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FRACTOGRAPHY OF FAILED AUTOMOBILE ABSORBER SPRINGS

[1]Peter Odesanmi Ojo, and [2]Olanrewaju Retime Bodede
[1,2]Department of Mechanical Engineering Technology
Rufus Giwa Polytechnic,
Owo. Ondo State.

ABSTRACT: *The materials used for this research work included failed samples of helical compression coil spring used for absorber of four wheeled vehicles (FWV). Ten failed samples were cut into sizes (70mm) using a cutting disc, thereafter they were prepared for microscopy by grinding them with abrasive wheel and they were mounted on the Scanning Electron Microscope (SEM) with EDS which also determined the chemical composition. Both metallographic examination and hardness testing were performed on the test samples, the results showed that due to the damage of the protective layer on the surface of the spring, the combination of corrosion and fatigue led to the fracture of the absorber spring.*

KEYWORDS: Fractography, failure analysis, failed samples, absorber springs

INTRODUCTION

Fractography is the study of fractured surfaces of materials, it is routinely used to determine the cause of failure in engineering structures which is often referred to as failure analysis; as such, it is critical to failure analysis of metals and plastics (Parrington, 2002).In materials science research, fractography is used to develop and evaluate theoretical models of crack growth behaviour (Wikipedia, 2009).Failure of automobile absorber springs could lead to fatal accidents especially when on high speed. The absorber springs are susceptible to metal fatigue, a phenomenon which results in the sudden fracture of a component after a period of cyclic loading in the elastic regime (The Open University, 2009). Metal fatigue cracks initiate and propagate in regions of stress concentration, this process consists of three stages:

i. Crack initiation
ii. Progressive crack growth and
iii. Final sudden fracture (Callister, 2000)

LITERATURE REVIEW

There are different types of springs with respect to their functions (Burr, 1981), however only compression springs as shown in figure 1 used in automobile shock absorbers are of importance in this research work. These springs are traditionally subjected to a combination of bending, torsion and fatigue which often cause failure of catastrophic consequences. There is no empirical work to determine the root cause of failure in springs; this is the vacuum this study intends to fill.

Plate 1: Sample of Failed absorber Spring

Das et al (2007) investigated the premature failure of suspension coil spring of a passenger car, which failed within few months after being put into use, it was discovered that inherent material defect in association with deficient processing led to the failure of the spring. Brian Ralston (2010) deduced that the factors influencing performance and failure of products generally among others are design, material, processing and environment as shown in figure 1.

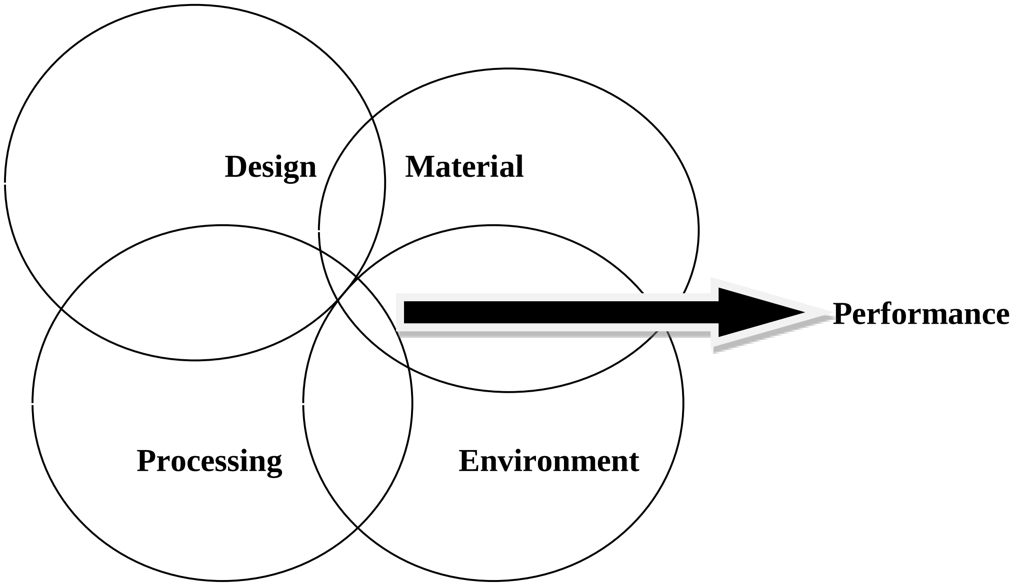

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Figure 1: Factors influencing Failure of Products

Design

To determine the stress generated in the absorber spring, consider a helical spring subjected to an axial load F.

Let: D = Mean Diameter of the spring coil,
d = Diameter of the spring wire,
n = Number of active coils,
G = Modulus of rigidity for the spring material,
F = Axial load on the spring,
τ = Maximum shear stress induced in the wire,
C = spring index = D/d
P = Pitch of the coils, and
δ= Deflection of the spring, as a result of an axial load F.

If we remove a portion of the spring, the internal reactions will be a direct shear and a torque T = F×D/2 where each will cause a shear stress, and the maximum shear will occur at the inner surface of the wire which is equal to,

τ max = T r/J + F/A

Substituting T= F× D/2, r= d/2, J = π/32 d4, A= π /4 d2 gives

$\tau = \frac{8FD}{\pi d3} + \frac{4F}{\pi d2}$

Defining the spring index which is a measure of coil curvature as, C = spring index = D/d, for most springs C ranges from 6 to 12

We get,

$\tau = \frac{2C+1}{2C}\ (\frac{8FD}{\pi d3}) = K_s\ (\frac{8FD}{\pi d3})$

Where K_s is called the "Shear stress correction factor" This equation assumes the spring wire to be straight and subjected to torsion and direct shear. However, the wire is curved and the curvature increases the shear stress and this is accounted for by another correction factor K_c and thus the equation becomes,

τ = Kc Ks 8FD/πd3

Where Kc is the "curvature correction factor" Or easier the two correction factors are combined together as a single correction factor K_B where:

$K_B = Kc \times Ks = \frac{4C+2}{4C-3}$

Thus,

$\tau = K_B \times 8FD/\pi d^3$

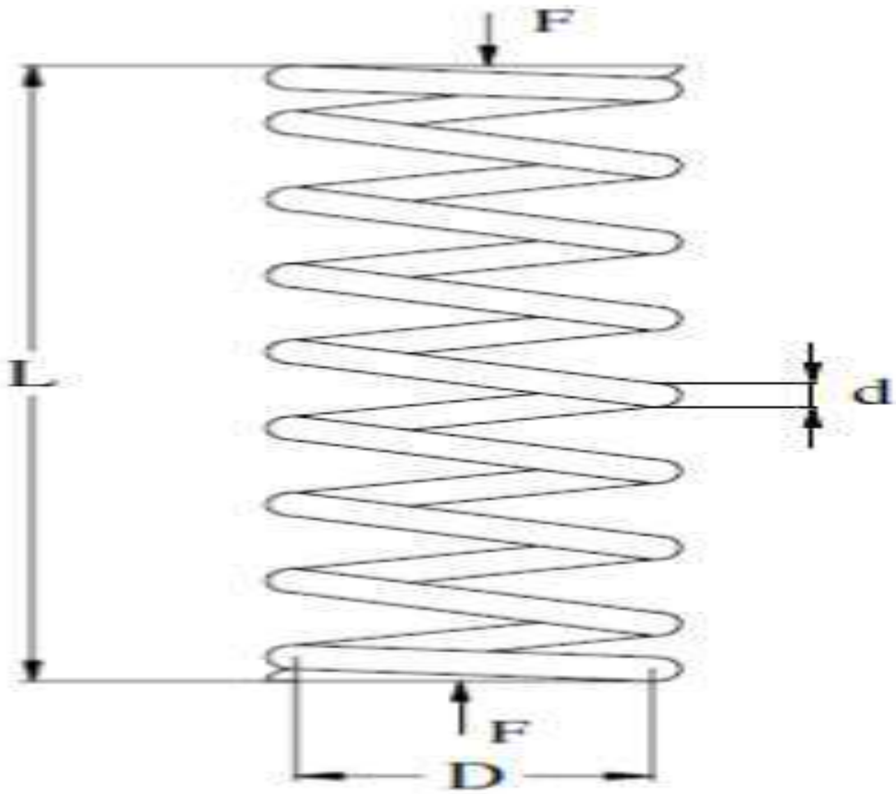

Figure 2: Schematic Diagram of Absorber Spring

Research Methodology

Materials and Equipment

Materials

Materials used for the project are failed samples of helical spring of four wheeled vehicle.

Equipment

Equipment used include cutting disc, scanning electron microscope
With energy dispersive X-ray spectrometer (Phenom Pro X SEM) with
Model Number: 800-07334 as well as optical microscope.

Experimental Procedure

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Plate 2: Samples of Prepared Absorber Springs

Samples of failed absorber springs namely F1, G1, H1, I1, J1; F2, G2, H2, I2, J2; F3, G3, H3, I3, J3 and F4, G4, H4, I4, J4 were cut into pieces with a cutting disc and prepared as follows (see plate 2)

F1, G1, H1, I1 and J1 were kept to be used as control samples, F2, G2, H2, I2 and J2 were prepared for hardness testing and microstructural analysis using the Brinell hardness tester and optical microscope respectively, F3, G3, H3, I3, J3 were prepared for fatigue testing which was not available while F4, G4, H4, I4, J4 were prepared for Scanning Electron Microscopy with EDS.

