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N/Réf : **AB – Dr. L. TIKANA 14-10**

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Archivage CopperCEEF

Comparative corrosion results of four leaded & lead-free copper base alloys

(ELV Automotive project.)

Dr. A. BORHAN

1 – Objet

Within the frame of the "ELV - Automotive project", CopperCEEF has been charged to perform comparative corrosion, metallographic and finally roughness tests on four copper base alloys.

Galvanic corrosion and **S**tress **C**orrosion **C**racking (**SCC**) tests have been considered for comparison. This report provides the experimental conditions together with the results of each test.

2 – Experimental

A – Alloys tested

The four alloys tested are presented in **table 1**.

	1	2	3	4
Symbol	**CuZn39Pb3**	**CuZn42**	**CuZn21Si3P**	**CuZn38As**
Number	**CW614N**	**CW510L**	**CW724R**	**CW511L**

Table 1

B - SCC tests

The tests have been performed using the two following **ISO international standards**:

ISO 7539-4 and ISO 7539-7

The operating conditions used are summerised in **table 2**.

Strain rate (s^{-1})	Temperature (°C)	PH	Corrosion solution concentration (ppm = µg/l)
10^{-6}	19.5 ± 0.5	4	200

Table 2

Two corrosion solutions including: NaCl and Na2SO4, have been considered.

In order to evaluate the susceptibility to stress corrosion cracking, we have used the low strain rate tensile test. Tests were first performed in air and then in contact with a corrosive environment.

In each case the total plastic strain ε_p (see **figure 1**) was determined before calculating the **C**oefficient of **S**ensitivity to **S**tress **C**orrosion **C**racking (C_{SCC}) as follows:

$$\boxed{C_{SCC}\,(\%) = [\varepsilon_p]_{\text{corrosive environment}} / [\varepsilon_p]_{\text{air}}} \qquad \textbf{[Eq. 1]}$$

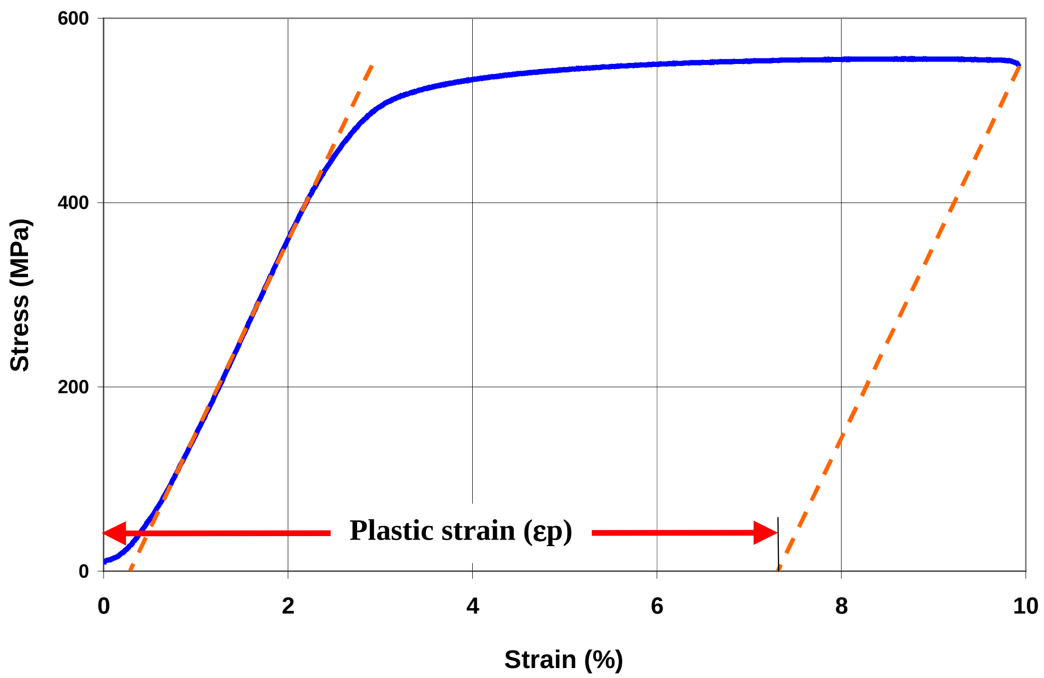

Figure 1

Round machined specimens with threaded ends were used. The dimensions of the specimens used are given in **figure 2**.

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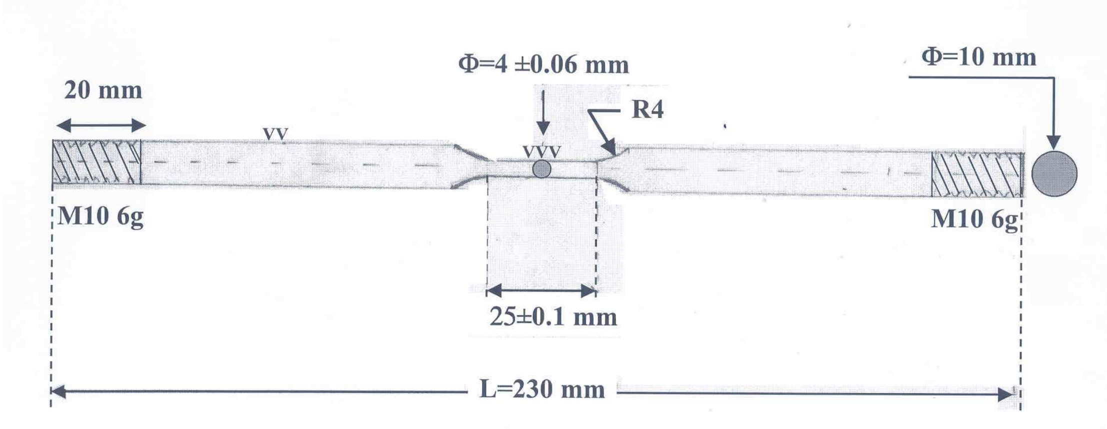

Figure 2

The following calculation based on the gage length (L = 25mm), let calculate the constant speed of the crosshead of the tensile machine to be used in order to apply a strain rate of 10^{-6} s^{-1} to the sample:

$$\boxed{\overset{\circ}{\varepsilon}\,(s^{-1}) = [V(mm/min) / (L * 60)]} \qquad \text{[}\textbf{Eq. 2}\text{]}$$

Where:

V = The speed of the crosshead (mm/min),

L = Gage length of the sample (25 mm).

Replacing the value of L, in [**Eq. 1**], gives:

$$\boxed{V = 0.0015 \text{ mm/min}}$$

Despite its very low level, the crosshead speed of the tensile machine was highly constant; As an example, **figure 3** shows the acquisition data performed during a real SCC test. A perfect linear relationship is found between the crosshead displacement and time; The slope of the linear graph is precisely 25 x 10^{-6} mm/s (= 0.0015 mm/min) **throughout the test duration**.

Machined samples were degreased prior to tests.

3 – Results

A – SCC tests

The stress-strain curves for different alloys as well as different environments (air, Na2SO4 and NaCl) are grouped in **appendix 1**.

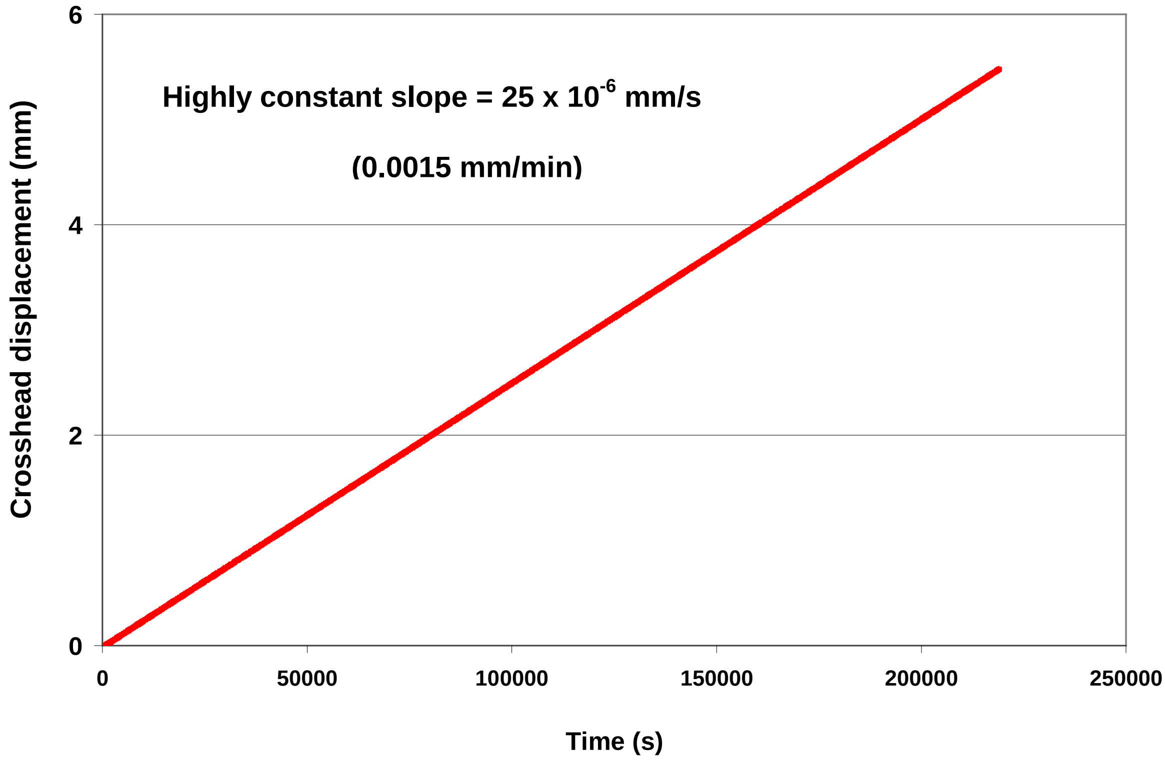

Figure 3

The calculated values of $\mathbf{C_{SCC}}$ are presented in **table 3**.

	NaCl	Na2SO4
CuZn42	**0,23**	**0,13**
CuZn39Pb3	**0,29**	**0,17**
CuZn21Si3	**0,98**	**1,1**
CuZn38As	**0.99**	**1.0**

Table 3

The $\mathbf{C_{SCC}}$ results of **table 3** are graphically shown by **figure 4**. The total plastic strains used to calculate the $\mathbf{C_{SCC}}$ values are graphically shown in **figure 5**.

The results presented in **figures 5** and **6** lead to the following conclusions:

1) The comparison of the $\mathbf{C_{SCC}}$ values between CuZn39Pb3 and CuZn42 suggests that the presence of lead in the brass would slightly improve the resistance to the SCC phenomenon.

