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CORNING GLASS WORKS
ELECTRO-OPTICS LABORATORY
RALEIGH, NORTH CAROLINA

IMPROVED SCREEN FOR REAR PROJECTION VIEWERS

Technical Report No. P-19-25, 26, 27

Date - October 13, 1967

Period Covered - July 22, 1967
to
October 13, 1967

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ABSTRACT

Modulation transfer function data has been obtained for a representative group of Corning and commercial rear projection screen samples.

It was determined that Fotoform® glass should not be considered as a rear projection screen material, because there is little flexibility in choice of optical properties, and such screens are very difficult and expensive to fabricate.

Electron photomicrographs of six BB-series glass ceramic materials have been obtained, and particle number density and average size have been determined.

The Electronic Products Division of Corning Glass Works has used existing technologies to fabricate very uniform ceramic powder screens.

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TECHNICAL REPORTS NO. 25, 26 and 27

I. Modulation Transfer Function Measurements

Modulation transfer function (MTF) data has been obtained for a representative group of Corning and commercial rear projection screen materials. The materials measured were Corning glass ceramic BB2A, Fotoform® glass, and a beaded screen, while the commercial materials measured were Polacoat LS60G and LS40-120, Trans-Lux AV6-G and 550R, and Polacoat TR50PL. The MTF data is shown in Fig. 1. The screens fell into two groups, with LS60G, TR50PL, and a Corning beaded screen having considerably better resolution than the other materials. At a space frequency of 10 lines/mm, the MTF's of all the low resolution materials are <0.2, while the MTF's of the high resolution group range from 0.6 - 0.7, therefore none of these materials meets the requirement of MTF ≥ 0.9 at 10 lines/mm.

The relatively low resolution of the Corning glass-ceramic and Fotoform® glass materials is due to excessive thickness of the scattering layer. High resolution glass ceramic screens are being fabricated by mixing finely ground ceramic powder with a plastic resin of the proper refractive index and applying this mixture to transparent substrates in very thin coats.

The beaded screen which was measured contained glass beads up to 50 microns in diameter. This maximum bead diameter could be decreased a factor of two, giving a comparable improvement in resolution.

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II. Fotoform® Glass Screens

The 8" x 10" Fotoform® glass screens which were being fabricated were broken during final grinding and polishing operations. A 4" x 4" screen was salvaged and its optical properties measured. The measurement results are shown in Fig. 2 and Fig. 3. It is seen that this screen had good efficiency, moderate brightness variation, and low diffuse reflectance.

In spite of certain desirable properties of this screen, mainly that the scattering layer and substrate are an integral unit, it is felt that Fotoform® glass should not be considered as a rear projection screen material, for the following reasons:

1) These screens are very difficult and expensive to fabricate.

2) The nature of Fotoform® glass and the necessary heat treatment dictates that there is little flexibility in choice of optical properties, while glass ceramics allow considerable flexibility.

III. Glass Ceramic Screens

A. Number Density and Particle Size Data

The most recent glass ceramic materials which were received and evaluated are the BA, BB, and BC series samples, for which the optical properties were summarized in technical report No. 21. Six of these samples - BB-1, 7, 11, 16, 18, and 19 - covering a range of axial gains from 1 to 6, were selected for further investigation. Quantities of ceramic powder made from each of these materials have been obtained for use in ceramic powder screen

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fabrication. Electron photomicrographs of these materials are shown in Figs. 4 through 9. Number density and average particle size data has been obtained from the photomicrographs and is shown in Fig. 10. The number density is typically 10^{13} per cm^3, which is apparently in the desired range for fabrication of thin-layer screens. The particle sizes are somewhat smaller than would be expected from the axial gain values of the original bulk samples. This may be evidence of the fact that there seems to be two separate crystal phases present in some of the materials, with the second phase consisting of very large particles. These materials will be used for screen fabrication until more suitable materials are obtained.

B. Fabrication

The Electronic Products Division of Corning Glass Works, using existing technologies, have fabricated ceramic powder screens from a mixture of ceramic powder and a plastic binder. Screens of this type have been made on rigid as well as flexible substrates. Very uniform screens have been made because of the precise control which is obtainable over the layer thickness. The optical properties of one such screen are shown in Figs. 11 and 13. The axial gain of this screen is higher than that obtained from the corresponding bulk material because a close refractive index match between the embedding resin and the bulk glass was not obtained, and refraction occurred at the interfaces of the bulk glass and the resin. Nevertheless, this screen has excellent properties for narrow viewing angle applications, as can be seen by comparing its optical

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properties with those of the high-gain Polacoat LS-75 (see Figs. 12 and 13). The search for compatible plastics of different refractive indices for index matching is continuing, and it should be noted that control of the index mismatch is potentially an additional technique for varying the optical properties of ceramic powder screens.