RESULTS AND DISCUSSION

The elemental composition of the steel making up the spring as determined by the SEM with EDS is presented in Table 1, the result of the hardness testing is presented in Table 2 while the electron microscopy results are presented in Plates 3 – 10. Plates 11 – 20 show the micrographs of the samples after. It was observed that the protective layers on the surfaces of the failed springs were damaged the combination of corrosion and fatigue led to the fracture of the samples. From the fractured surface, crack gradually propagated due to the combination of corrosion attack and cyclic loading during motion.

Table 1: Chemical Composition of the Spring Steel

Element	C	Si	Mn	P	S	Cr	Ni	Mo	Al	N
wt. %	0.56	1.39	0.66	0.007	0.006	0.62	0.02	0.01	0.005	0.0056

Table 2: Result of Brinell Hardness Test

MATERIAL SAMPLE	MAXIMUM FORCE/PEAK LOAD (N)	BALL INDENTAL DIAMETER (mm)	INDENTATION DIAMETER (mm)	TEST TIME (Sec.)	BRINELL HARDNESS VALUE (HB)
F2	6444.00	10.00	1.83	15.00	242.62
G2	6381.60	10.00	2.00	15.00	201.05
H2	6262.20	10.00	2.40	15.00	136.32
I2	6485.40	10.00	2.33	15.00	148.44
J2	6417.60	10.00	2.50	15.00	128.43

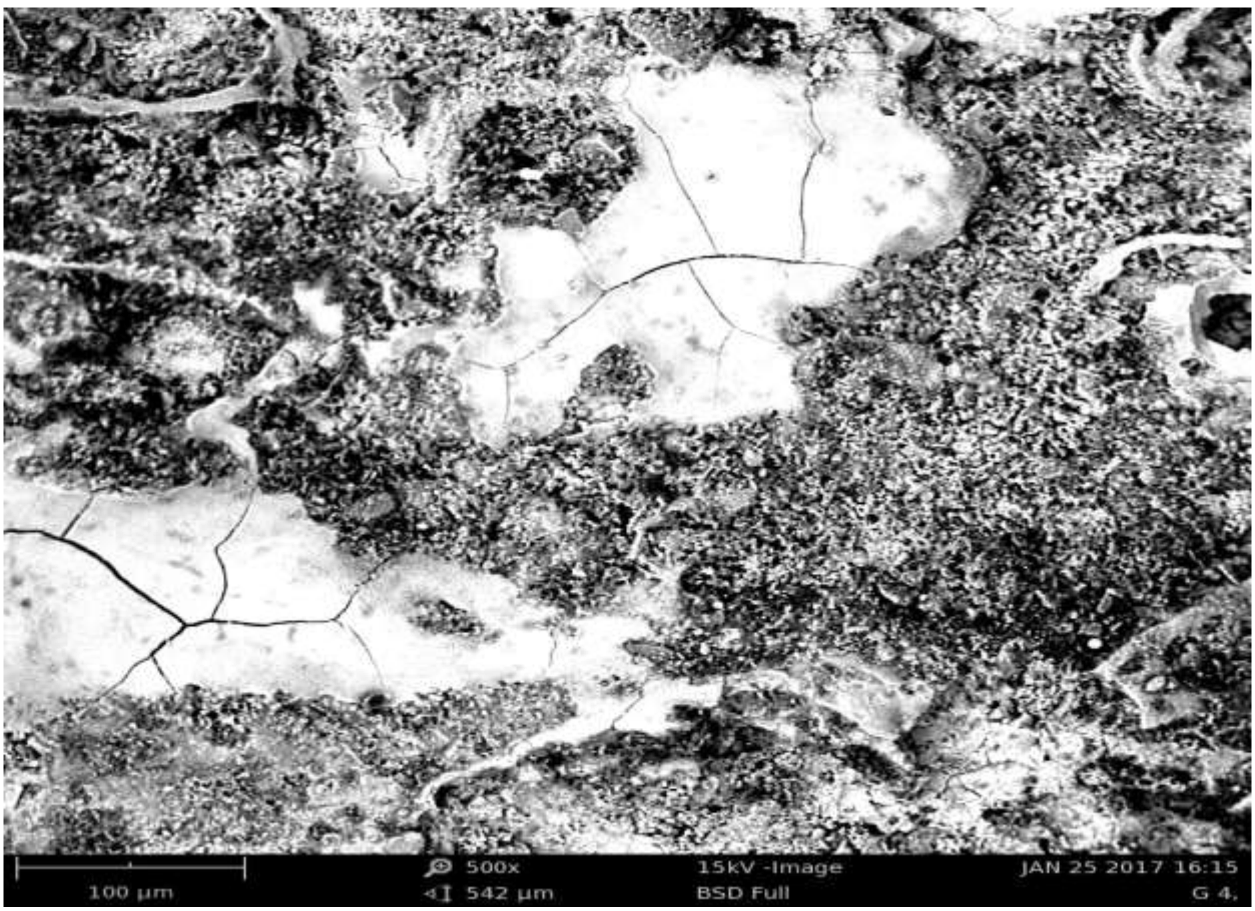

Plate 3: SEM Result of G4 (X 500)

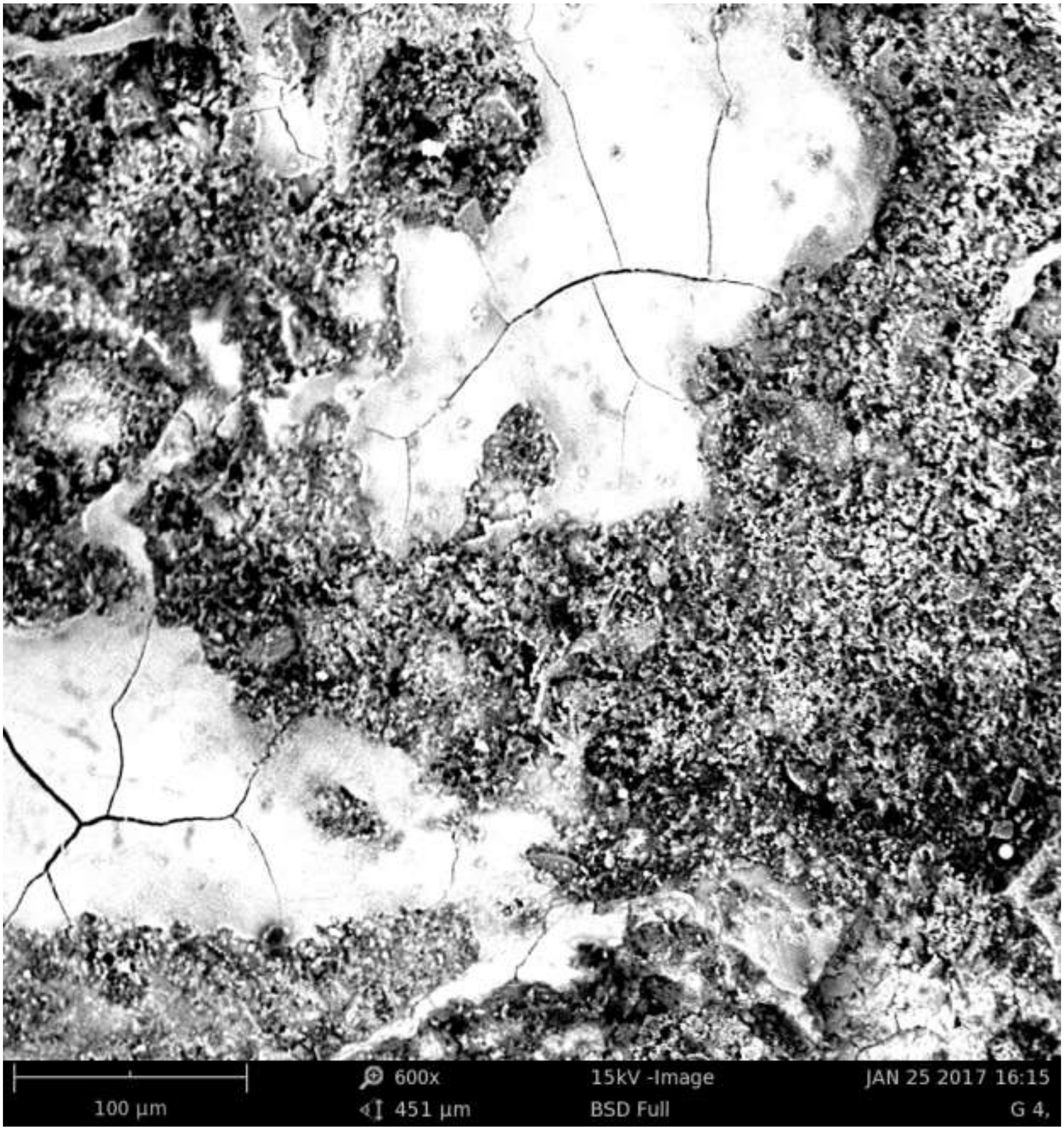

Plate 4: SEM Result of G4 (X 600)

