Colorless Copper-Containing Coatings With High Antimicrobial Efficacy and Formulation Versatility

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Supplementary Information

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Copper Quantification Method Development

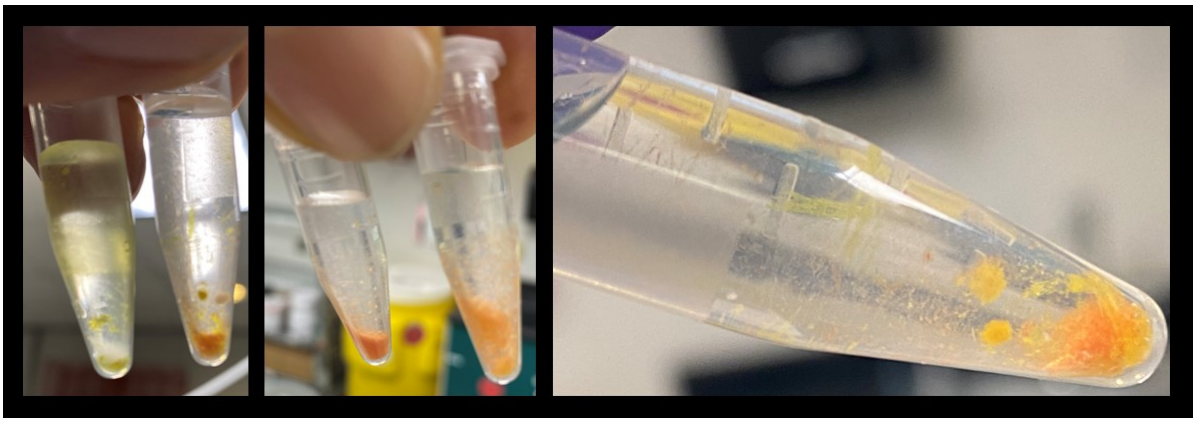

Figure S1: Visual example of CGC + Phosphite extraction samples prepared by the Neocuproine method showing crystallization and precipitation of the copper in microcentrifuge tubes.