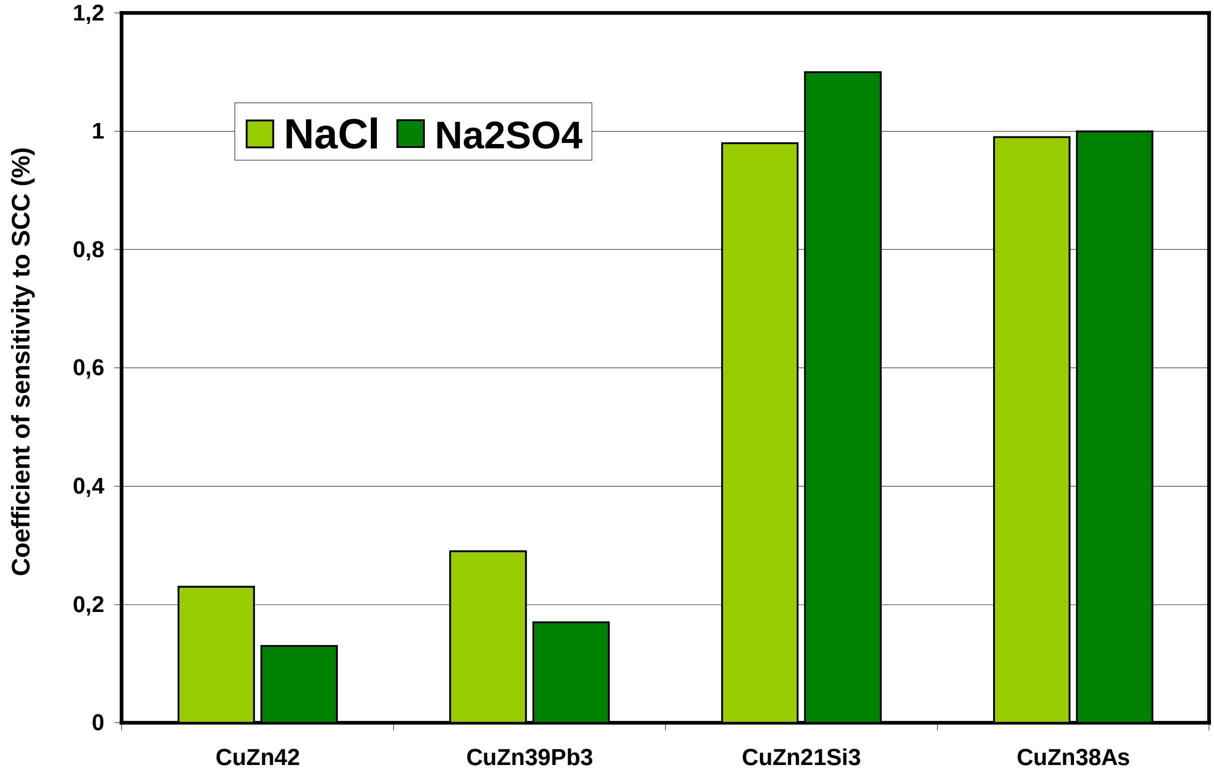

Figure 4

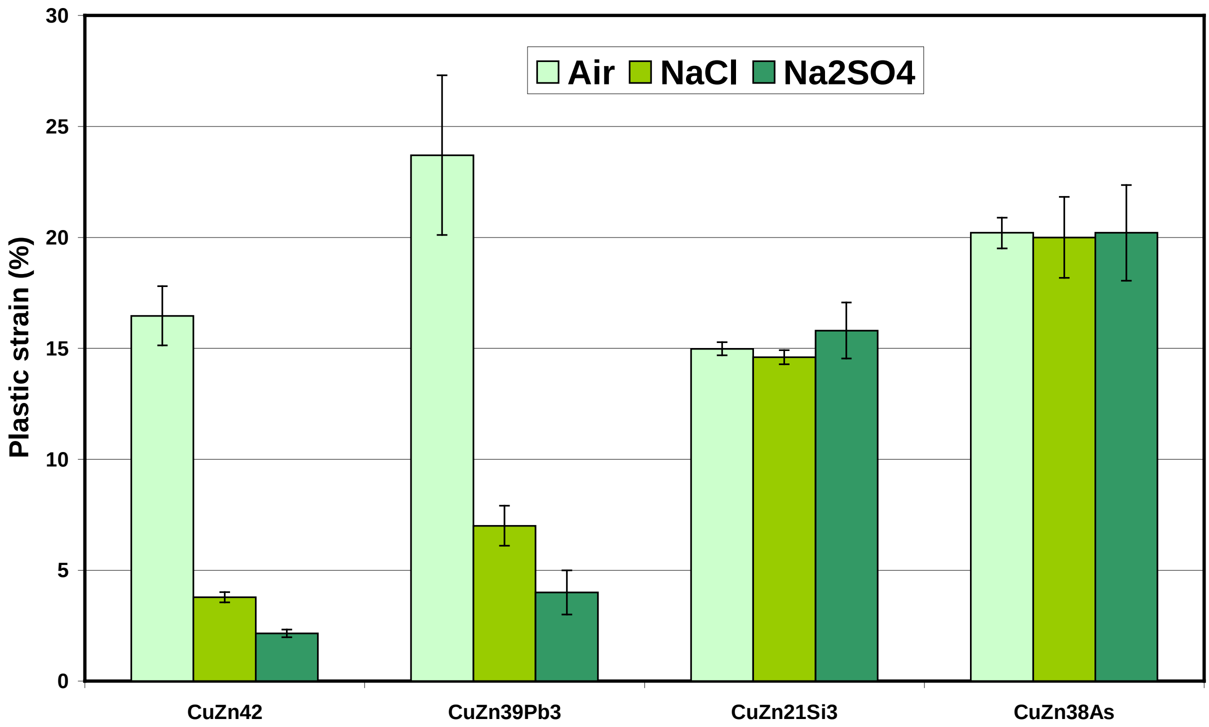

Figure 5

2) Compared with the NaCl, the Na2SO4 is a more corrosive environement.

3) For both of the corrosives environements examined, the preponderant factor for the SCC, is the PH of the solution; The concentration of the solution appears not to have a significant influence on the $\mathbf{C_{SCC}}$ level (within the frame of experimental conditions used).

B – Roughness tests

The results of the longitudinal roughness measurements (Ra and Rz) performed on the gage lengh of the machined samples are presented in **table 4** and **figures 6** and **7**.

The best results are obtained for the CuZn39Pb3 and the worse for the CuZn42.

	Ra		Rz	
	Average	S.D.	Average	S.D.
CuZn42	1,39	0,04	7,27	0,32
CuZn39Pb3	0,17	0,01	1,85	0,16
CuZn21Si3	0,75	0,13	4,24	0,31
CuZn38As	0,51	0,03	2,9	0,3