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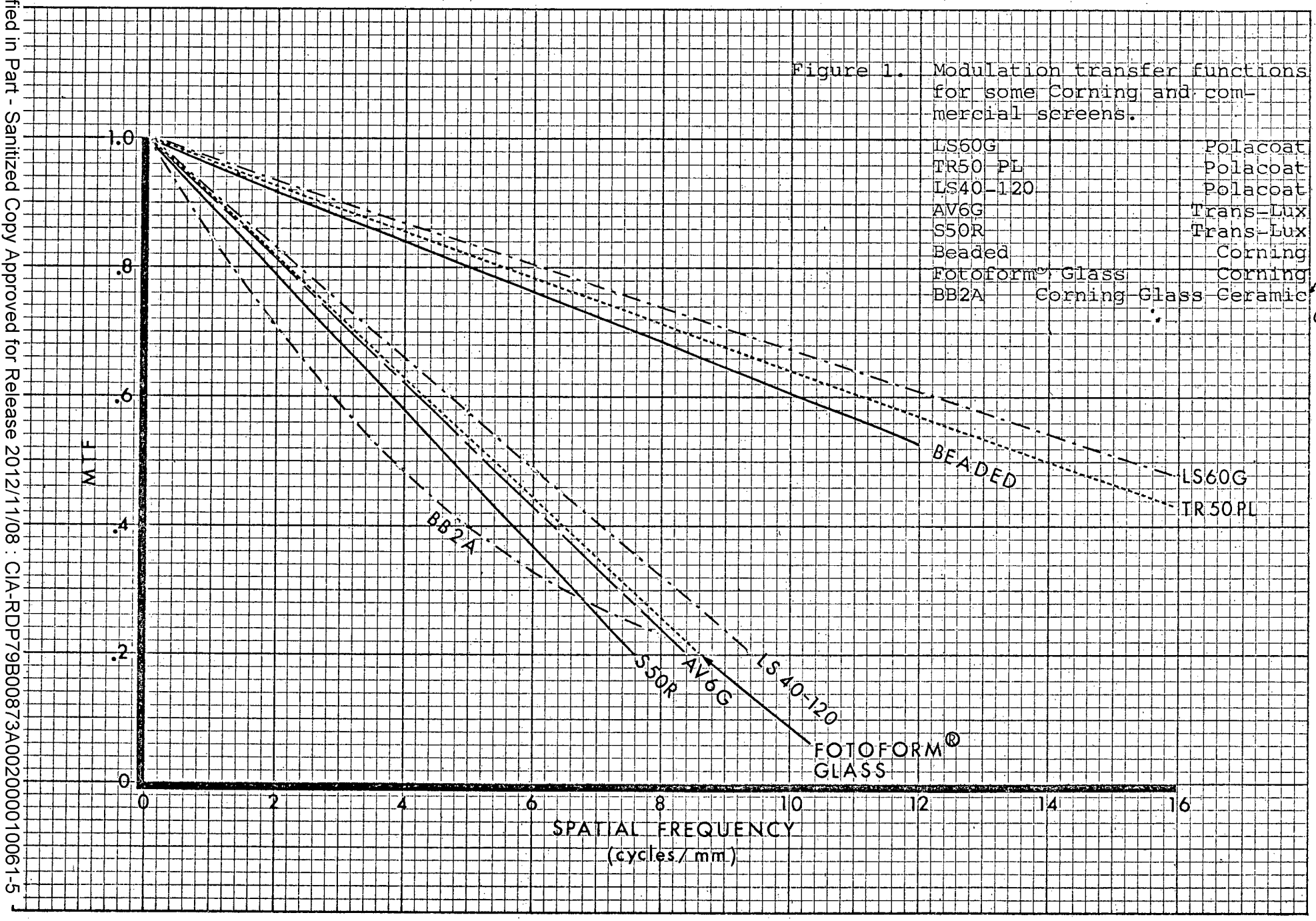

Figure 1. Modulation transfer functions for some Corning and commercial screens.