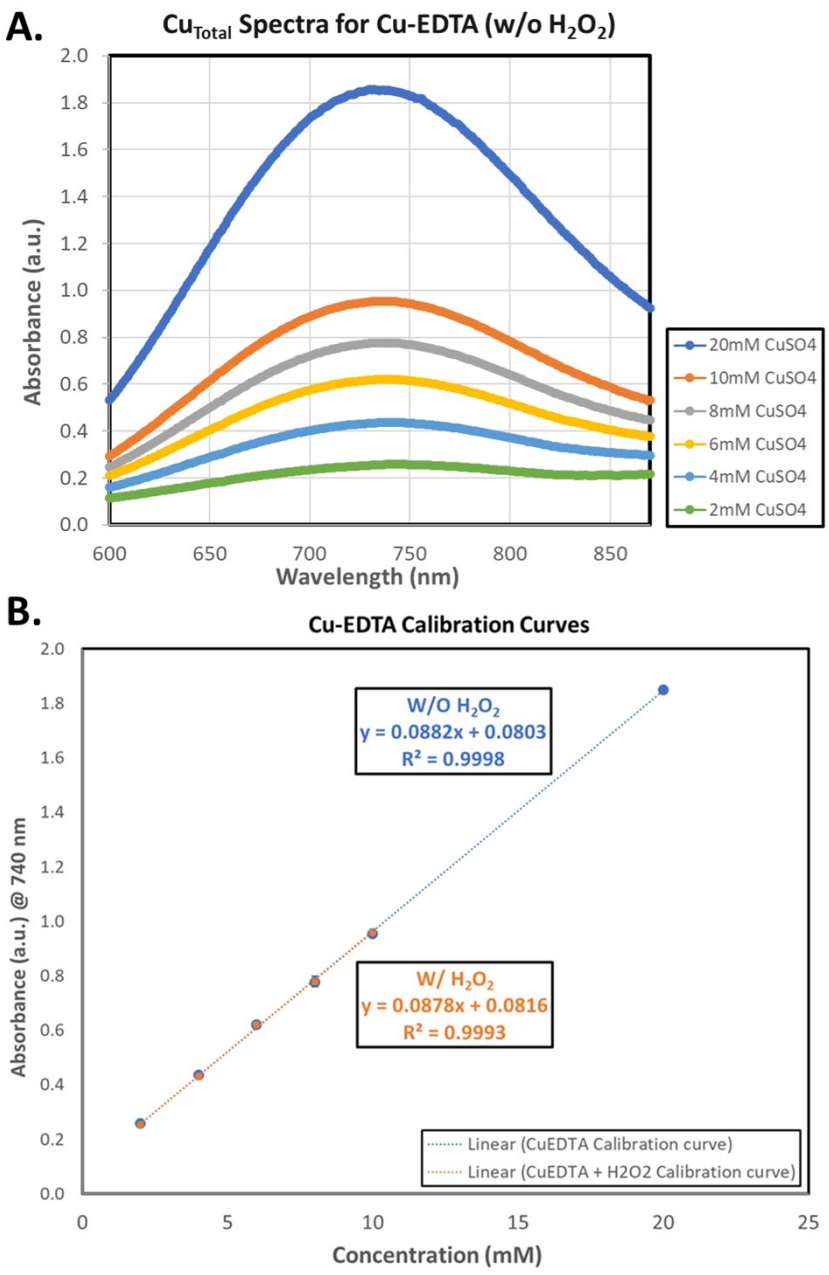

Figure S2: A. UV-vis data for the copper sulfate/EDTA calibration curve. B. Absorbance at 740 nm versus Cu^{2+} concentration calibration curves and line of best fit.