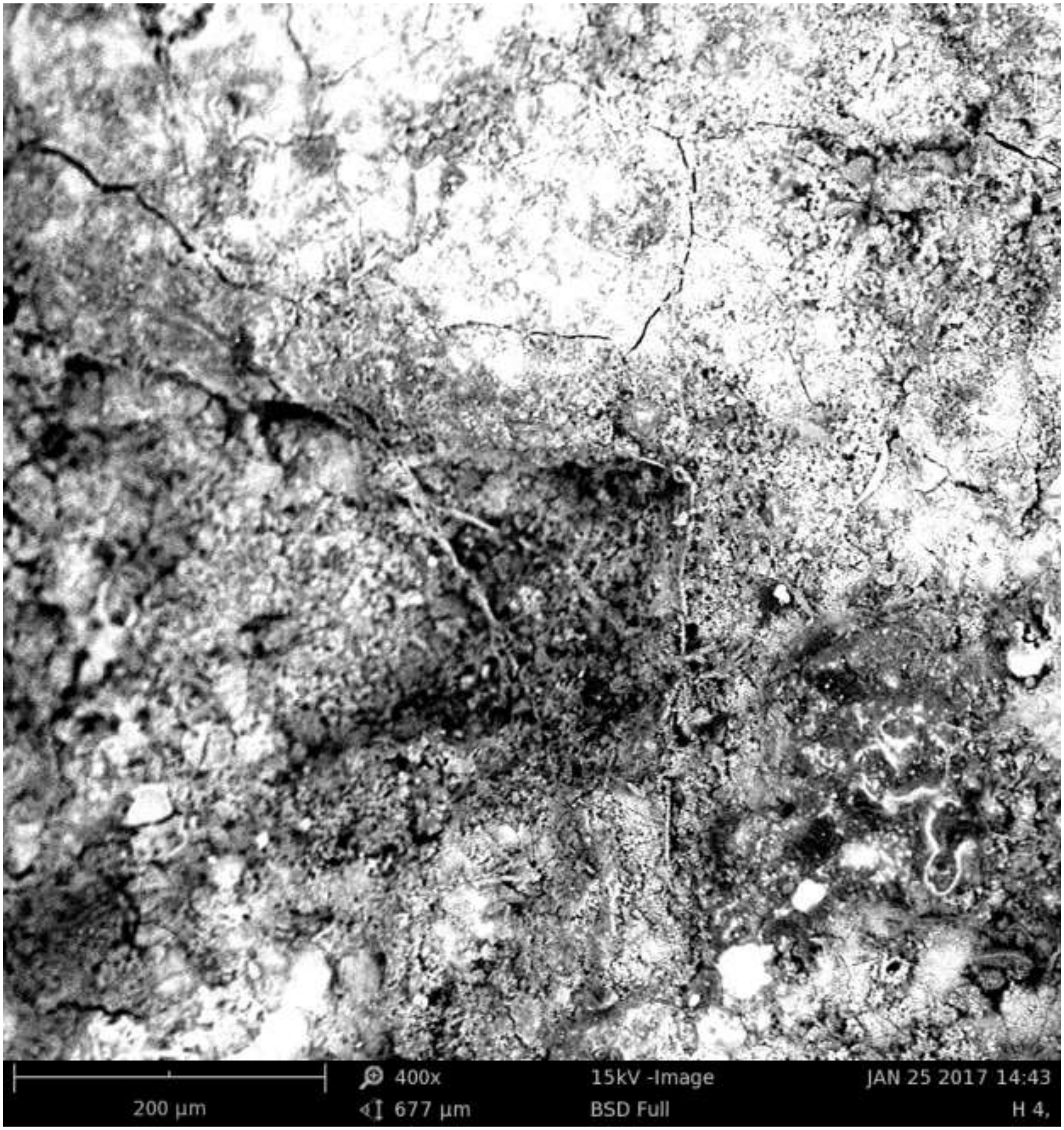

Plate 5: SEM Result of H4 (X 400)

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Plate 6: SEM Result of H4 (X 600)

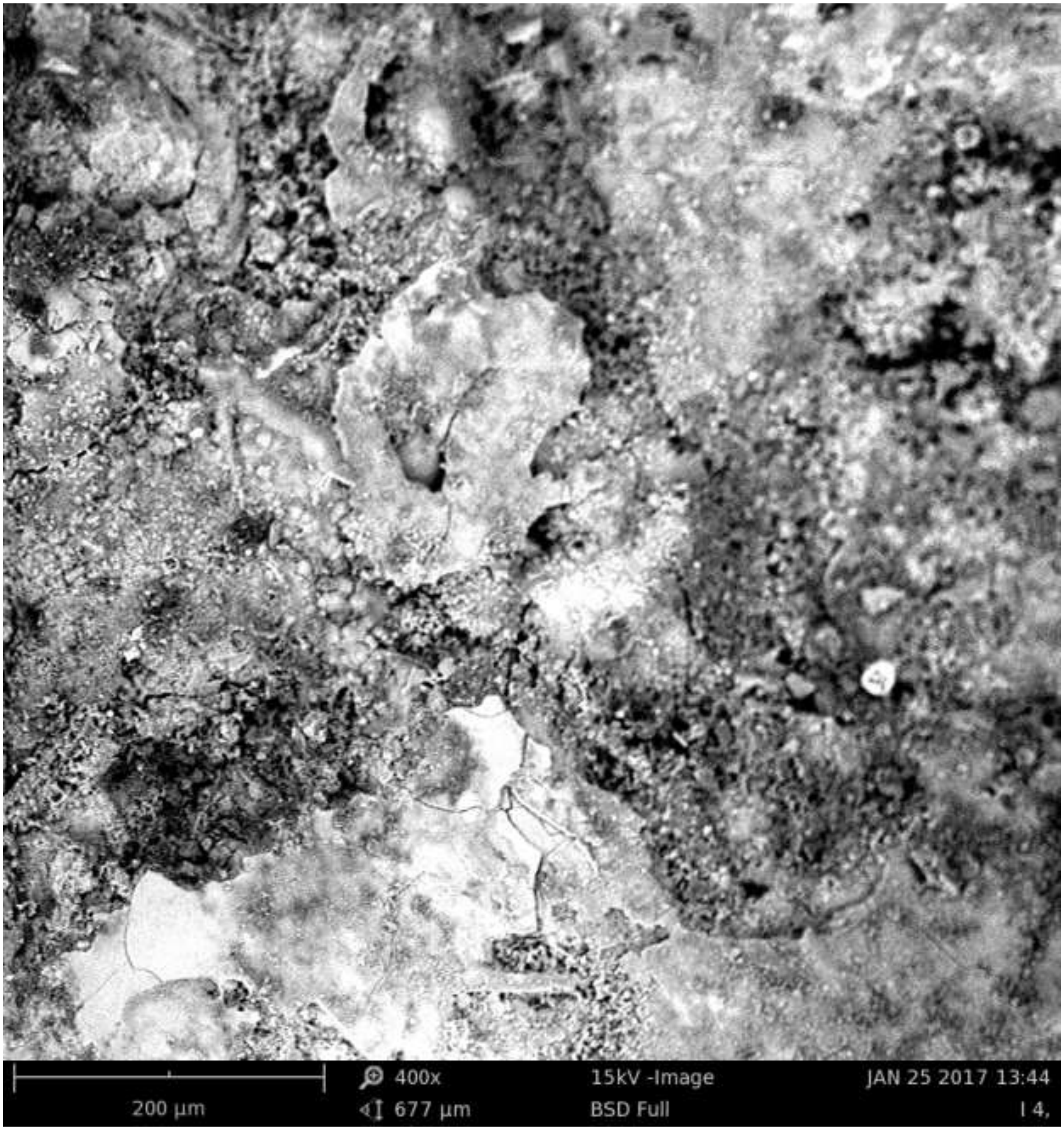

Plate 7: SEM Result for I4 (X 400)

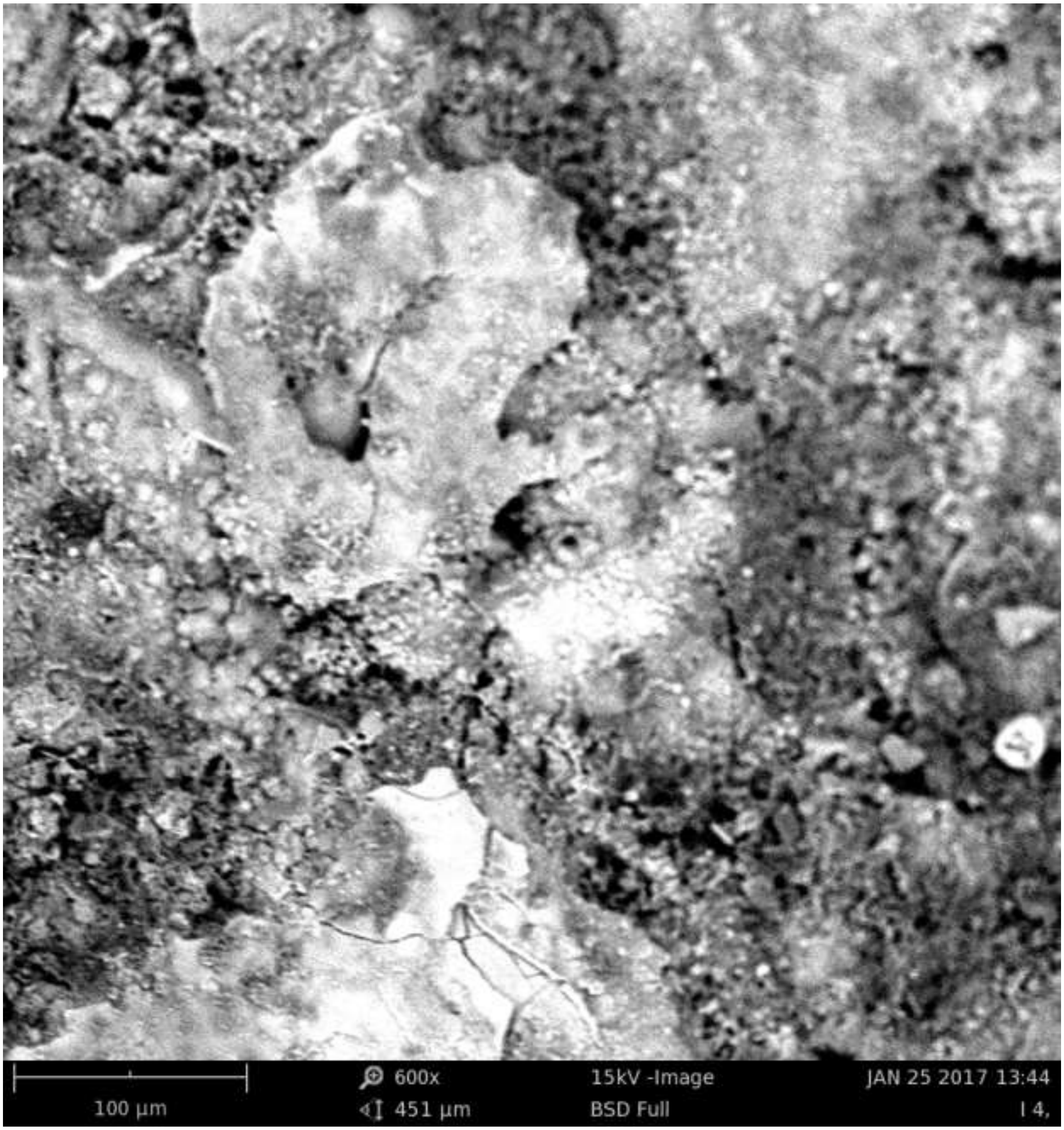

Plate 8: SEM Result of I4 (X 600)

