig. 1.** (a) Camera connector, (b) direction of movement of contactor, (c) matched contactor.

## 2. Experimental

### 2.1. Experimental details

As shown in Fig. 2(a), ECR fretting test system was constructed for pogo pins and plane contacts. Fig. 2(b–c) shows the schematic diagram for a measuring apparatus for ECR distribution; the four-terminal method is one of the most commonly used methods in determining contribution of resistance present at interfaces between two conductors [6]. Table 1 provides the conditions for measurement of ECR.

Fretting experiments were carried out using the ECR fretting test system manufactured by Tribology Research Institute, Southwest Jiaotong University. The detailed structure of the test is as follows; displacement was measured by a laser sensor (Figs. 2(a)-7). The sensor (Fig. 2(a)-3) under the lower sample was used to measure friction forces and normal loads and to transmit data to collection cards manufactured by NI Company.

The upper sample comprised pogo pins (C3604: Cu, 57.0%–61.0%; Fe ≤ 0.5%; Pb, 1.8%–3.7%; Sn: Fe + Sn ≤ 1.2, and balanced total impurities). Pogo pins employed standard parts to obtain same initial roughness. Red copper was used as plane sample material (C11000: Cu, 99.9%; P, 0.0116%; Fe, 0.016%; Pb, 0.0019%; S,0.0047%; Zn,0.0216%; Sn, 0.0034%, and balanced total impurities). Pogo pins and plane sample contacts were degreased with alcohol and coal oil using an ultrasonic cleaner, dried, and carefully mated in fretting test assembly to create a point contact in pogo pin/plane geometry (Fig. 2(c)).

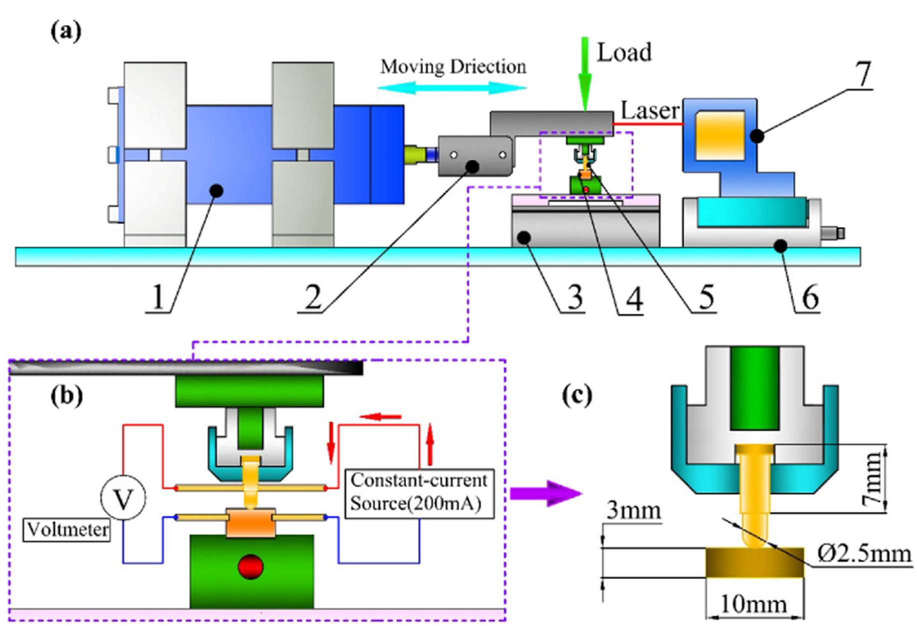


**Fig. 2.** (a) Electrical contact resistance (ECR) fretting test system (1. Piezoelectric ceramic actuator. 2. Upper fixture 3. Force transducer. 4. Flat sample. 5. Ball sample. 6. Precision lead screw 7. Displacement sensor). (b) Operating principle of fretting equipment and resistance measurement mechanism. (c) Size of upper and lower samples.