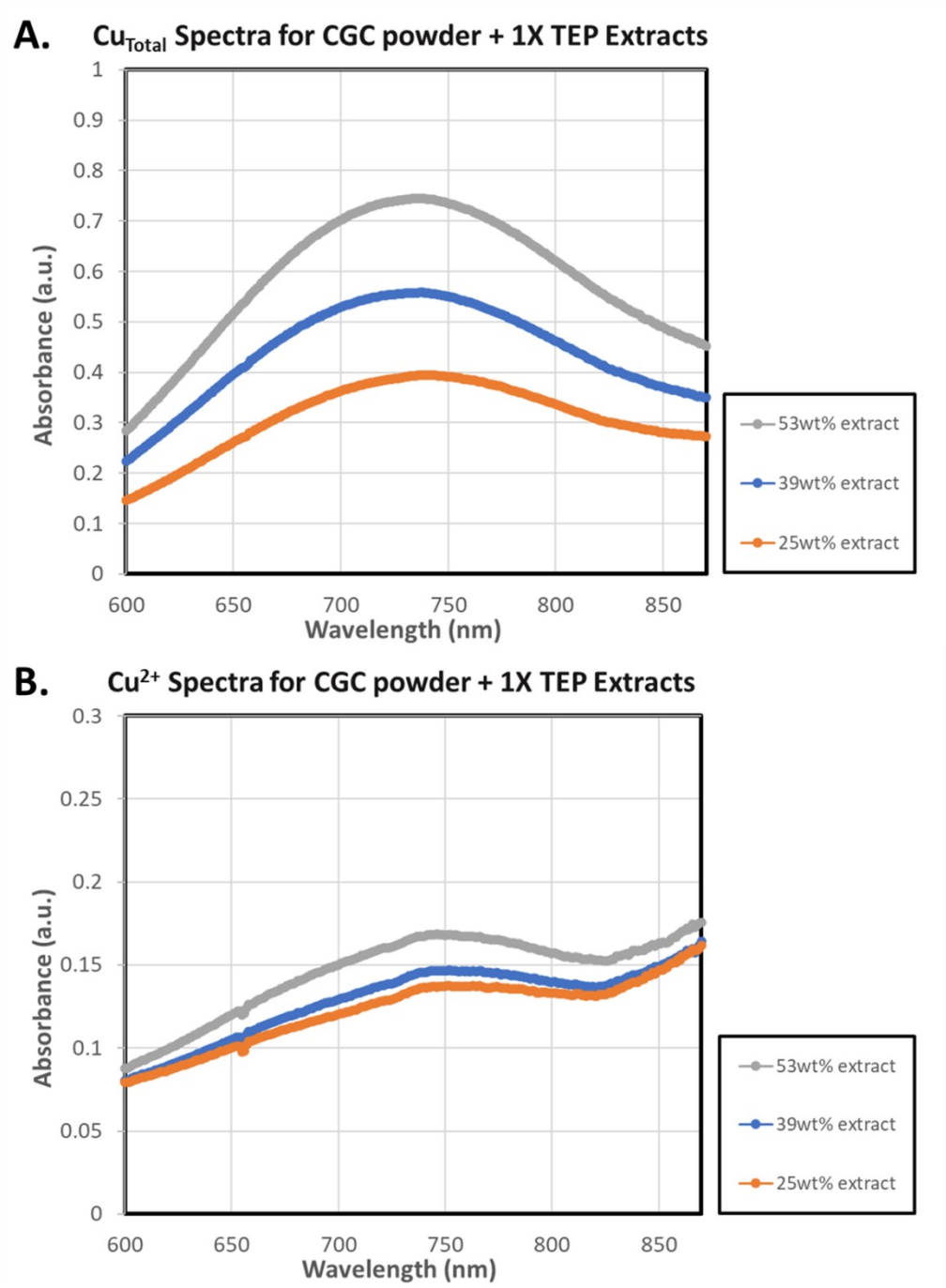

Figure S3: UV-vis spectrum for CGC powder extracts with TEP. **A.** Sample Cu_{Tot} curves. **B.** Curves used to derive $[Cu^{2+}]$. $[Cu_{Tot}]$ determination was made by adding 700 µl of 20 mM EDTA, 388 µl H_2O, 42 µl of copper extract solution, 20 µL of H_2O_2. $[Cu^{2+}]$ determination was made by adding 700 µl of 20 mM EDTA, 398 µl H_2O, 42 µl of copper extract solution. $[Cu^{1+}]$ is calculated by taking the difference between $[Cu_{Tot}]$ and $[Cu^{2+}]$.