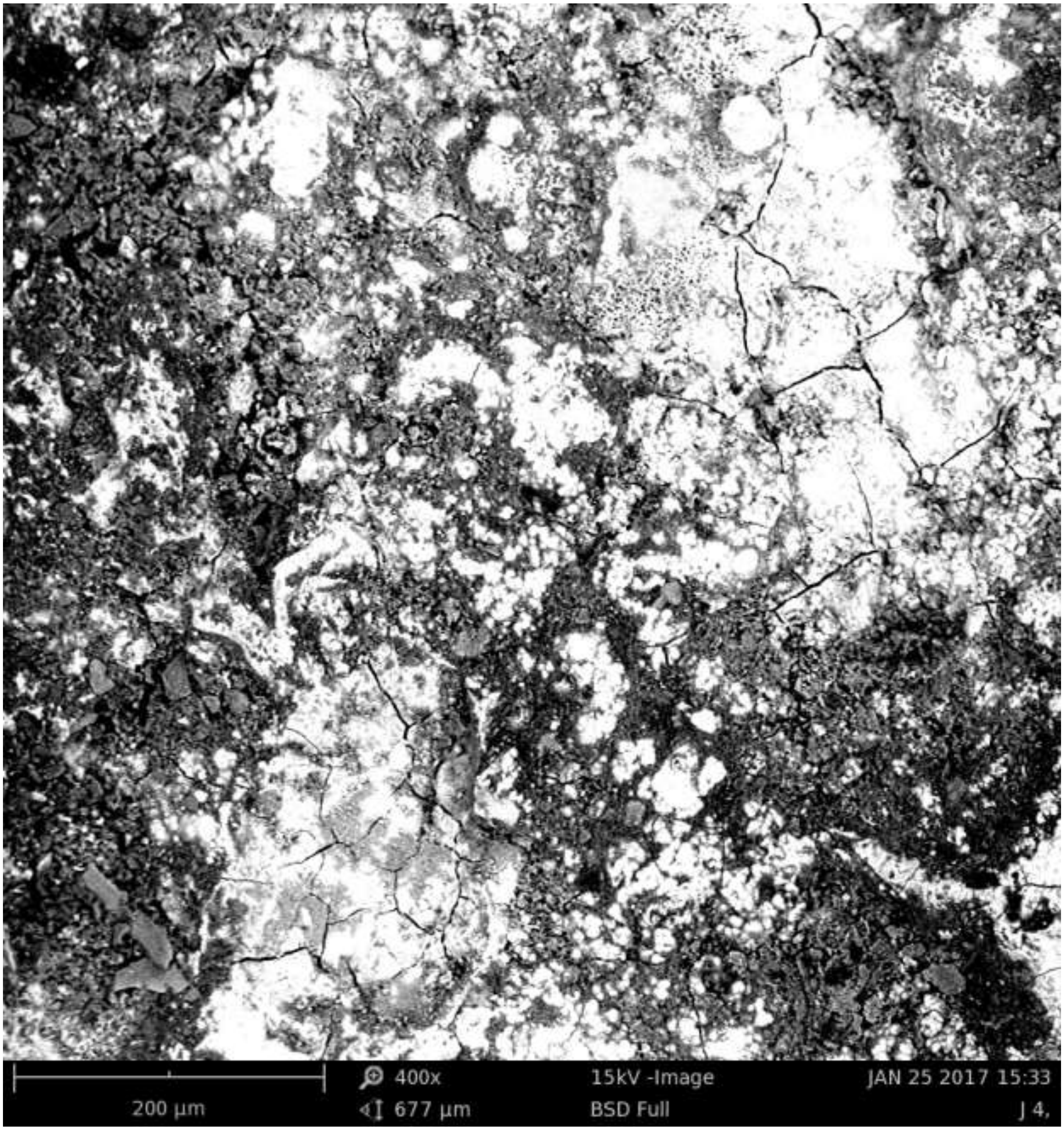

Plate 9: SEM Result of J4 (X 400)

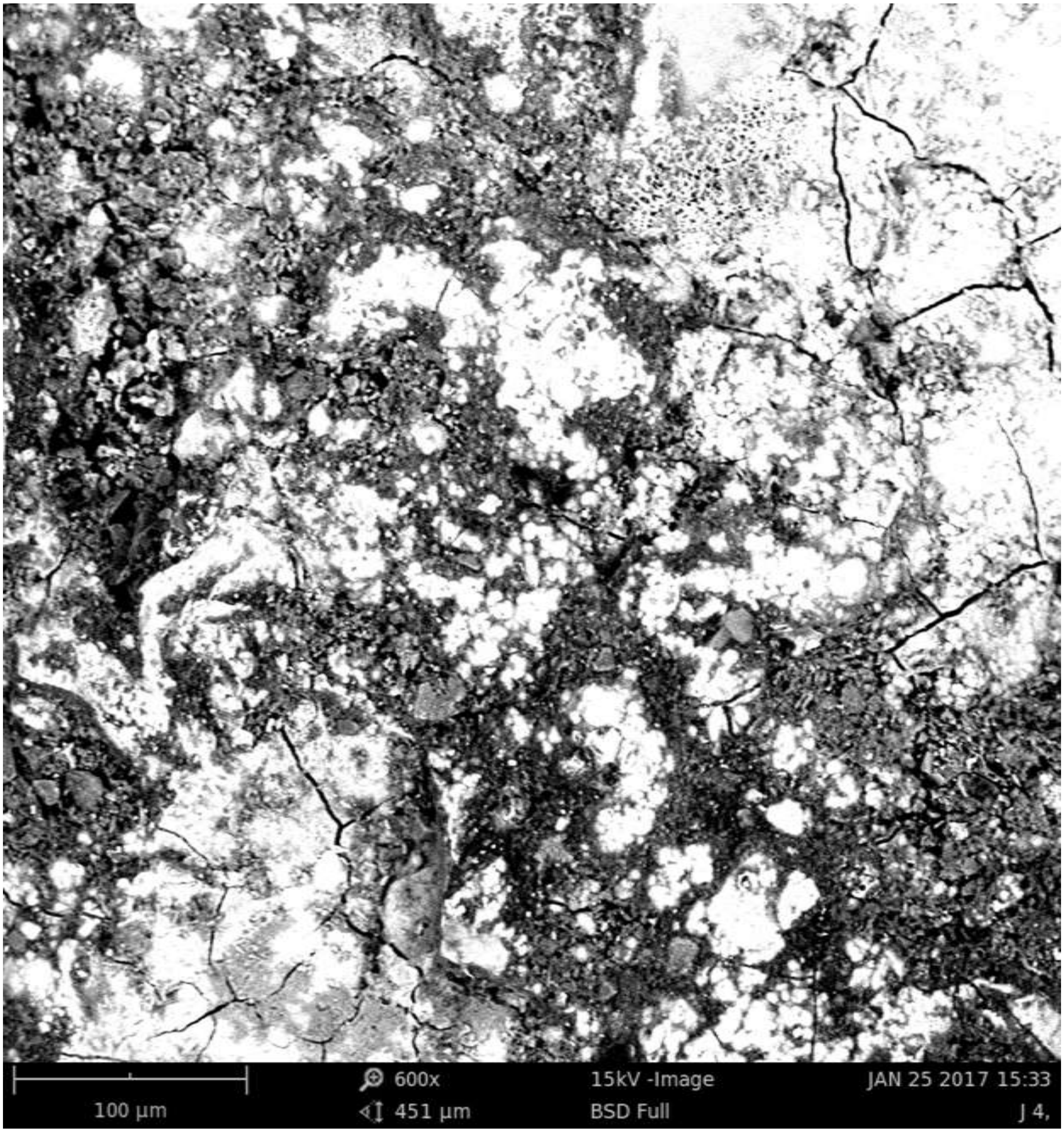

Plate 10: SEM Result of J4 (X 600)