Table 4

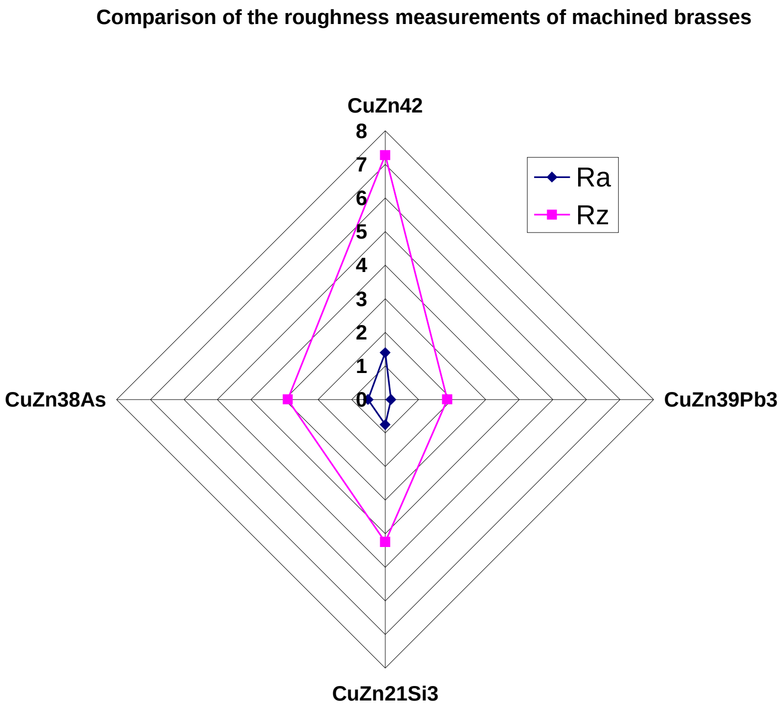

Figure 6

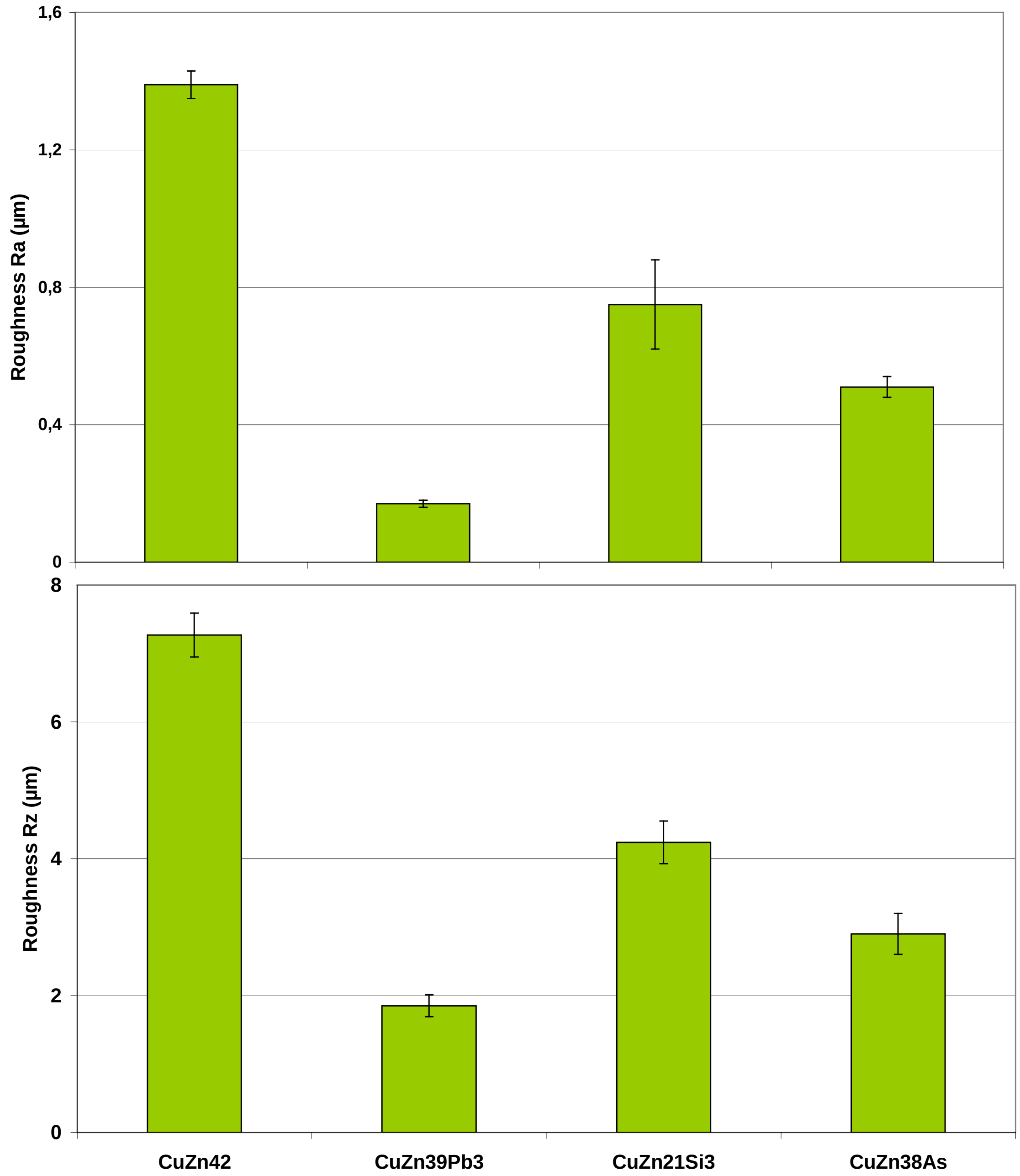

Figure 7

C – Microstructure

Figure 8 to **11** show the optical micrographs of the four lead-free alloys.

As far as the scattered SCC results obtained for the CW614N leaded brass, it appears that the main origin is the microstructure variations of the alloy.

Figure 12 shows the microstructures (with the same magnification) of two CW614N samples with différent SCC results; The phase distribution (morphology, percentage, ...) of the two alloys are significantly different and should be the major origin of the SCC scattering.

It is important to note that the morphology as well as the size distribution of each phase can significantly modify the surface as well as the bulk properties of the leaded brasses.

Consequently, the machinability (chips breakage, surface roughness, machining force,...) as well as the corrosion behavior (dezincification, SCC, ...) can be directly influenced by the microstructure parameters.