$^{31}P\{^{1}H\}$ NMR Parameters for Copper(I) Coordination Environment

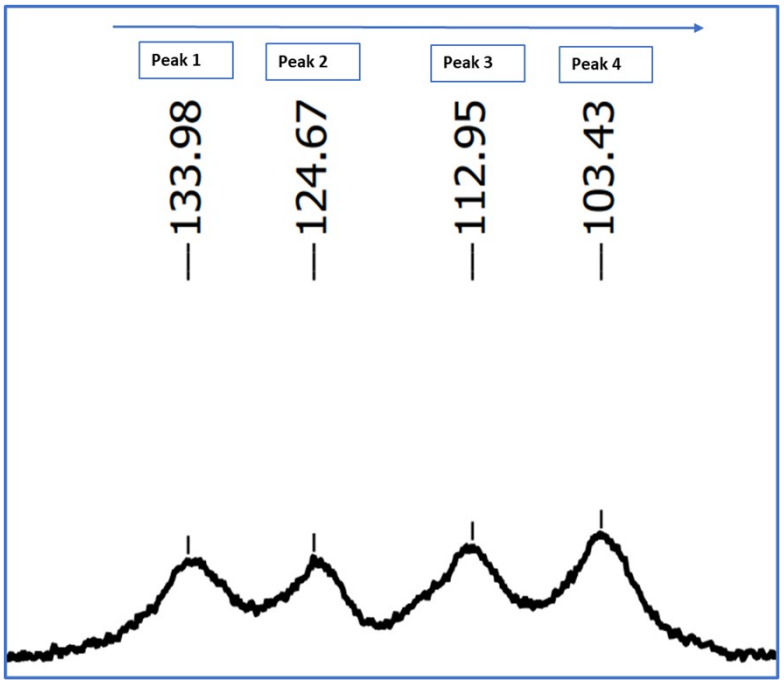

Figure S4: $^{31}P\{^{1}H\}$ NMR spectrum of CGC extract with TEP showing an asymmetric quartet structure due to spin-spin coupling of the phosphorus nuclei to the copper nucleus (^{63}Cu, ^{65}Cu; I = 3/2) in water.

The following expressions were used to investigate the possible relationship between the ^{31}P NMR parameters and the coordination environment about the copper(I) atom [1-5].

$$\Delta V1\ (kHz) = \frac{[121.41\ \times\ (\ peak\ 1 - peak\ 2)]}{1000}$$

$$\Delta V2\ (kHz) = \frac{[121.41\ \times\ (\ peak\ 2 - peak\ 3)]}{1000}$$

$$\Delta V3\ (kHz) = \frac{[121.41\ \times\ (\ peak\ 3 - peak\ 4)]}{1000}$$

$$\Delta Vi\ (kHz) = \frac{[\Delta V1 + \Delta V2 + \Delta V3\ ]}{3}$$

Center δ	Peak 1	Peak 2	Peak 3	Peak 4
ppm	ppm	ppm	ppm	ppm
118.71	133.98	124.67	112.95	103.43

Table 1. Summary calculations of $^{31}P\{^{1}H\}$ NMR parameters used to determine number of phosphorous atoms coordinated to the copper(I) center.

				118.71	Center (ppm)		
9.31	ppm	1130.33	Hz	1.13	ΔV1	kHz	Low field line spacing
11.72	ppm	1422.93	Hz	1.42	ΔV2	kHz	
9.52	ppm	1155.82	Hz	1.16	ΔV3	kHz	High field line spacing
				1.24	ΔVi (average)	kHz	*Coordination number information
				1.02	ΔV3/V1 (ratio)		Asymmetry of the line spacing

*How to interpret the line spacing <ΔVi> of the quartet?		
~1.6	kHz	One coordinated phosphine
1.2	kHz	Two coordinated phosphine
0.9	kHz	Three coordinated phosphine

Interpretation of results	
1.24	The derived ΔVi_{Av} value suggests a two coordinate phosphorous-copper(I) complex is present.