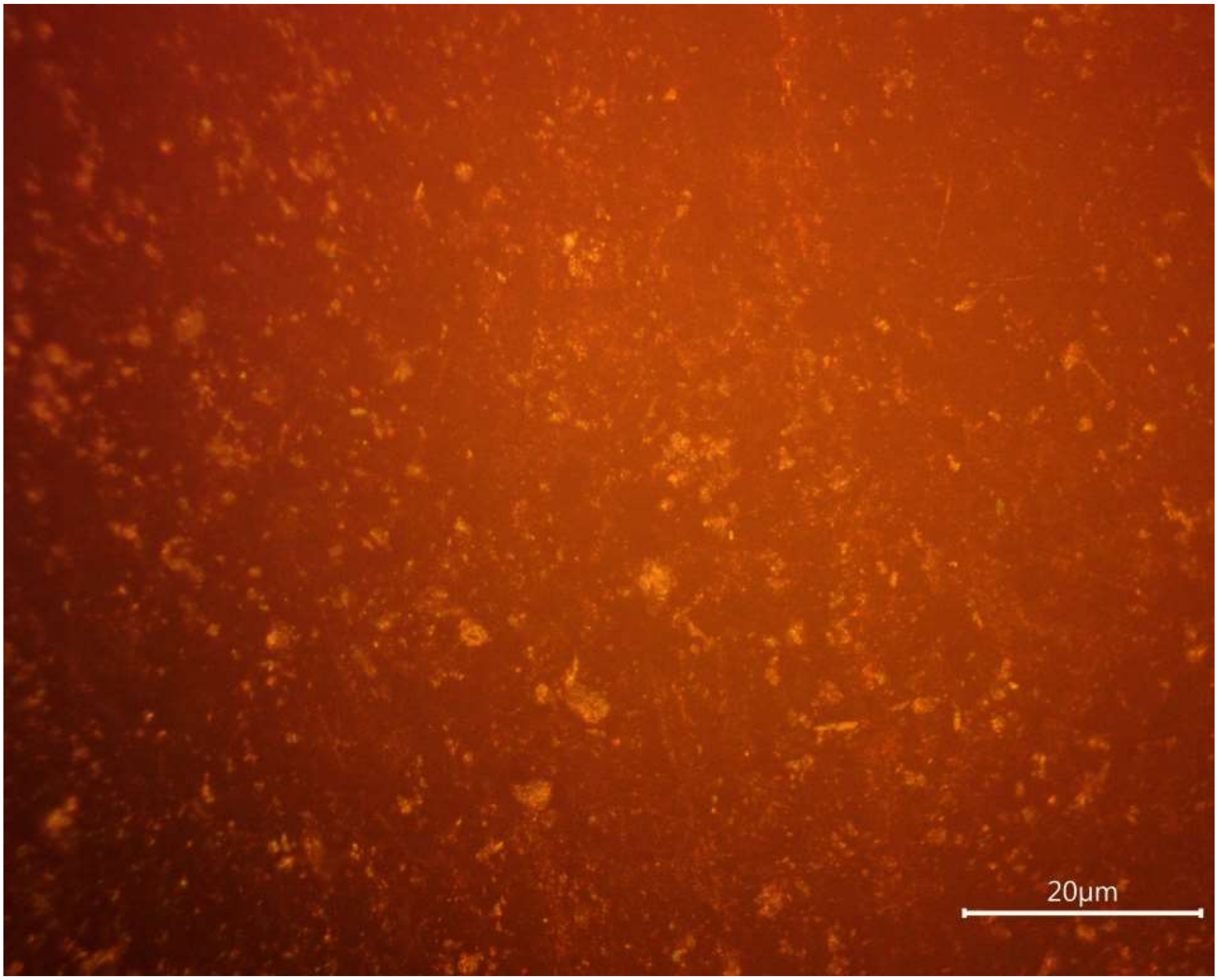

Plate 11: Micrograph of F2 (100X)

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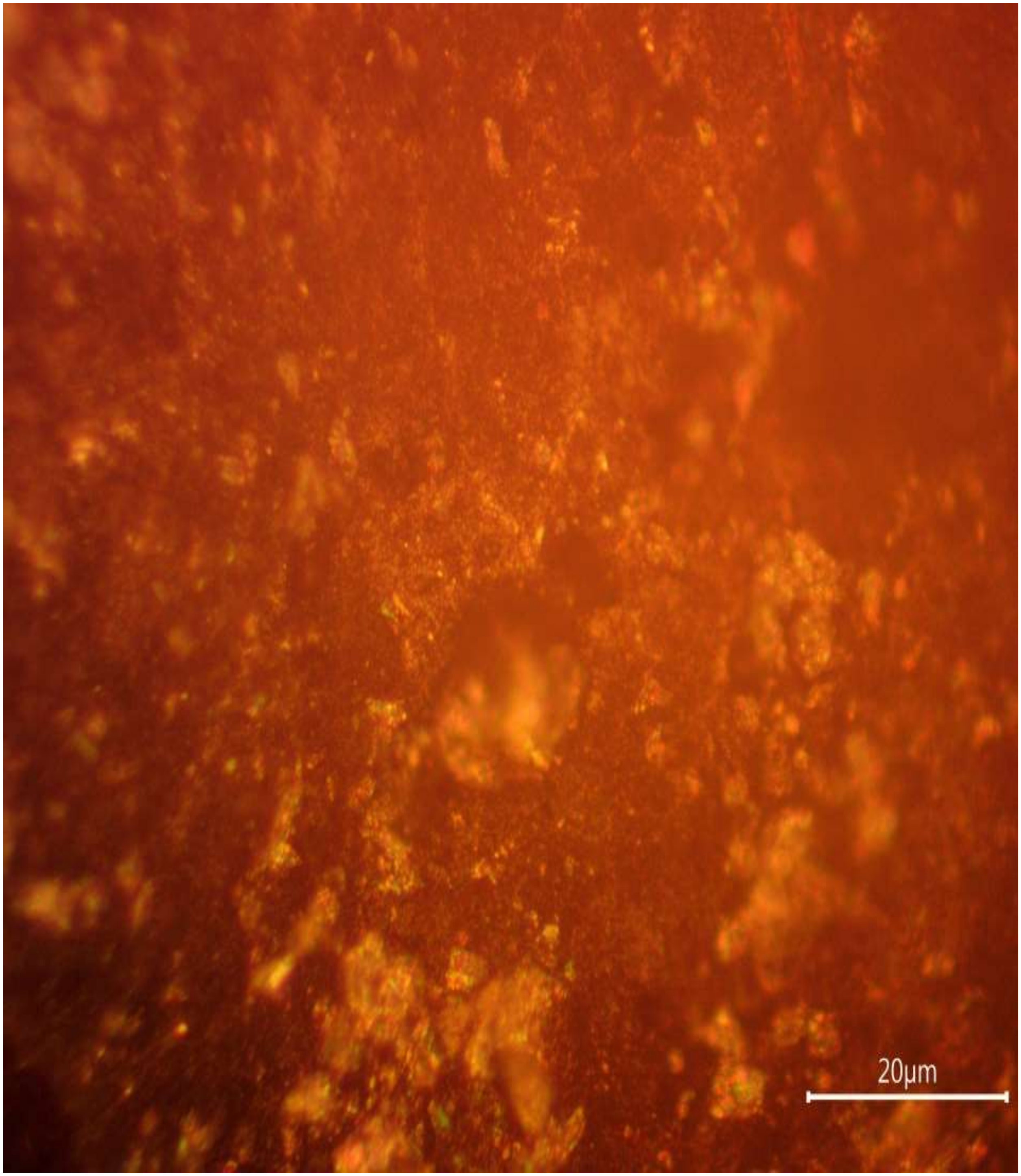

Plate 12: Micrograph of F2 (400X)

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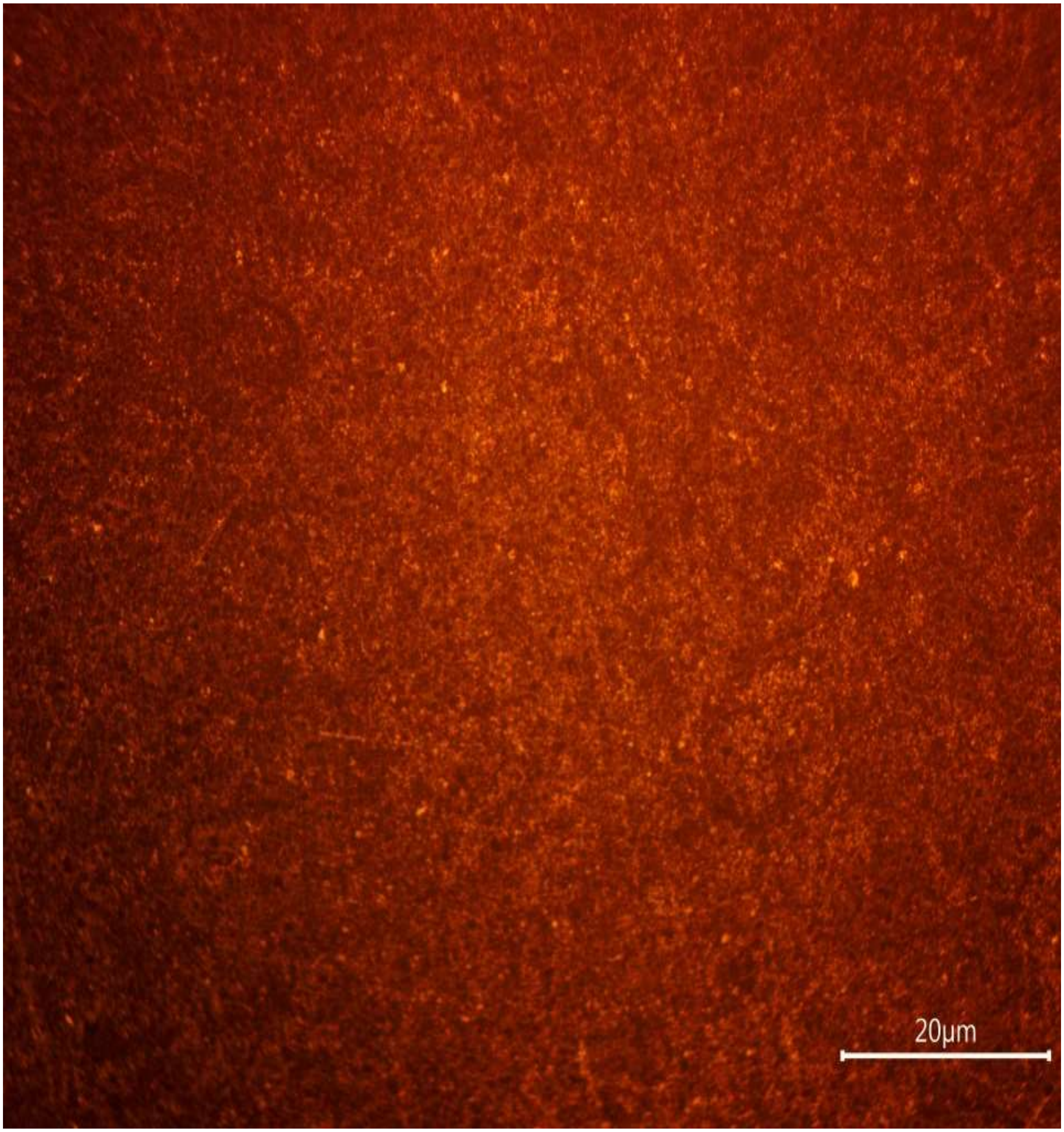