Figure 8

CW614N

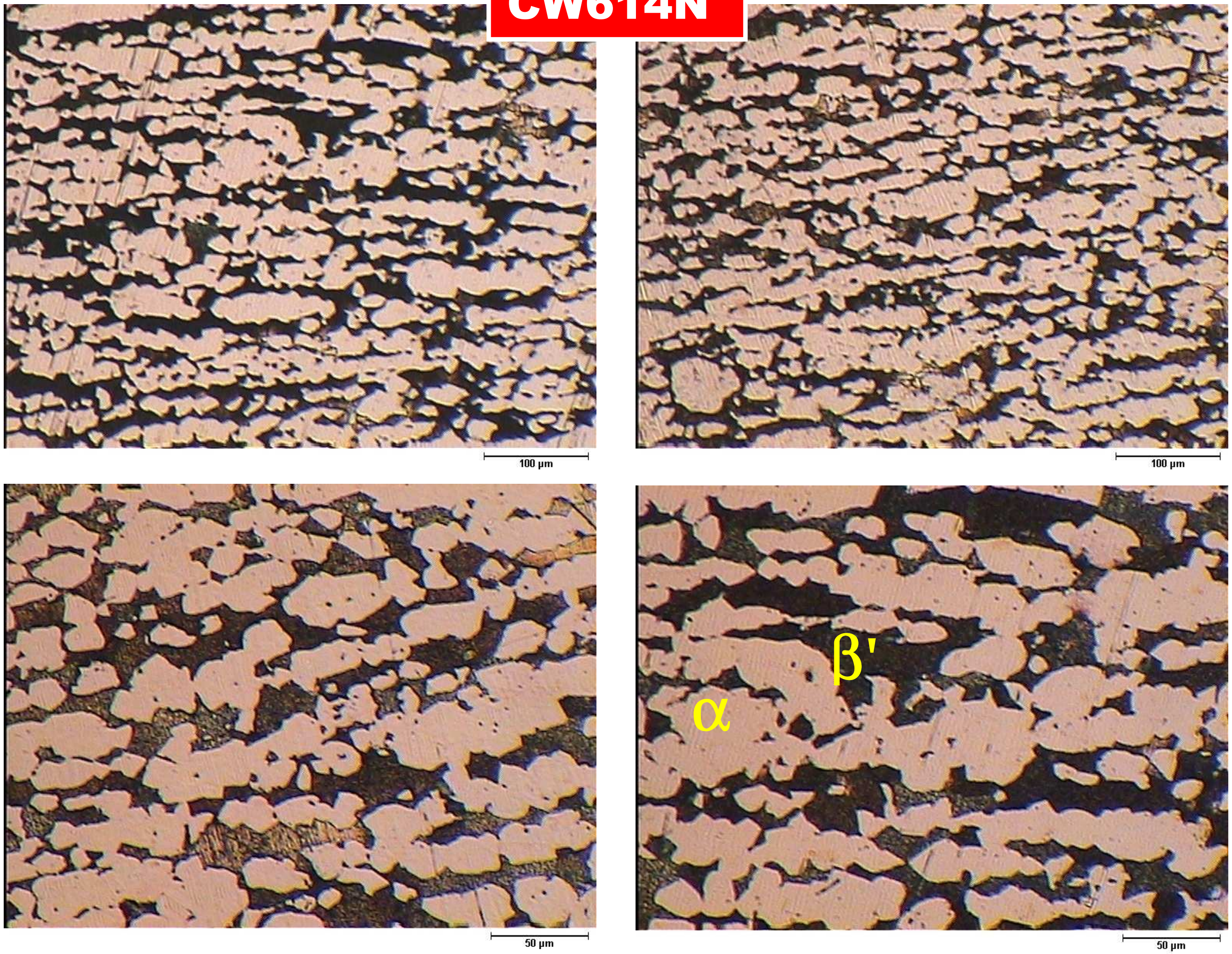

Figure 9

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CW511L

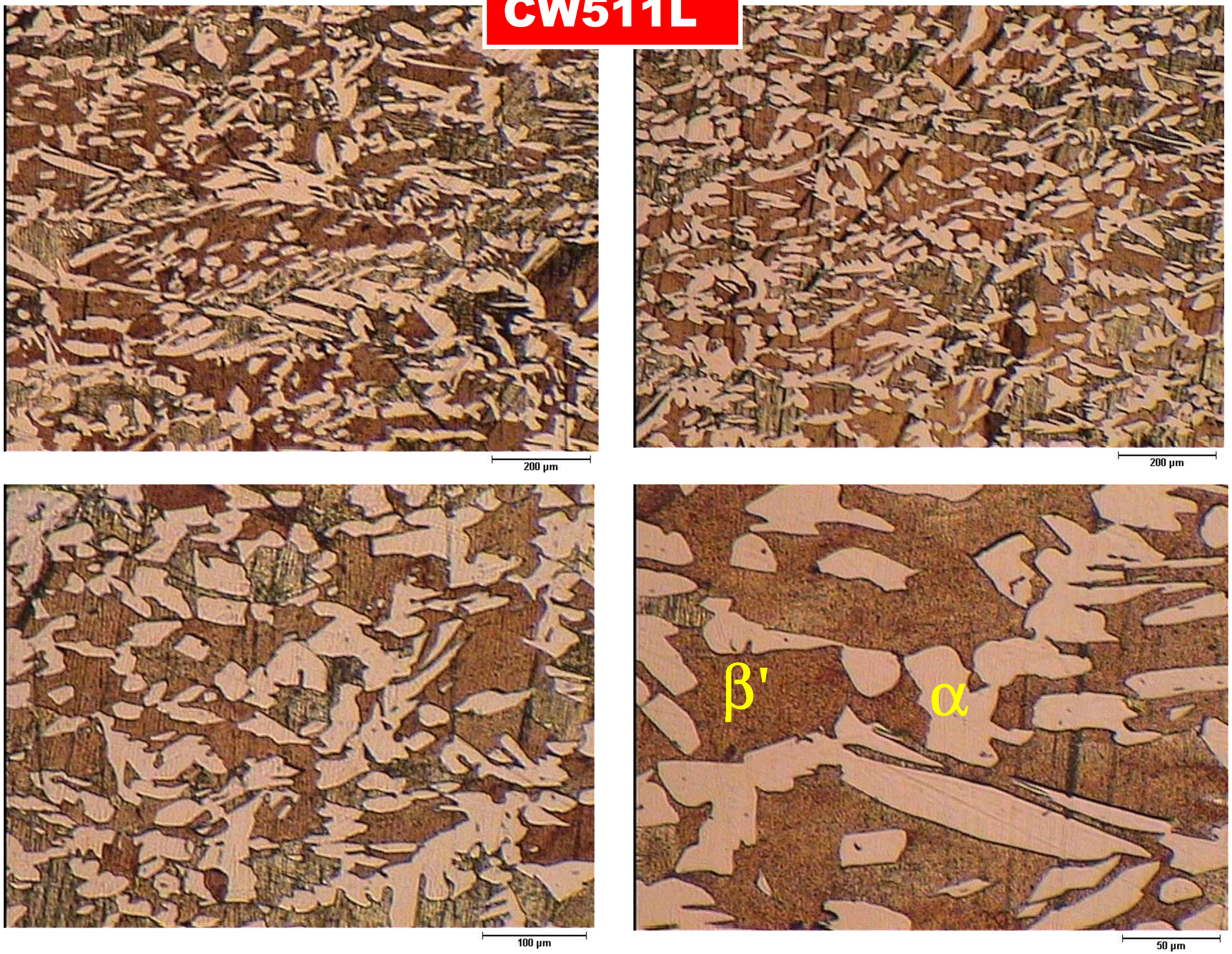

Figure 10

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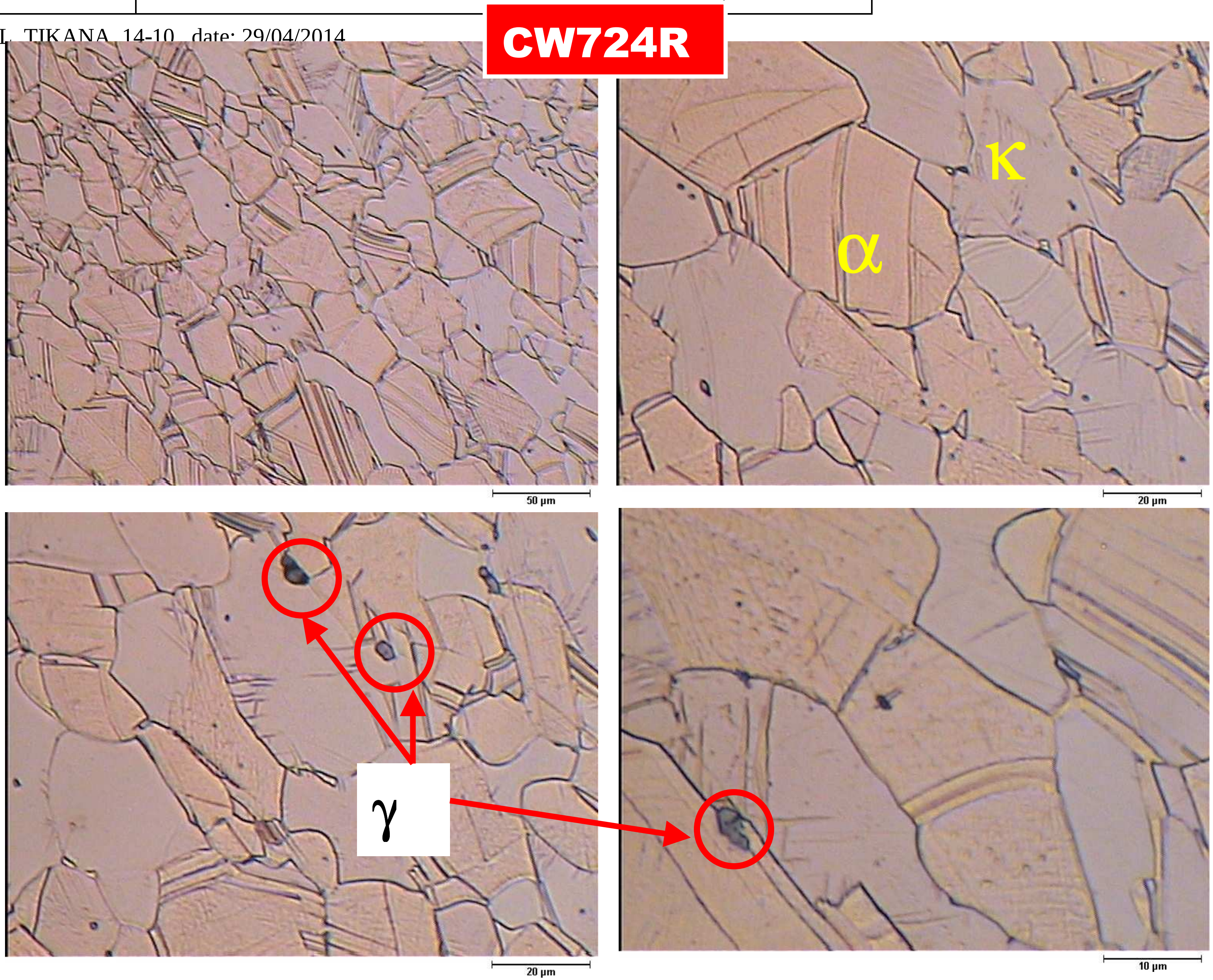

Figure 11

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CW510L

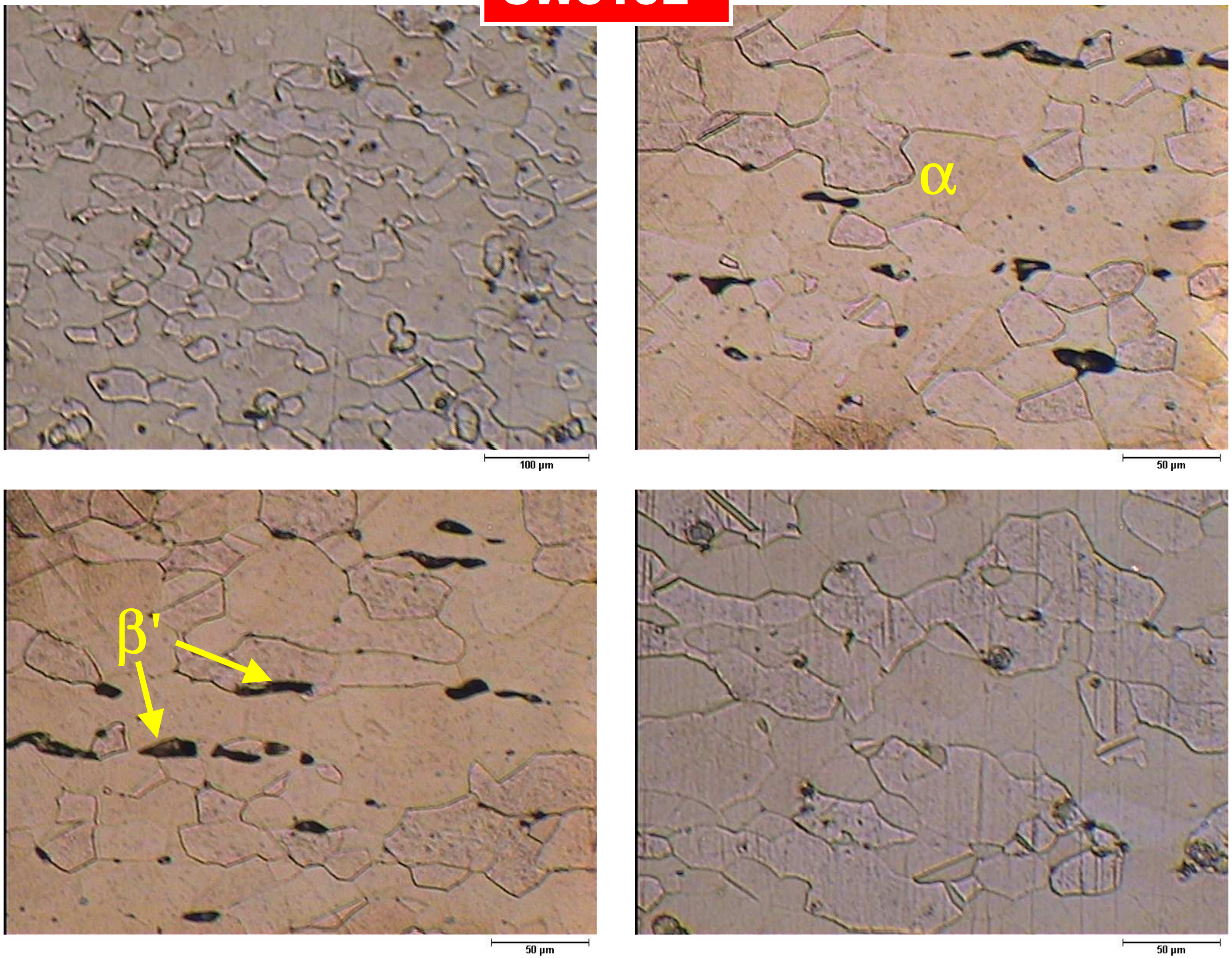

Figure 12

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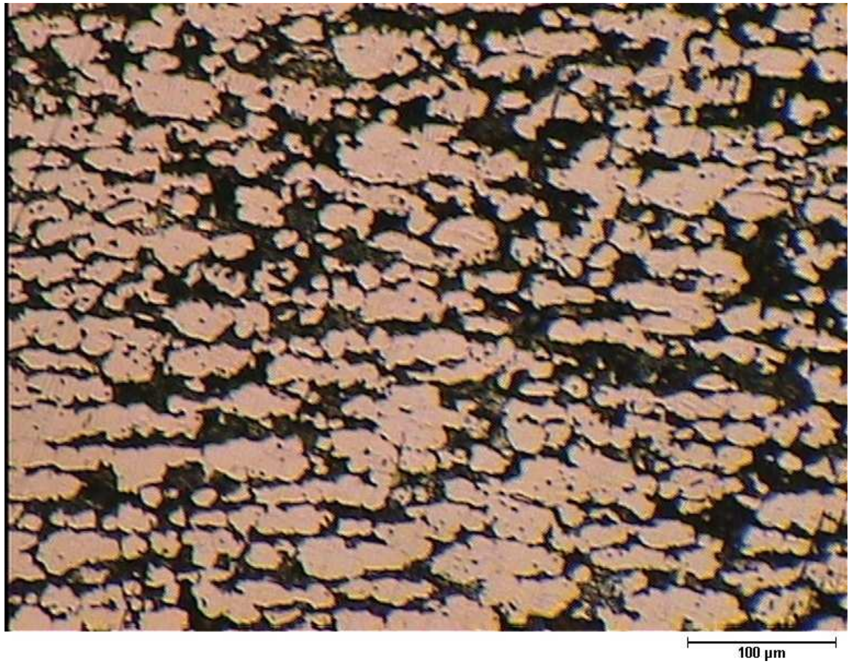
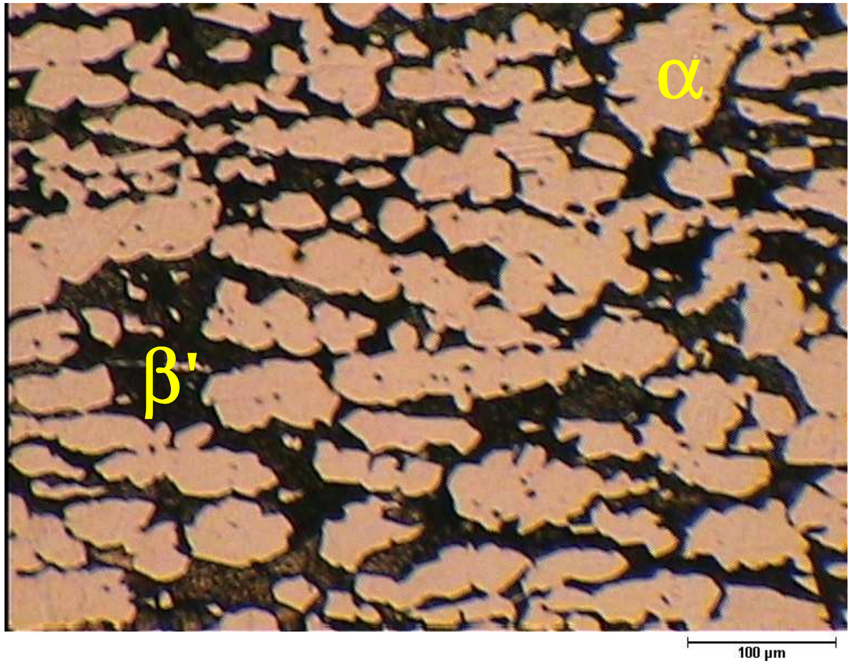
CW614N