Antimicrobial Glass Film Surface Metrology

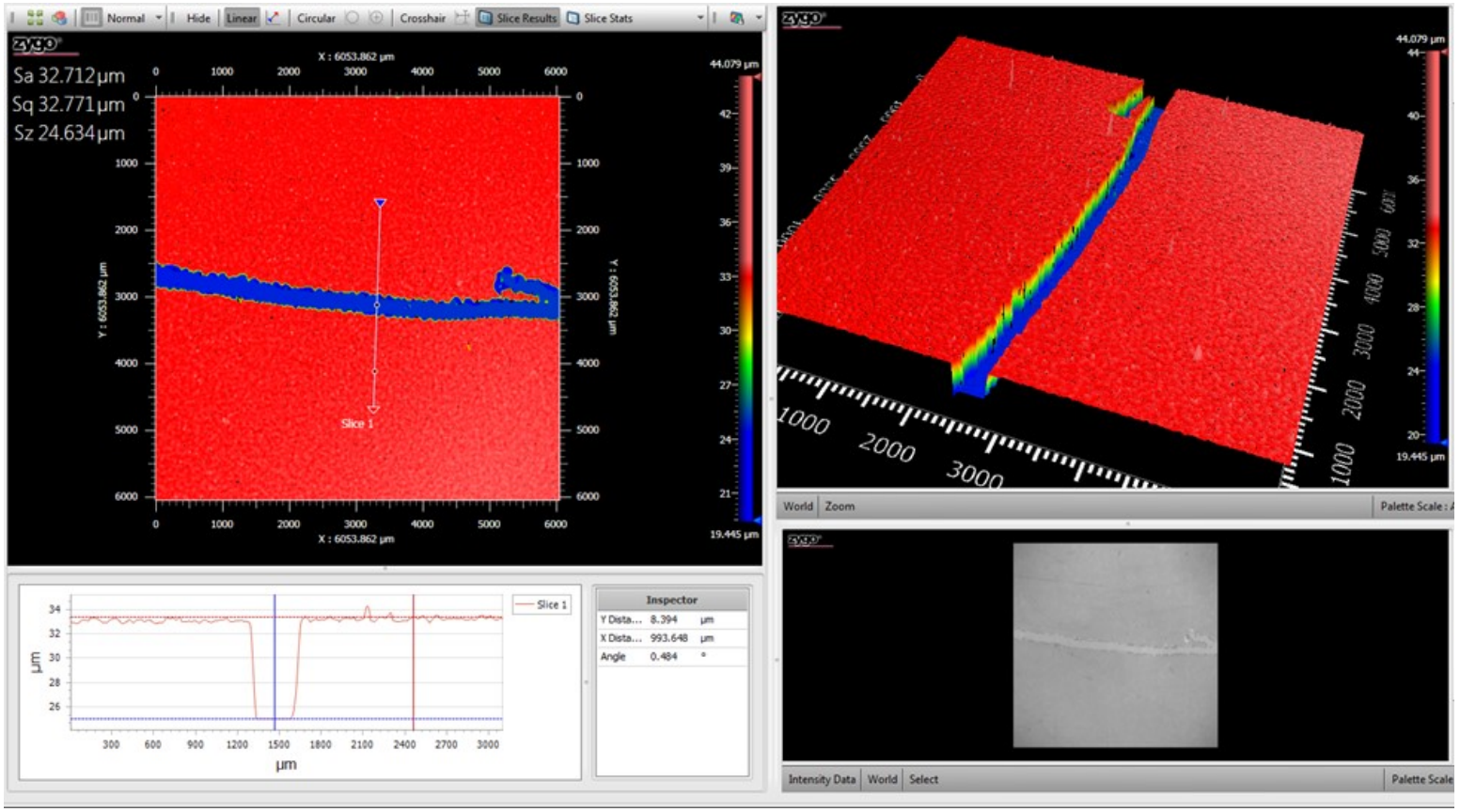

Figure S5: Zygo film thickness measurement for Ferro 221 series coating on Corning® EAGLE XG® Glass with no copper glass-ceramic (CGC) powder or CGC powder extract, flash cured at 150 °C.