Plate 13: Micrograph of G2 (100X)

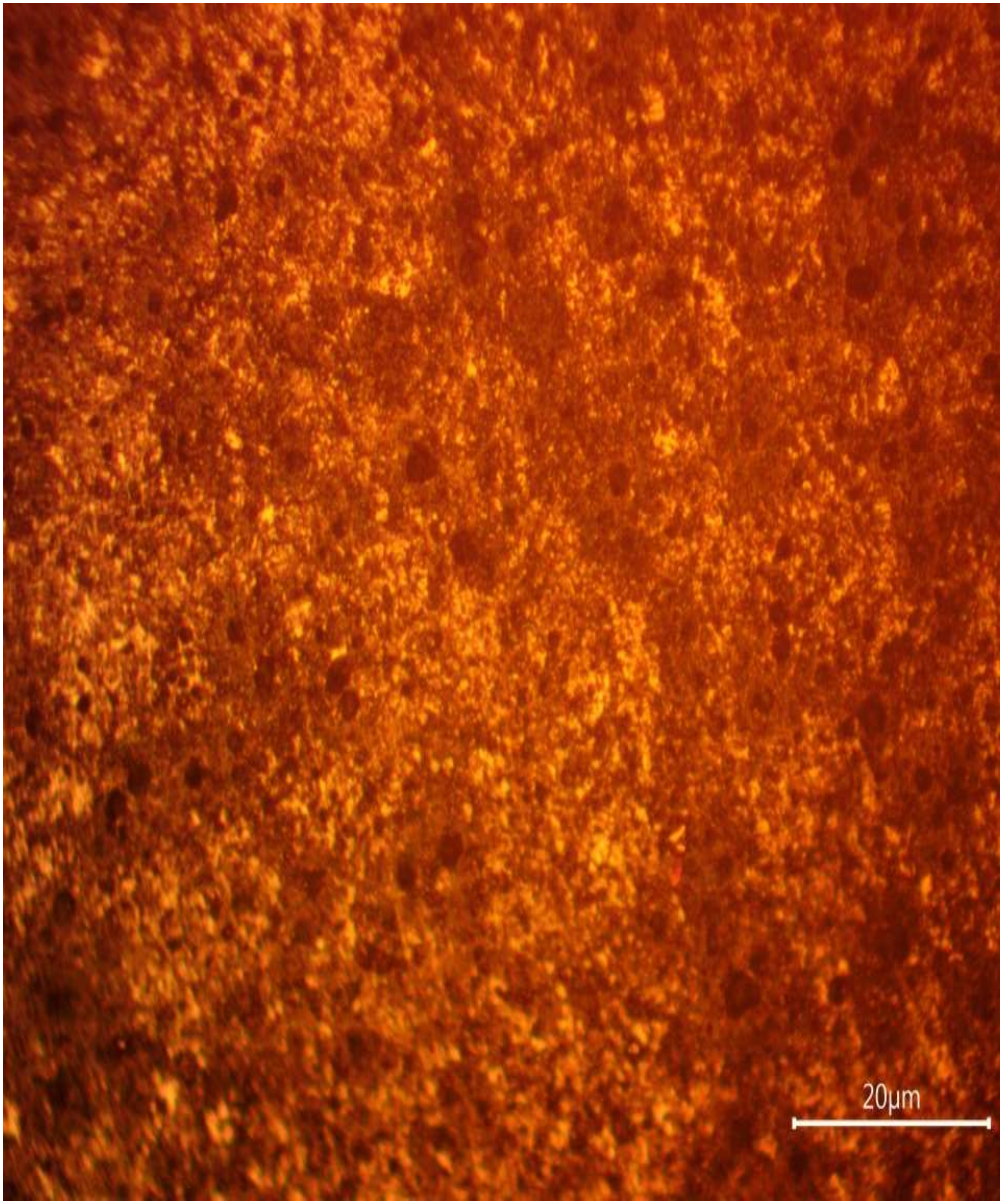

Plate 14: Micrograph of G2 (400X)

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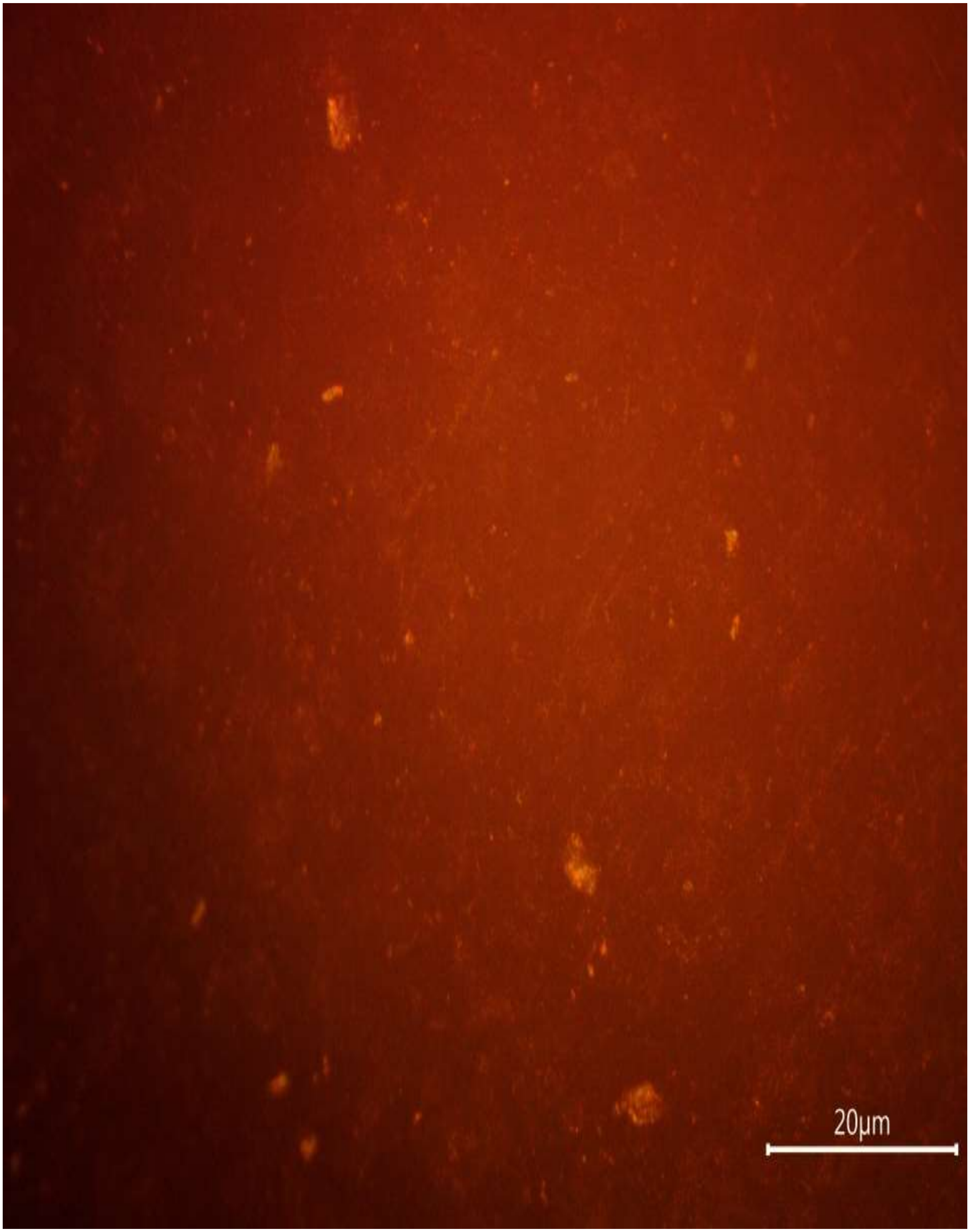

Plate 15: Micrograph of H2 (100X)