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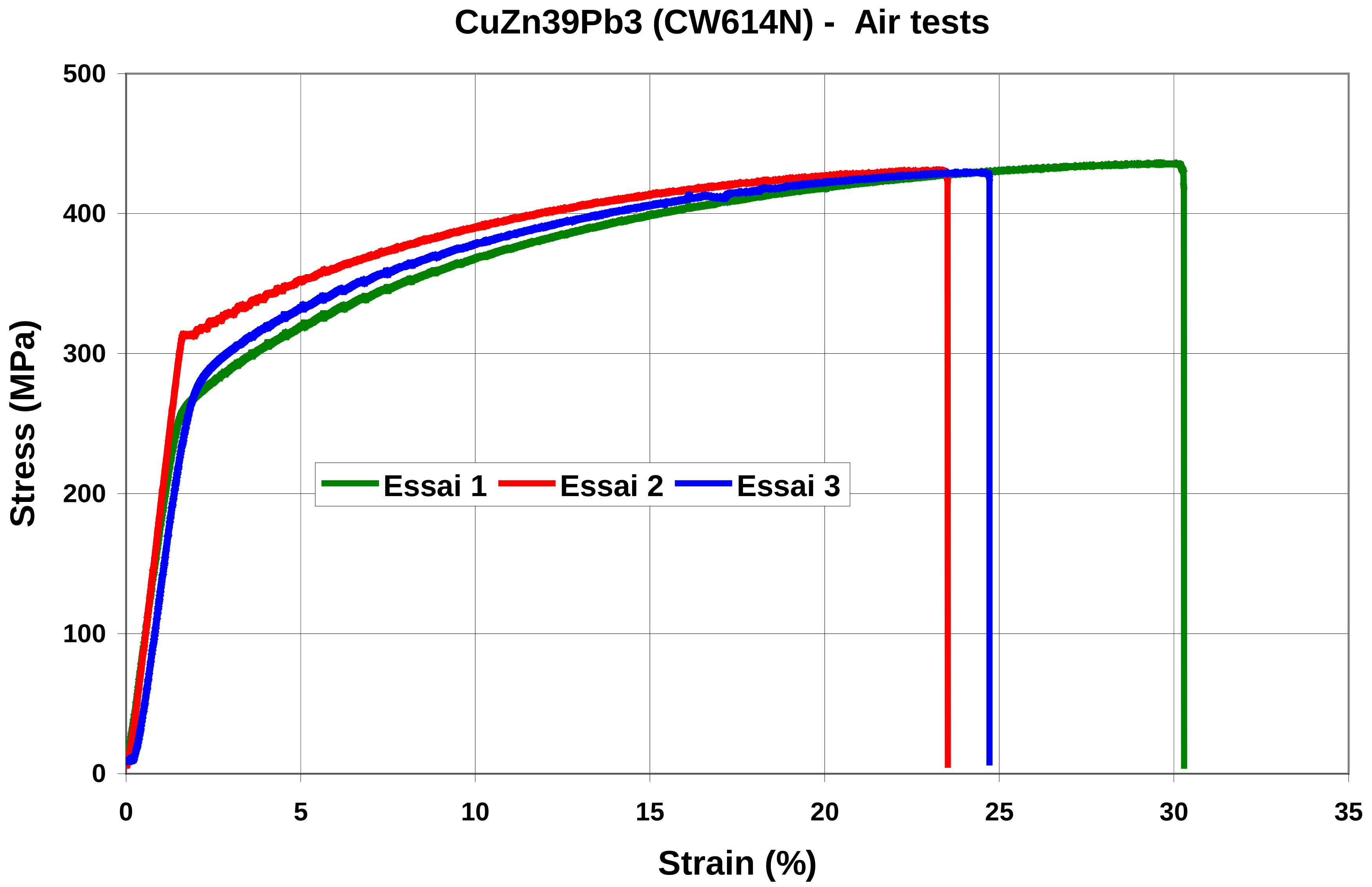

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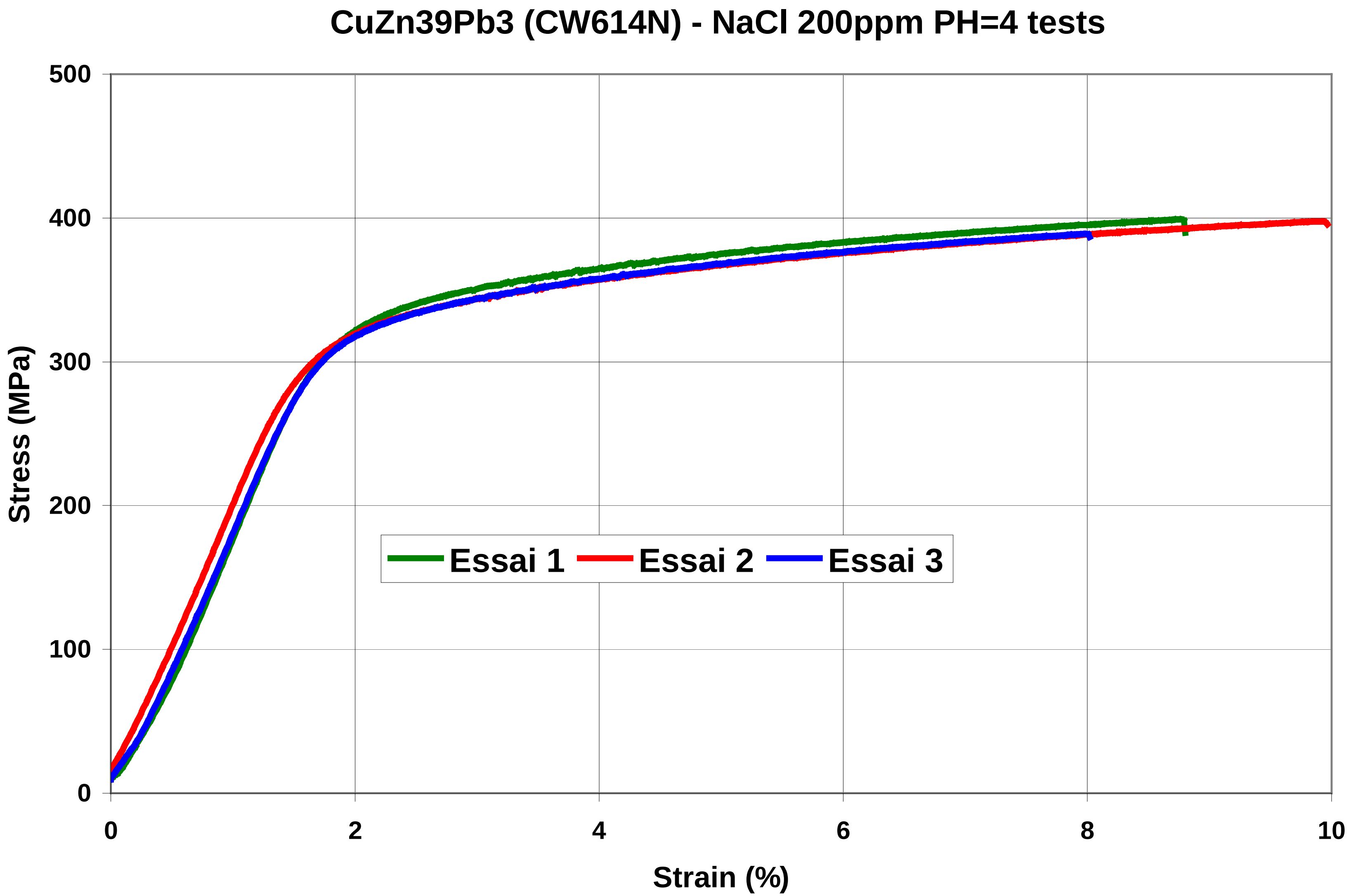

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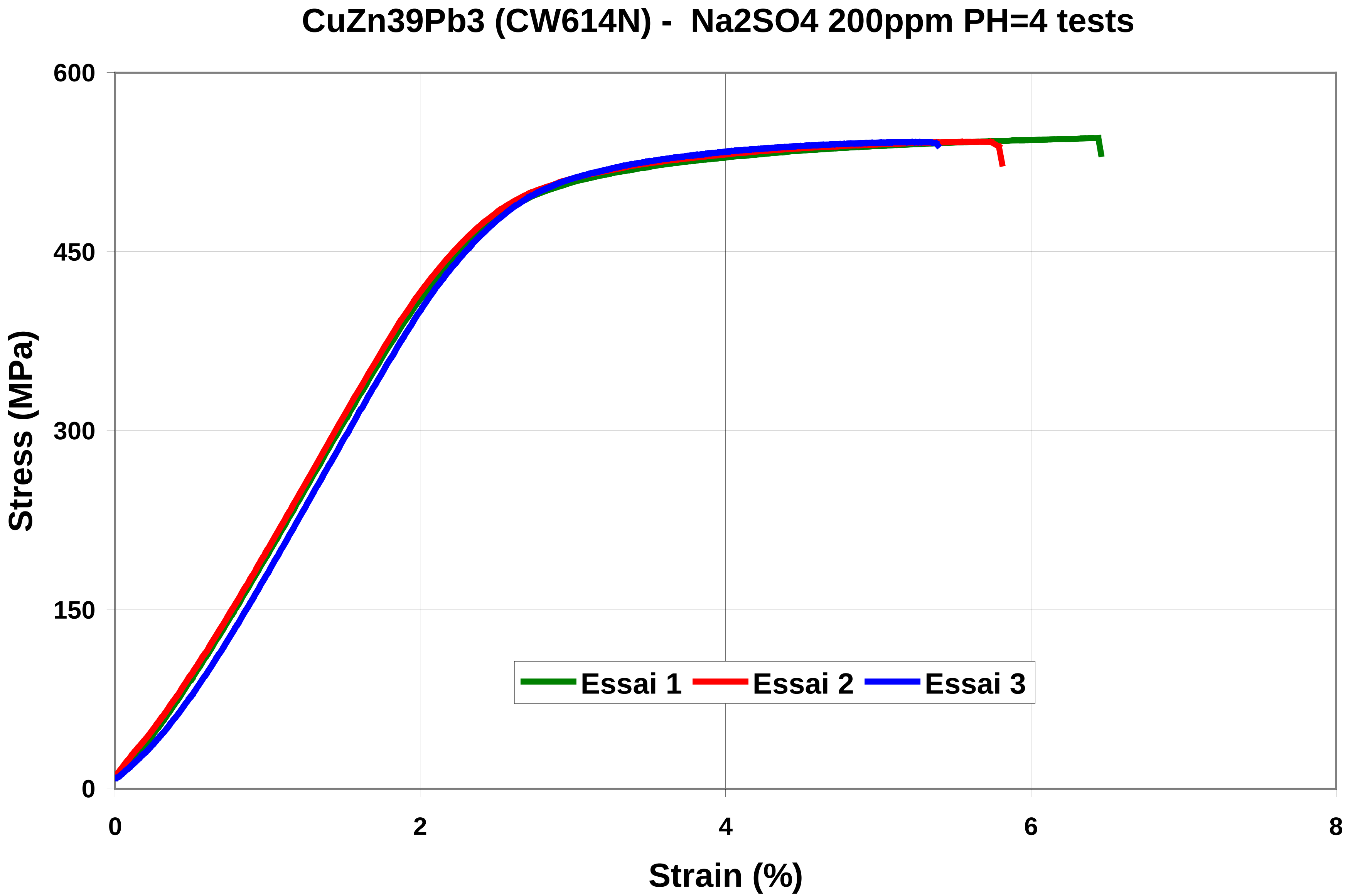