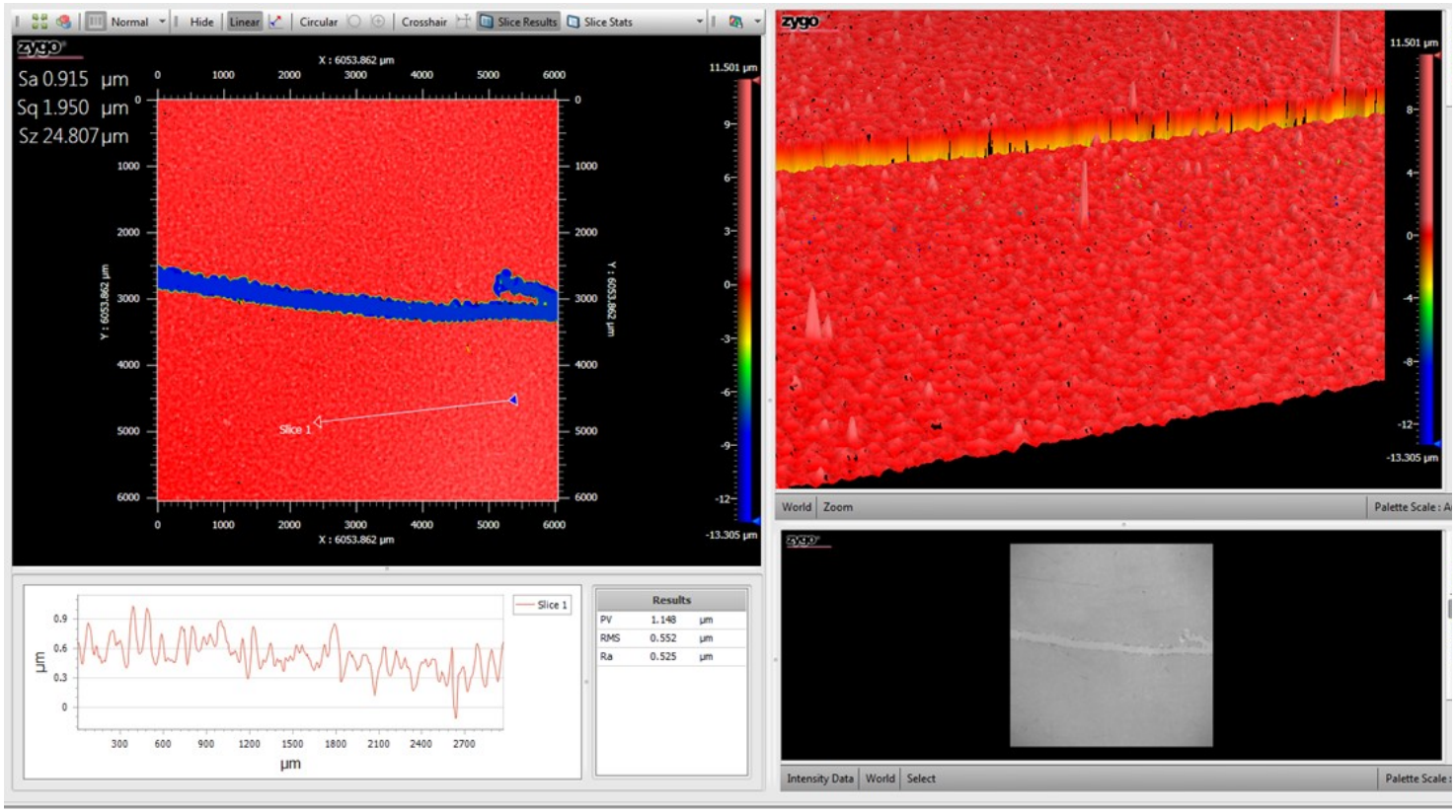

Figure S6: Zygo film surface roughness measurement for Ferro 221 series coating on Corning EAGLE XG Glass with no copper glass-ceramic (CGC) powder or CGC powder extract, flash cured at 150 °C.