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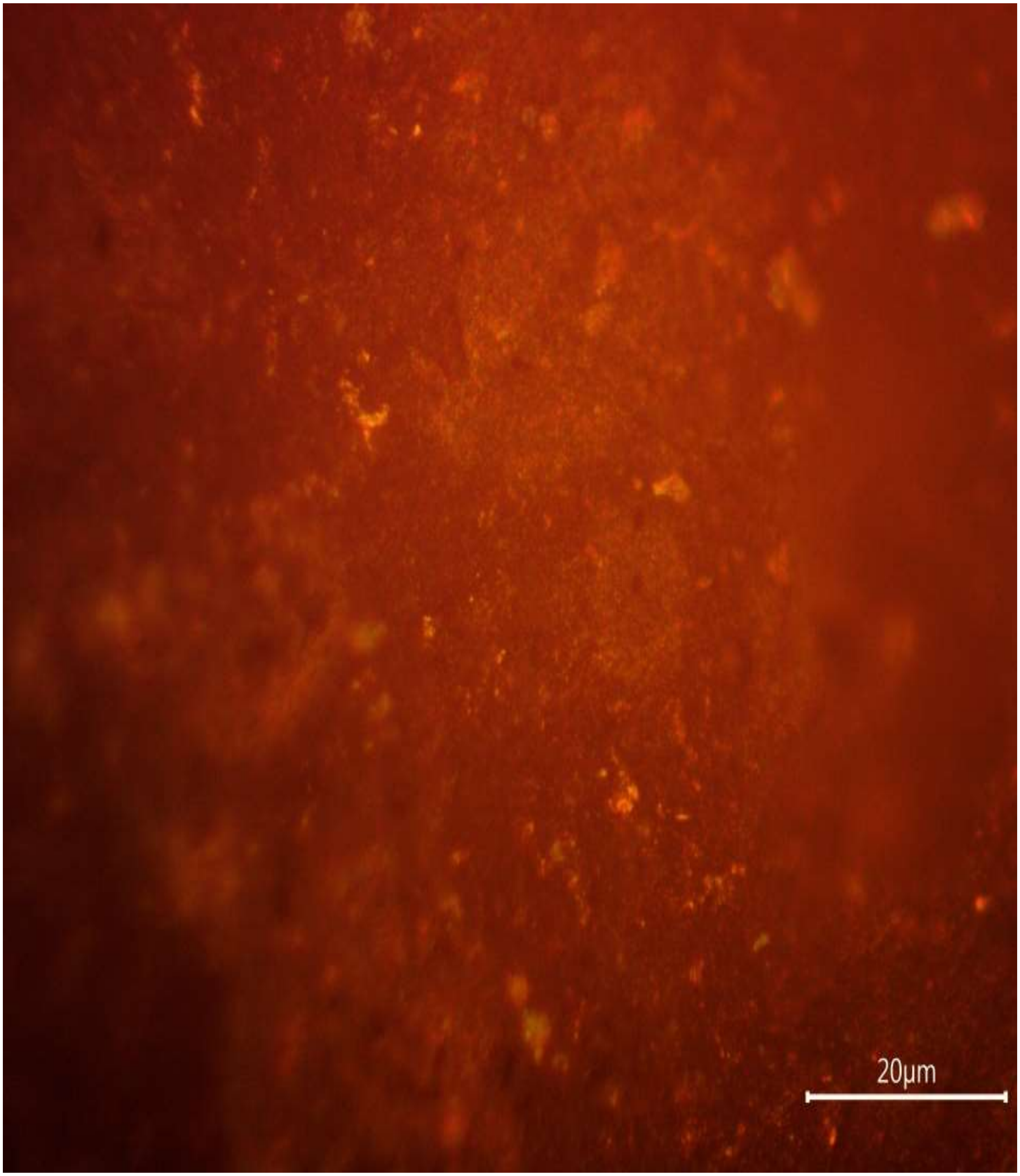

Plate 16: Micrograph of H2 (400X)

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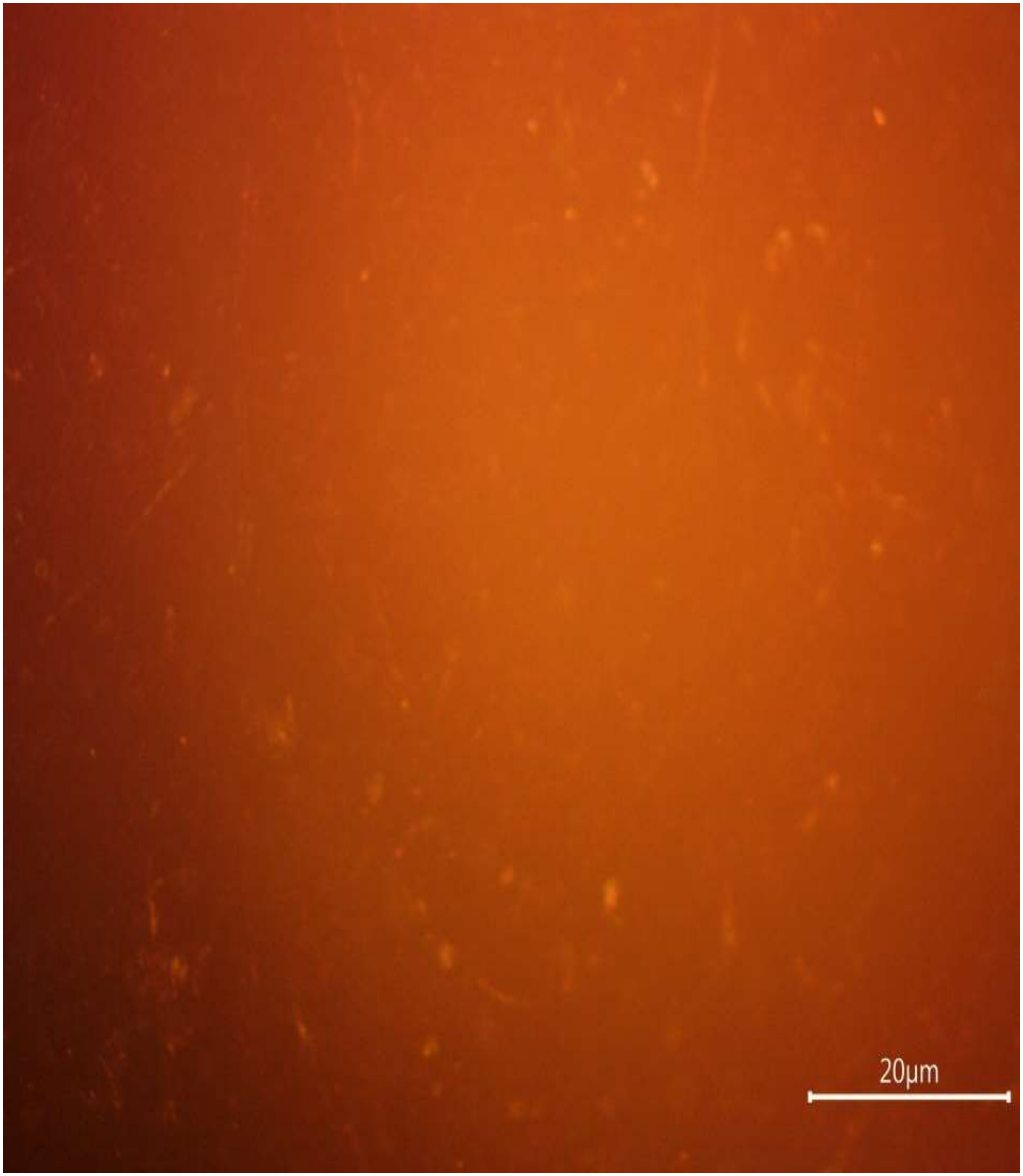

Plate 17: Micrograph of I2 (100X)

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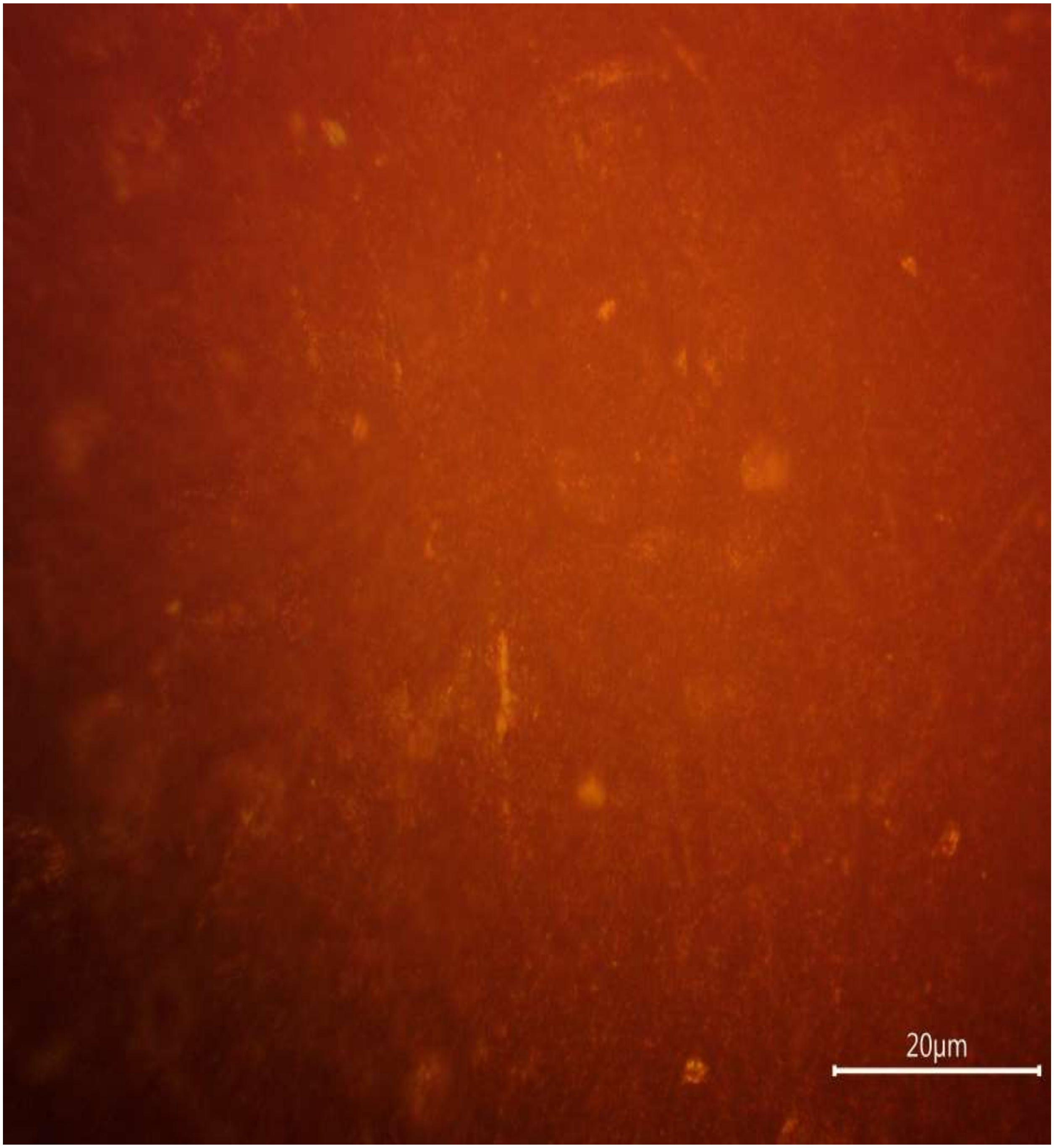