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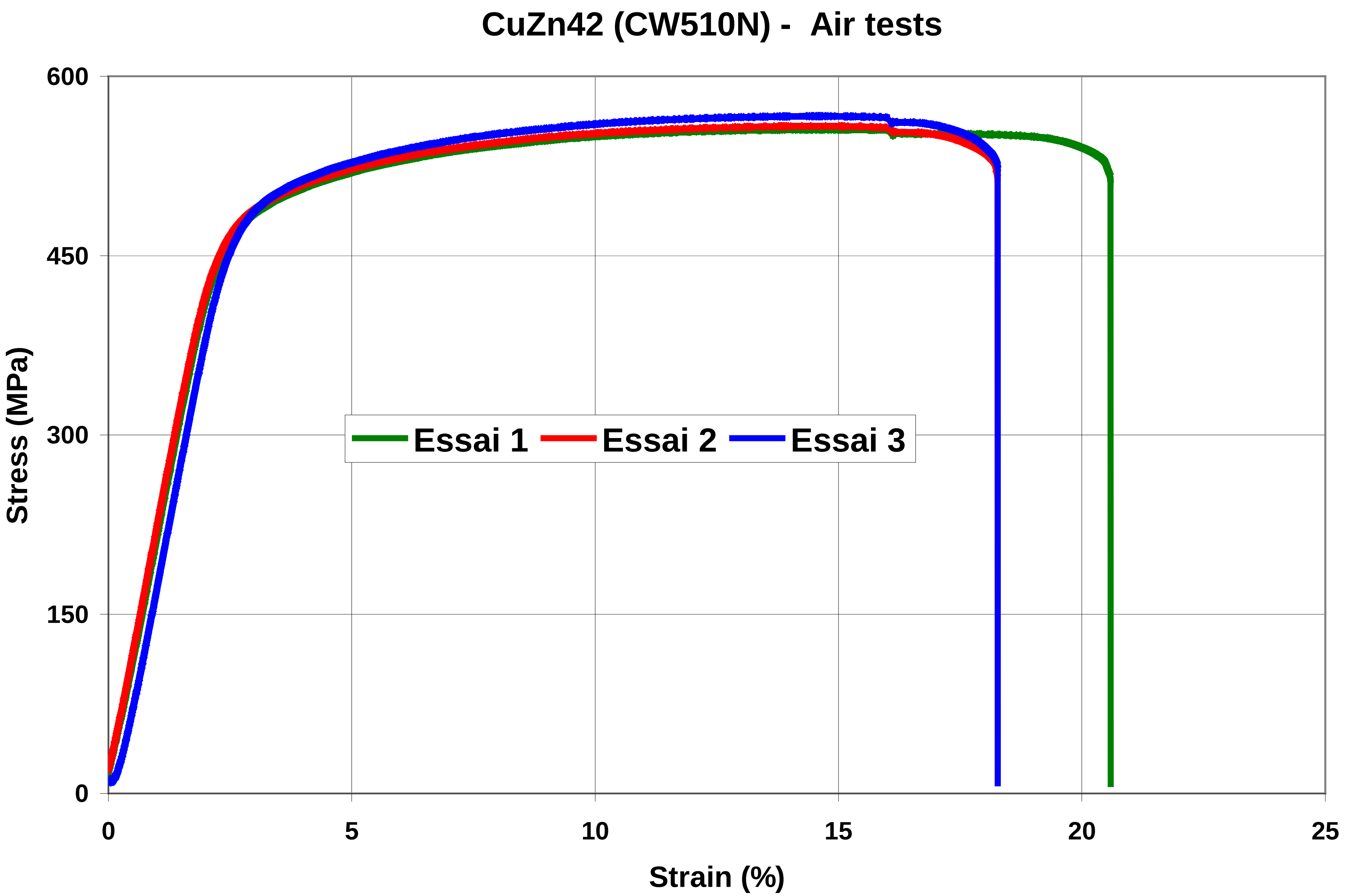

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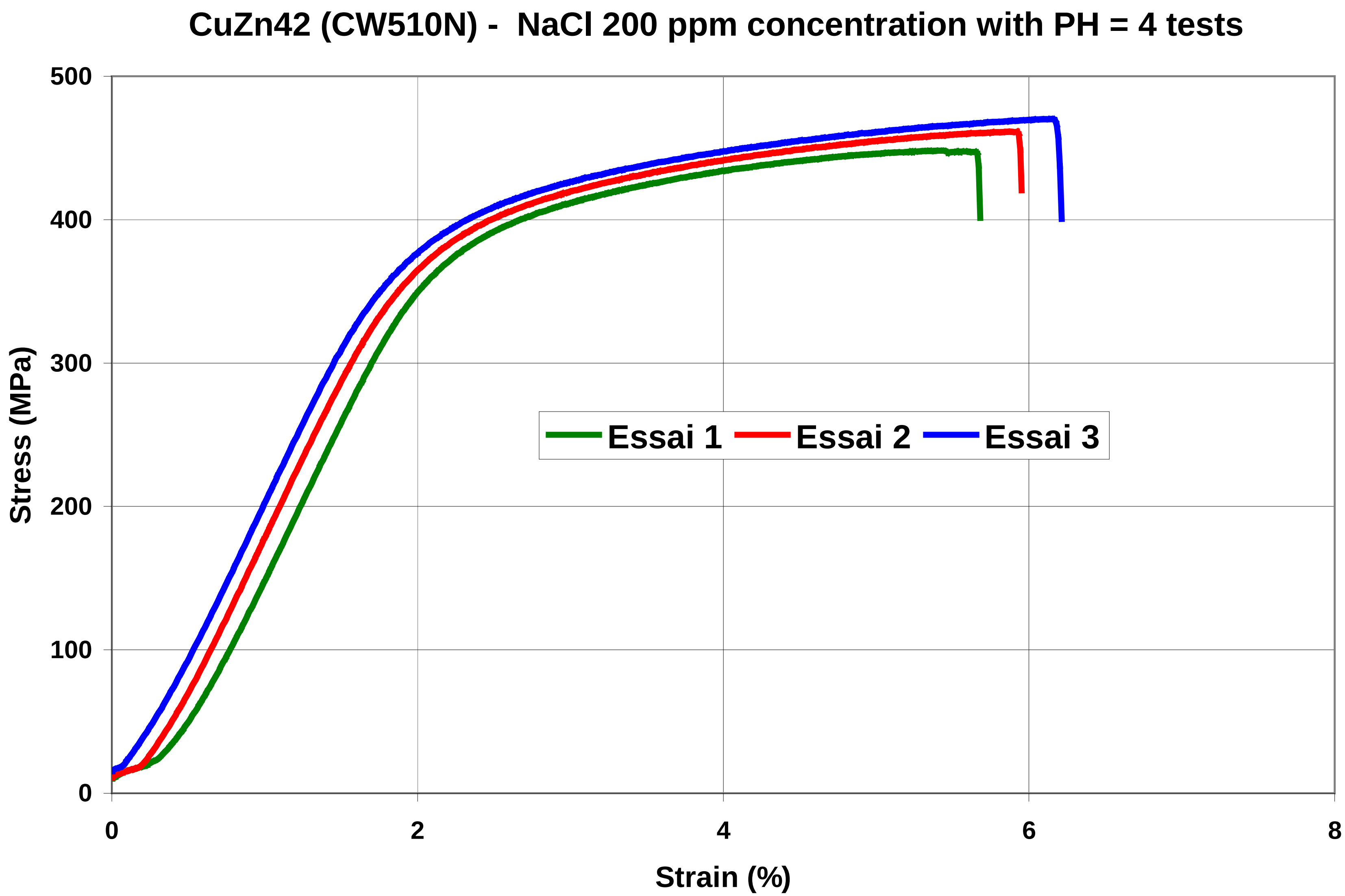