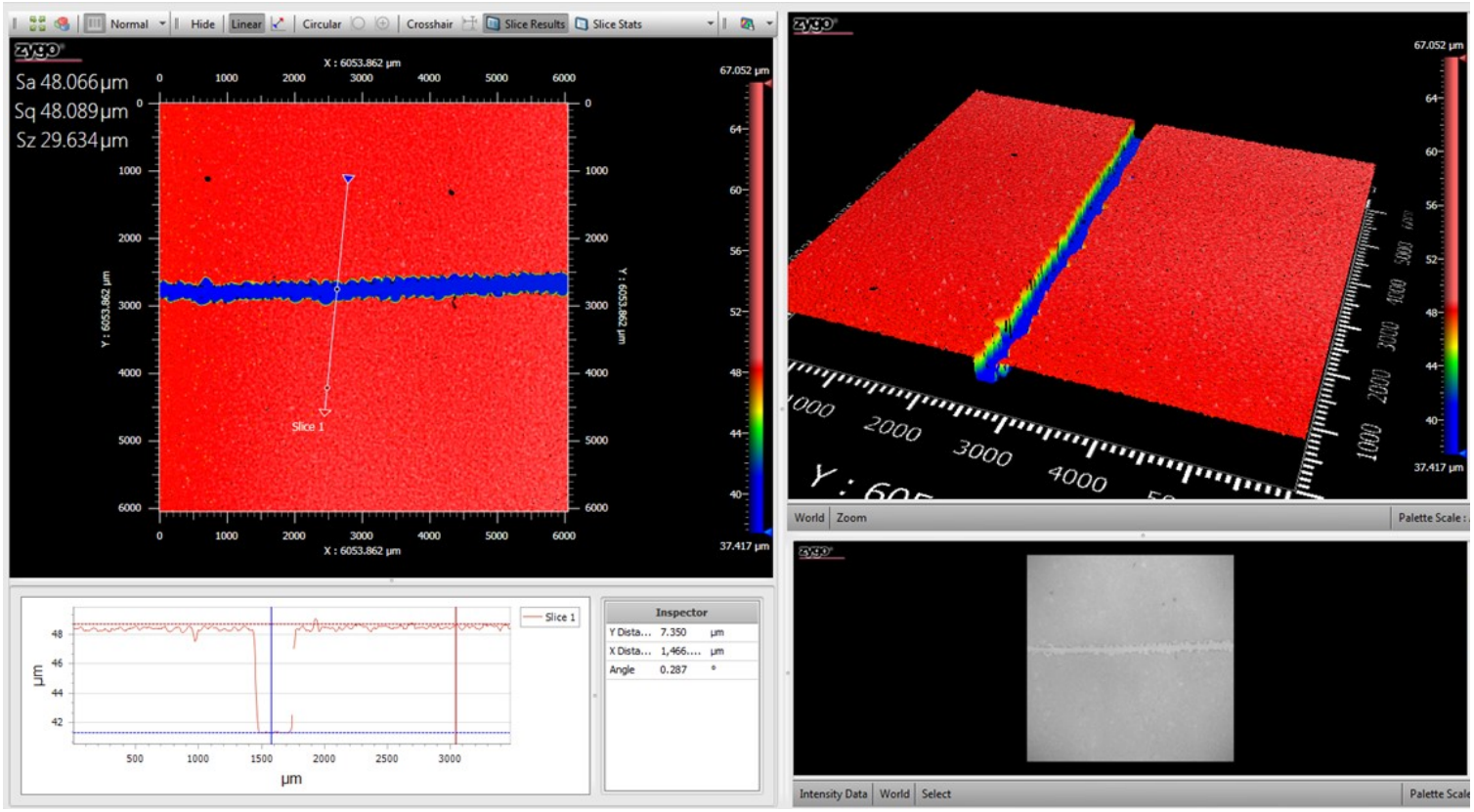

Figure S7: Zygo film thickness measurement for Ferro 221 glass coating on Corning EAGLE XG Glass dosed with copper glass-ceramic (CGC) powder extracts with triethyl phosphite (TEP) ($[Cu]_{Tot}$ = 600ppm) and cured at 120 °C.