Plate 18: Micrograph of I2 (400X)

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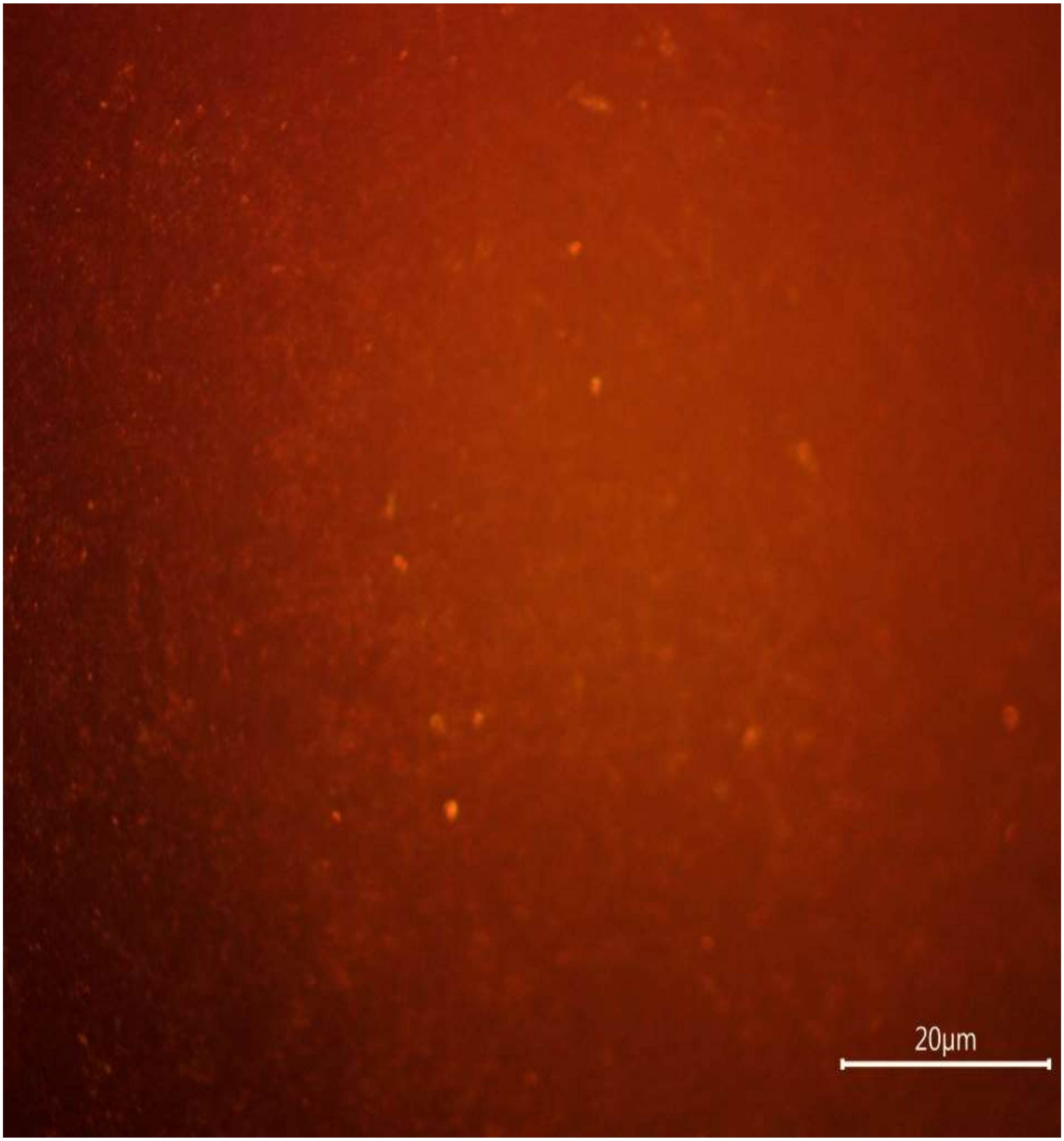

Plate 19: Micrograph of J2 (100X)

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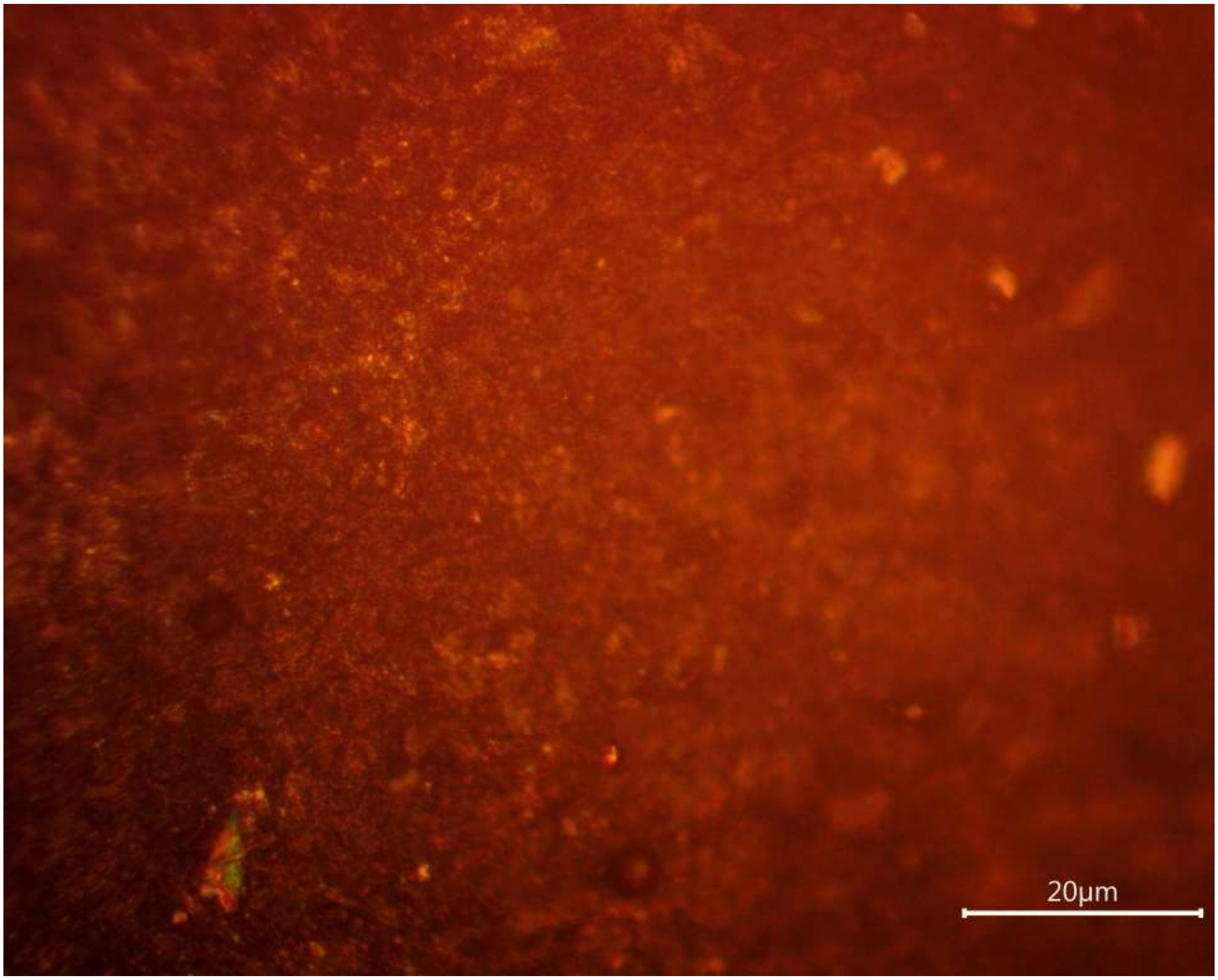

Plate 20: Micrograph of J2 (400X)

CONCLUSION

Since the protective layers on the surfaces of the failed springs were damaged, then the combination of corrosion and fatigue led to the fracture of the samples. Conclusively, cracks gradually propagated from the fractured surfaces due to the combination of corrosion attack and cyclic loading during motion of the four wheeled vehicle (FWV).

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