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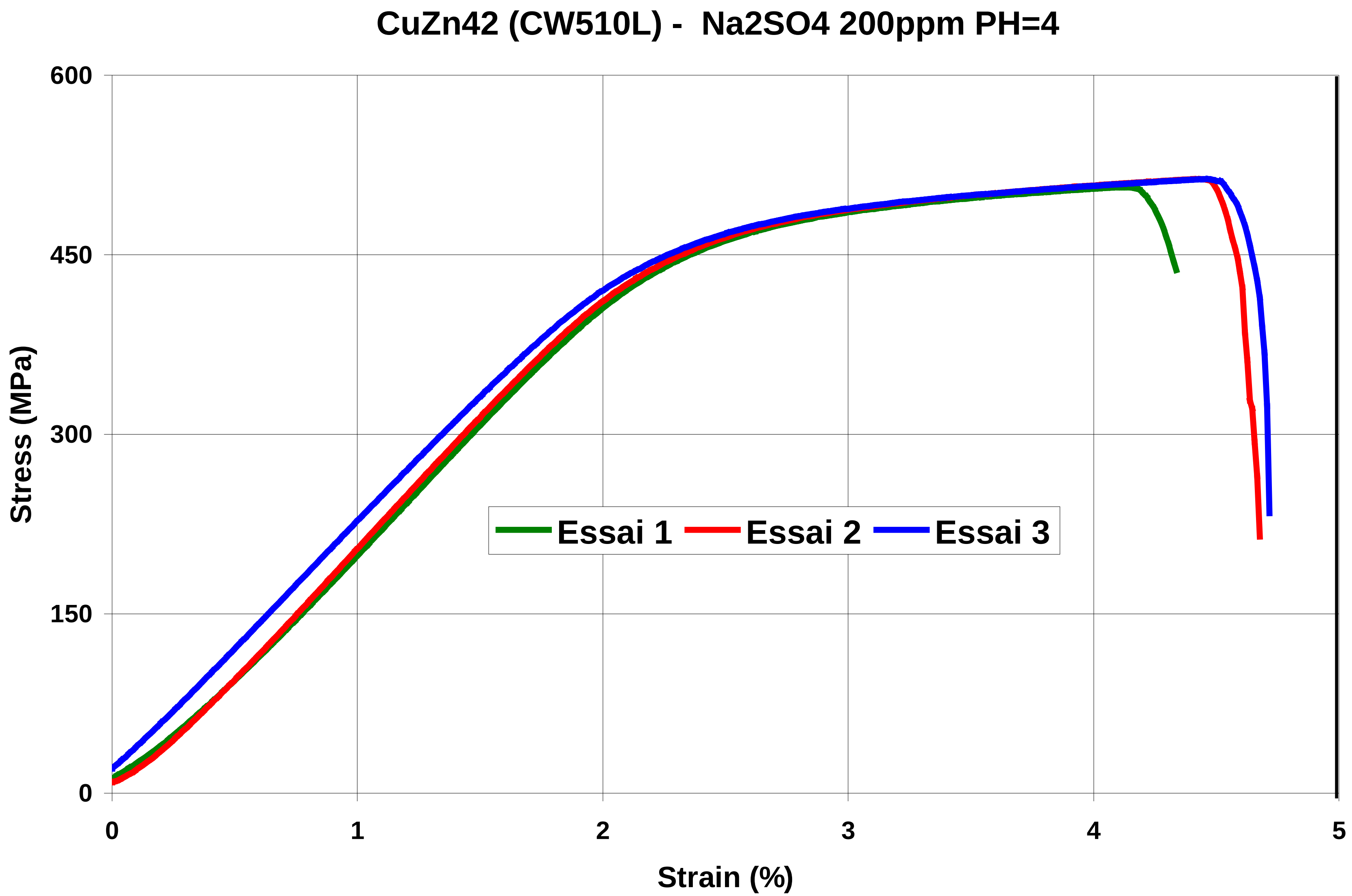

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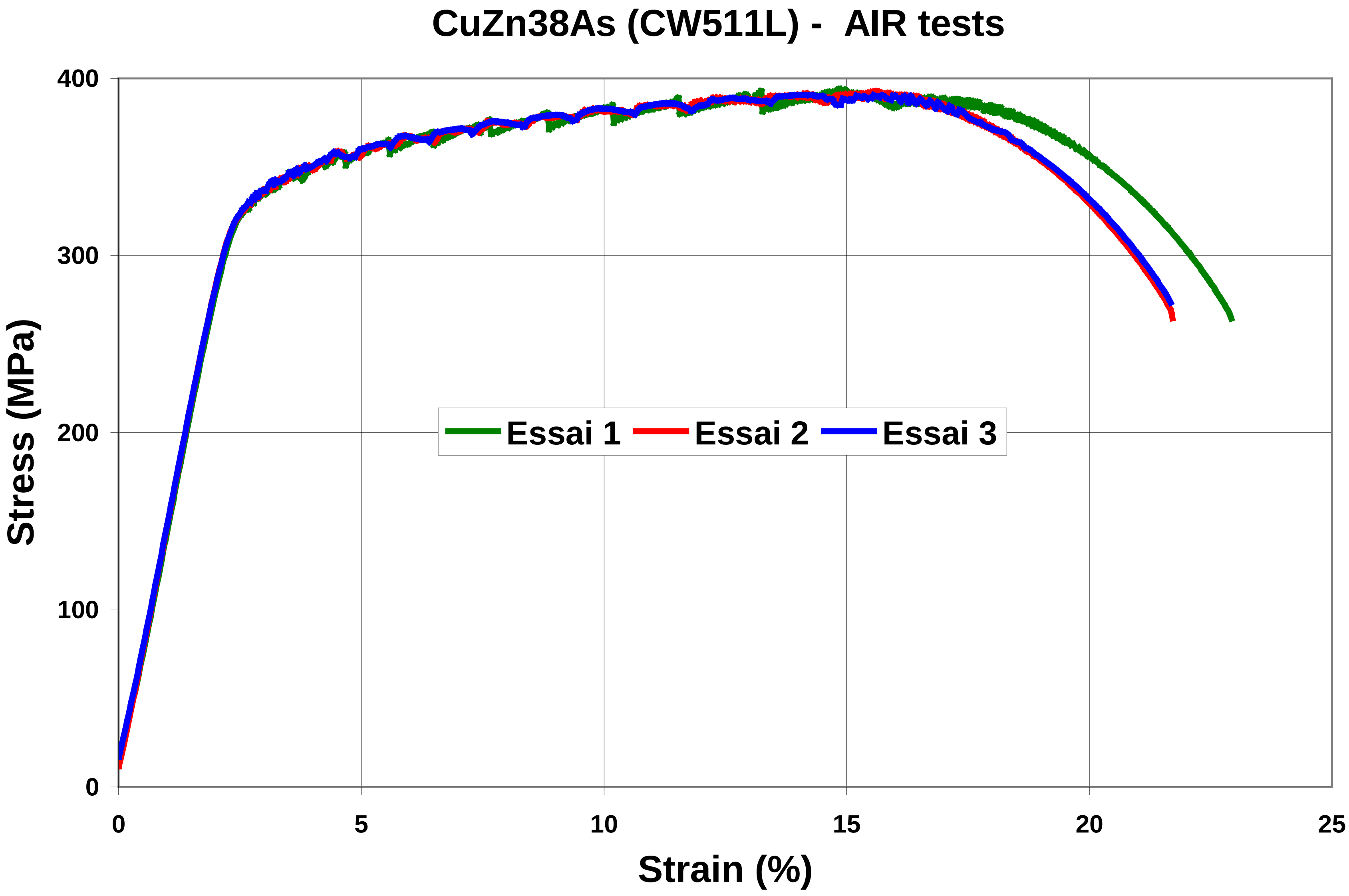

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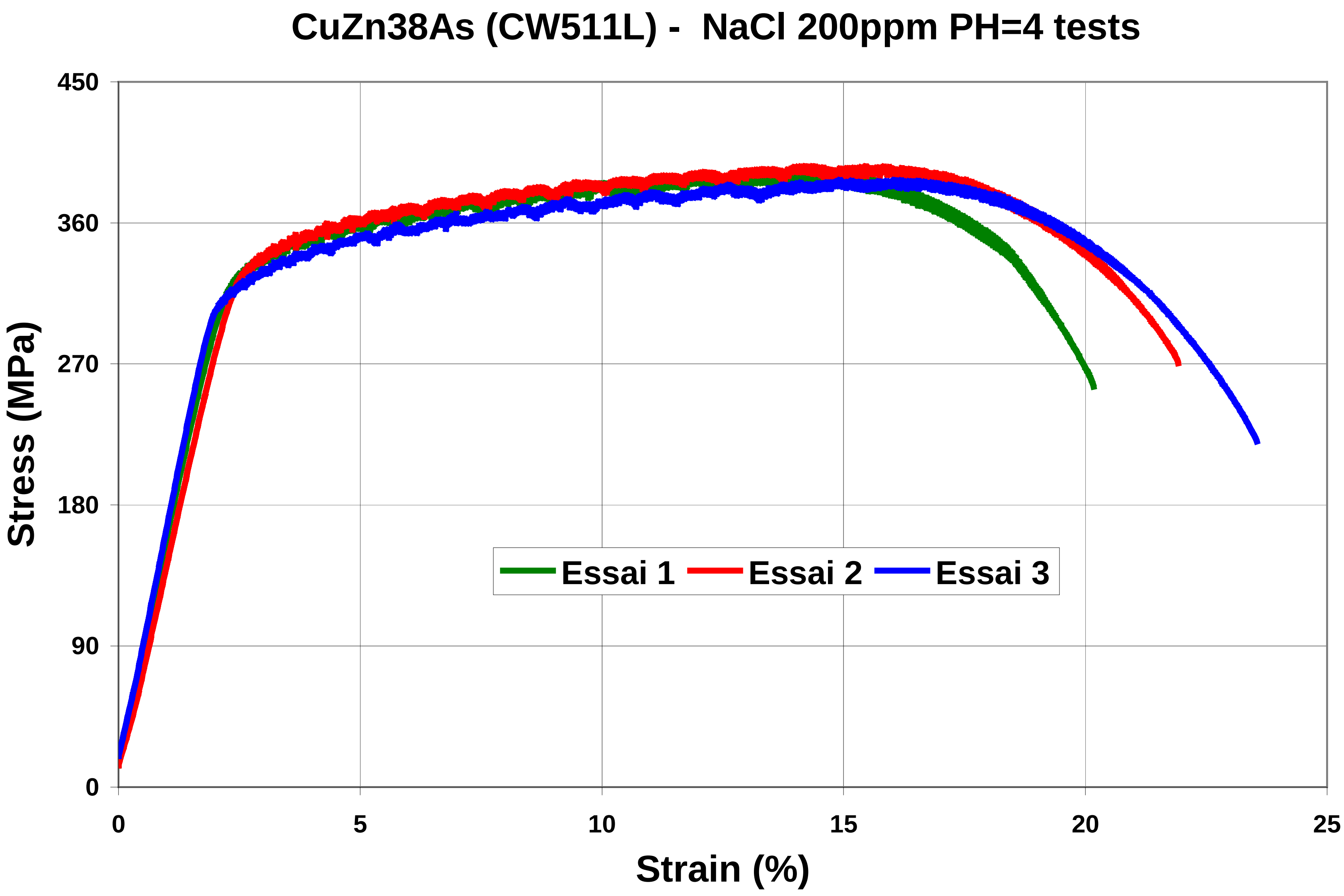