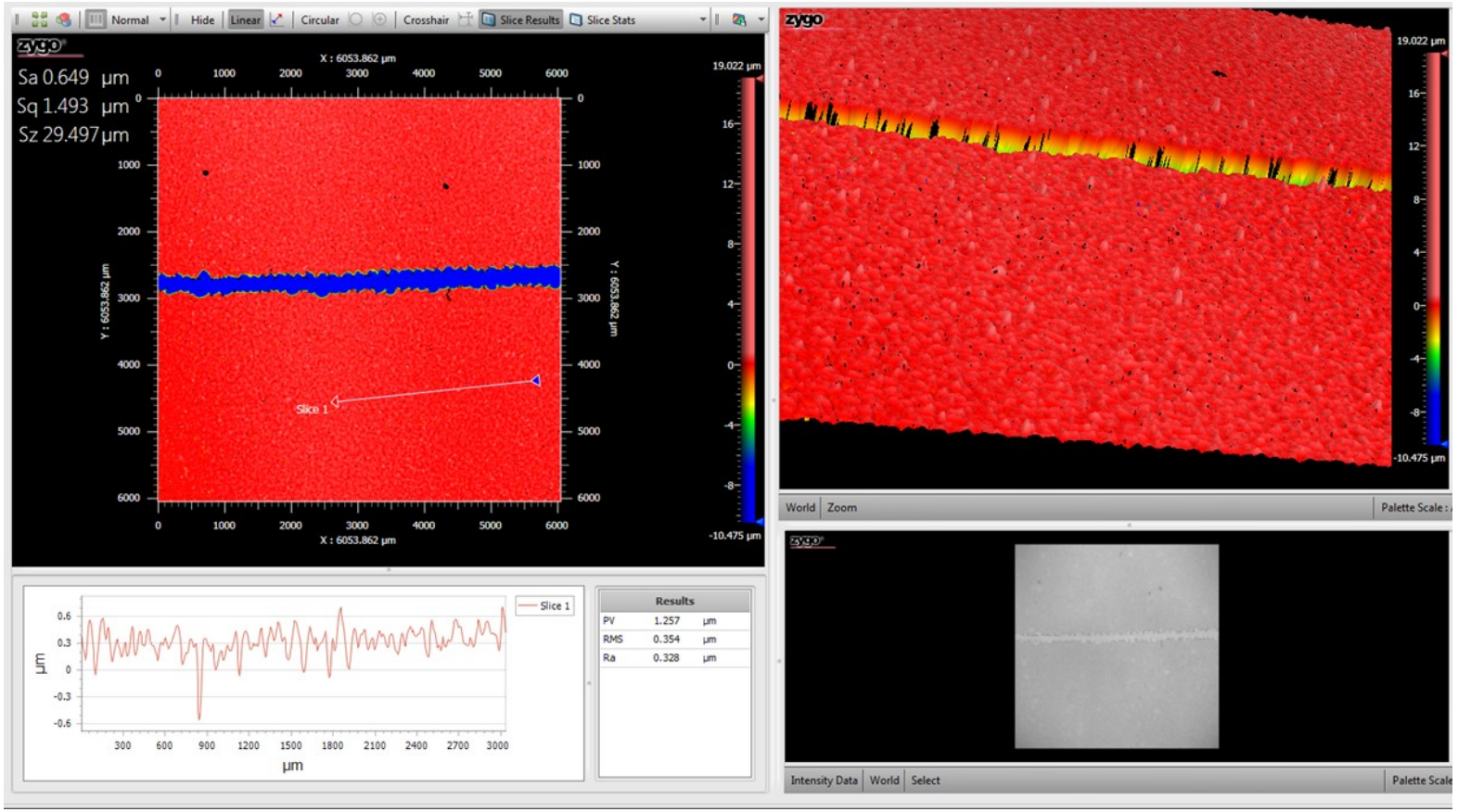

Figure S8: Zygo film surface roughness measurement for Ferro 221 glass coating on Corning EAGLE XG Glass dosed with copper glass-ceramic (CGC) powder extracts with triethyl phosphite (TEP) ($[Cu]_{Tot}$ = 600ppm) and cured at 120 °C.

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1. Bowmaker, G.A., et al., *Structural, vibrational and solid-state NMR studies of the halogenocuprate (I) complexes [(PPh3) 2CuI2]-and [(PPh3) CuI3Cu (PPh3)].* Inorganic Chemistry, 1989. **28**(20): p. 3883-3888.

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