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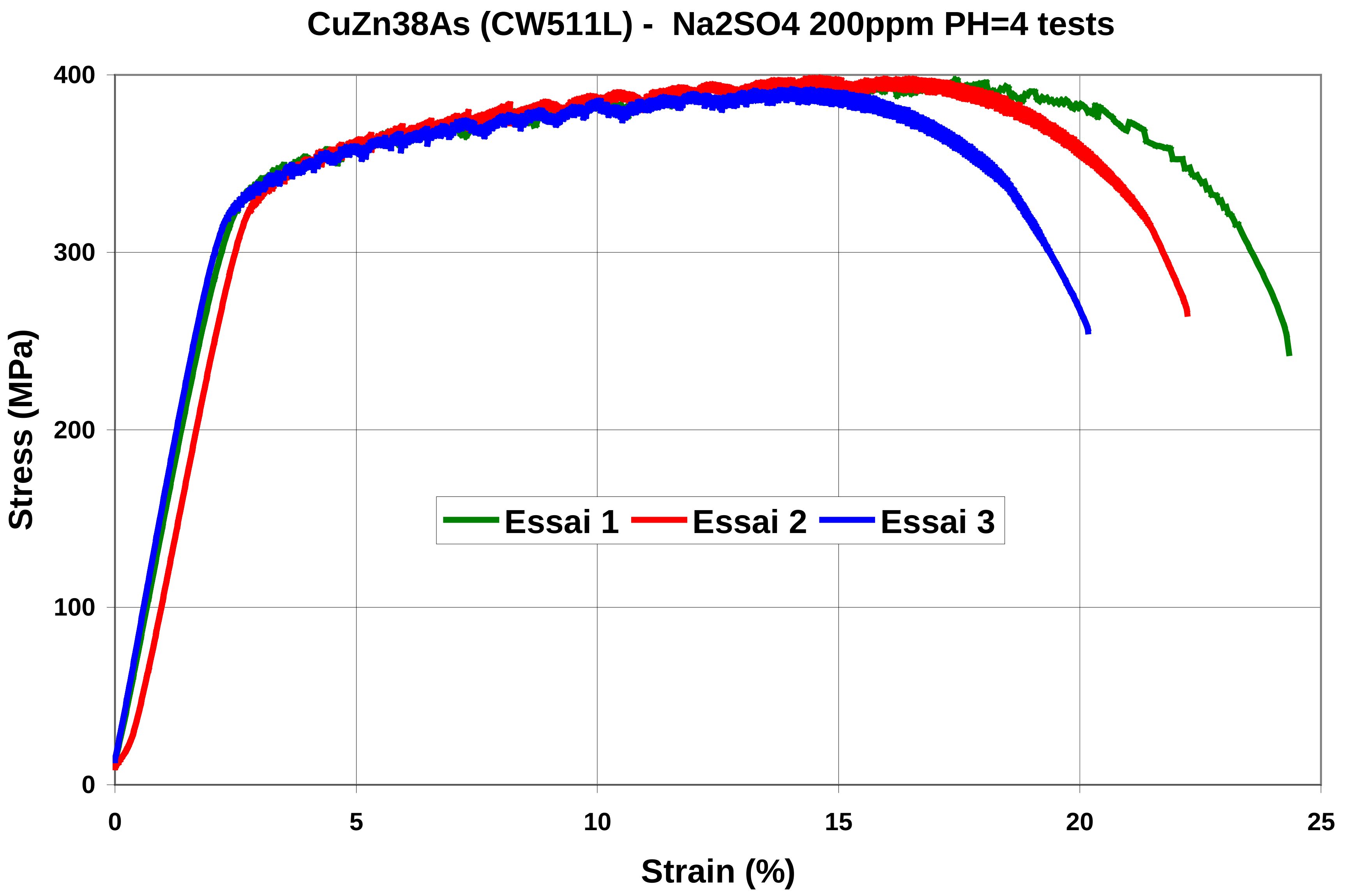

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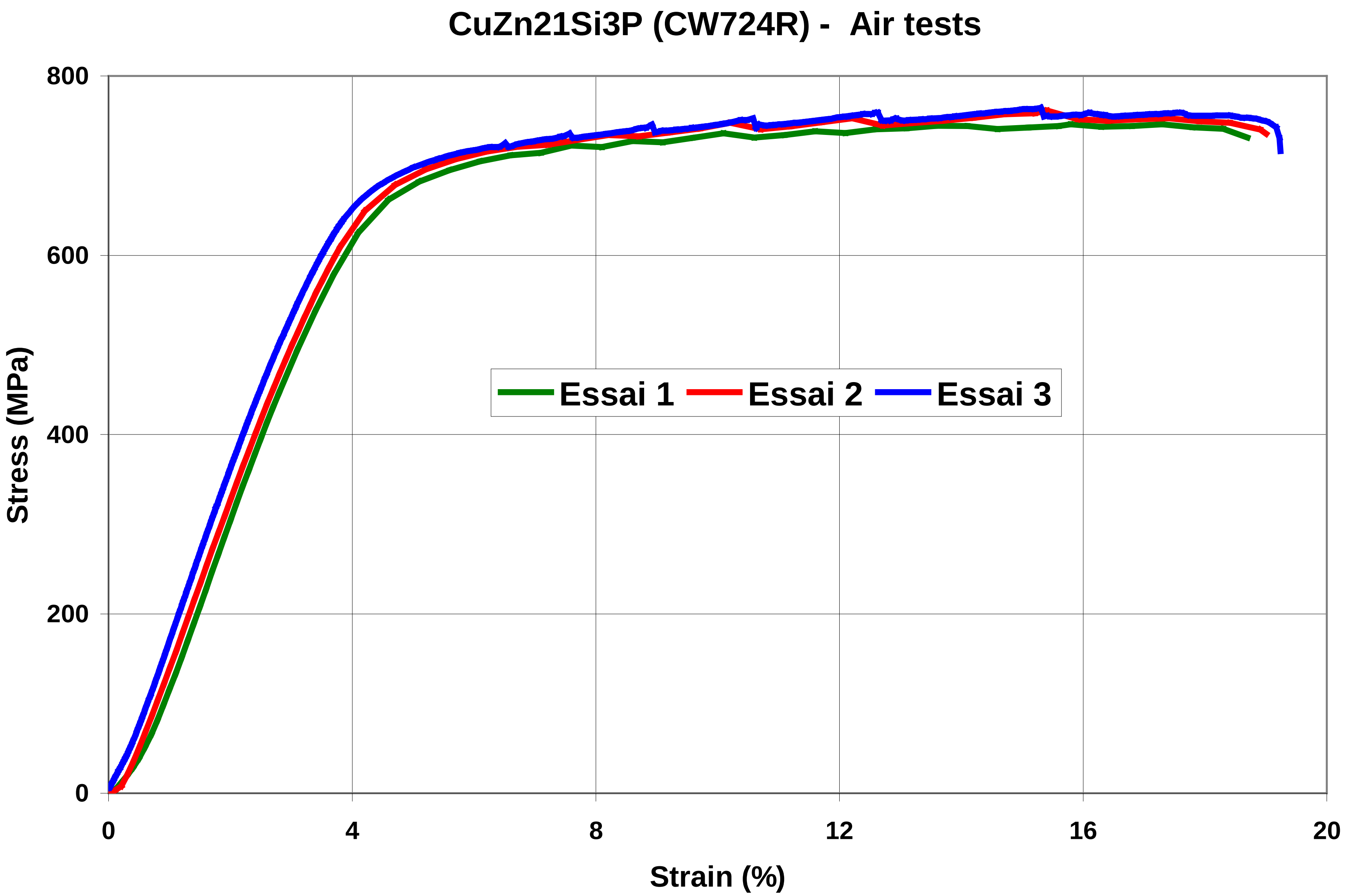

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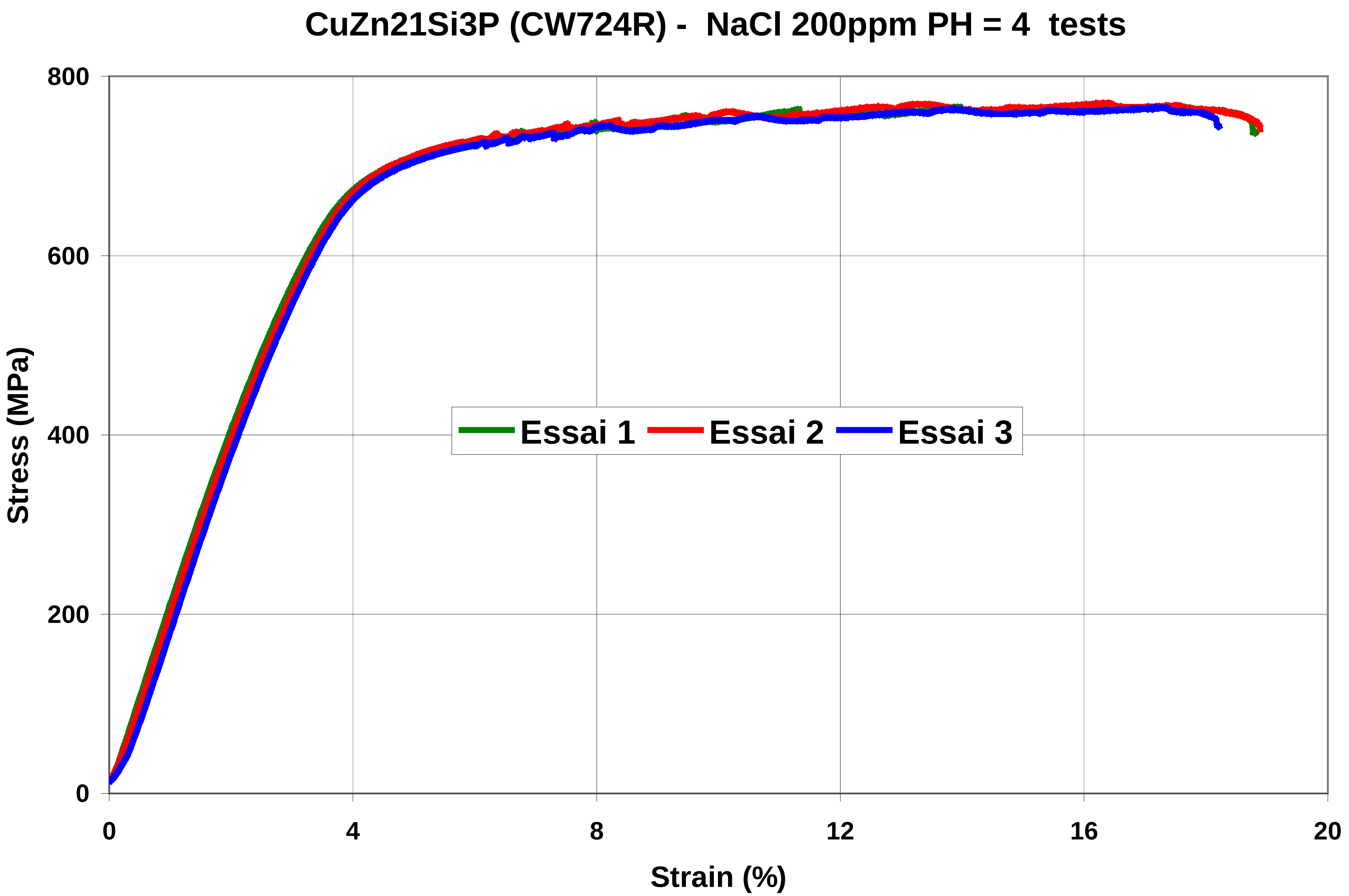

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