LS60G	Polacoat
TR50 PL	Polacoat
LS40-120	Polacoat
AV6G	Trans-Lux
S50R	Trans-Lux
Beaded	Corning
Fotoform® Glass	Corning
BB2A	Corning Glass Ceramic

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ON AXIS

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Figure 2. ANGULAR GAIN FUNCTION FOR SAMPLE **Fotoform® Glass**

FRACTION OF POWER INSIDE 90 DEGREES = .753

FRACTION OF POWER INSIDE 45 DEGREES = .554

BRIGHTNESS VARIATION = +- .515625

SPECULAR TRANSMITTANCE = 0

R_d = 7.3%

ANGLE K	I[K]	GAIN[K]
0	.97	4.294
5	.867	3.851
10	.768	3.453
15	.676	3.098
20	.583	2.744
25	.489	2.39
30	.416	2.125
35	.328	1.771
40	.264	1.527
45	.219	1.372
50	.167	1.151
55	.123	.952
60	.09	.797
65	.063	.664
70	.042	.544
75	.027	.465
80	.007	.186
85	.001	.066
90	0.00	0.00

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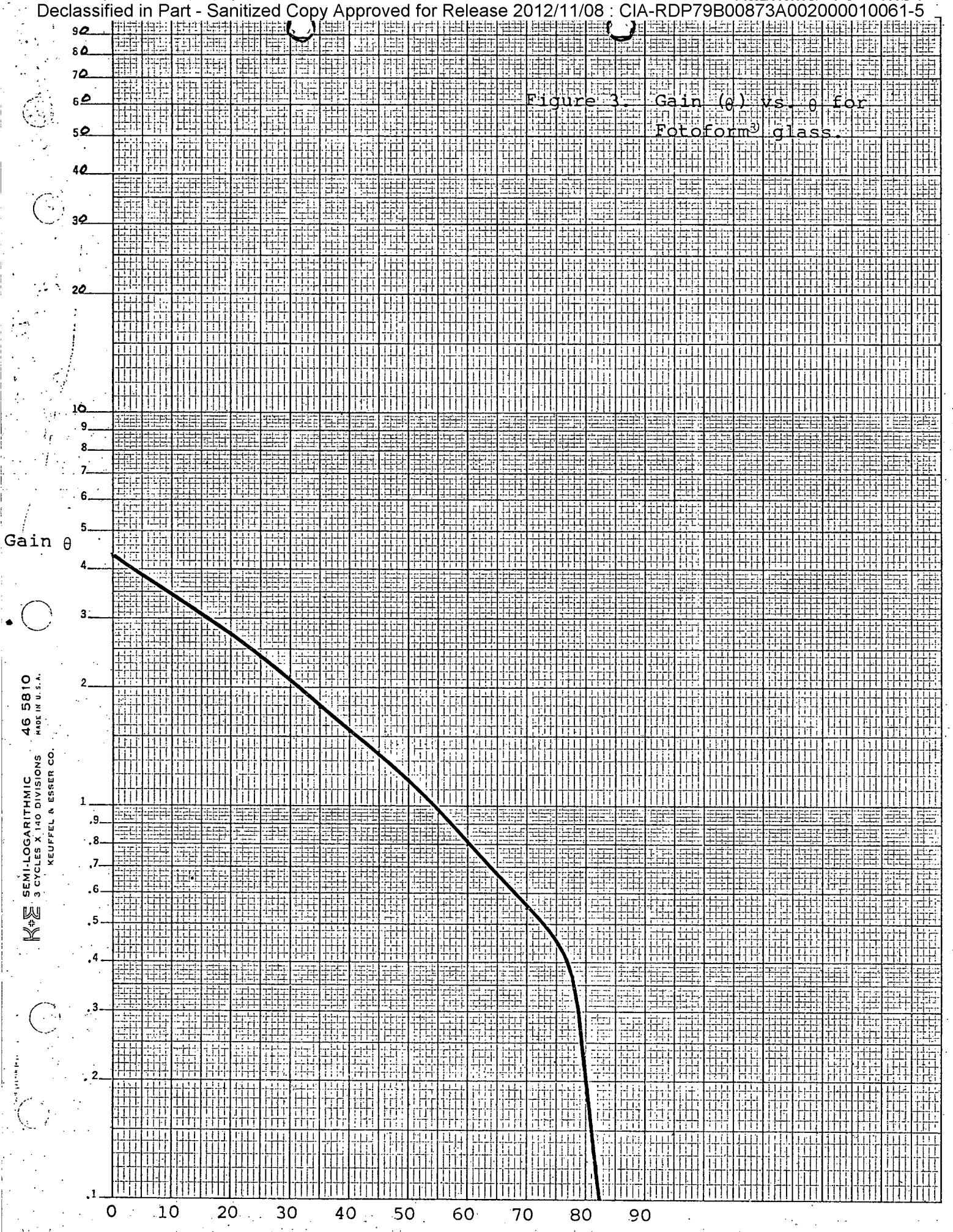

Figure 3. Gain (θ) vs. θ for Fotoform® glass.

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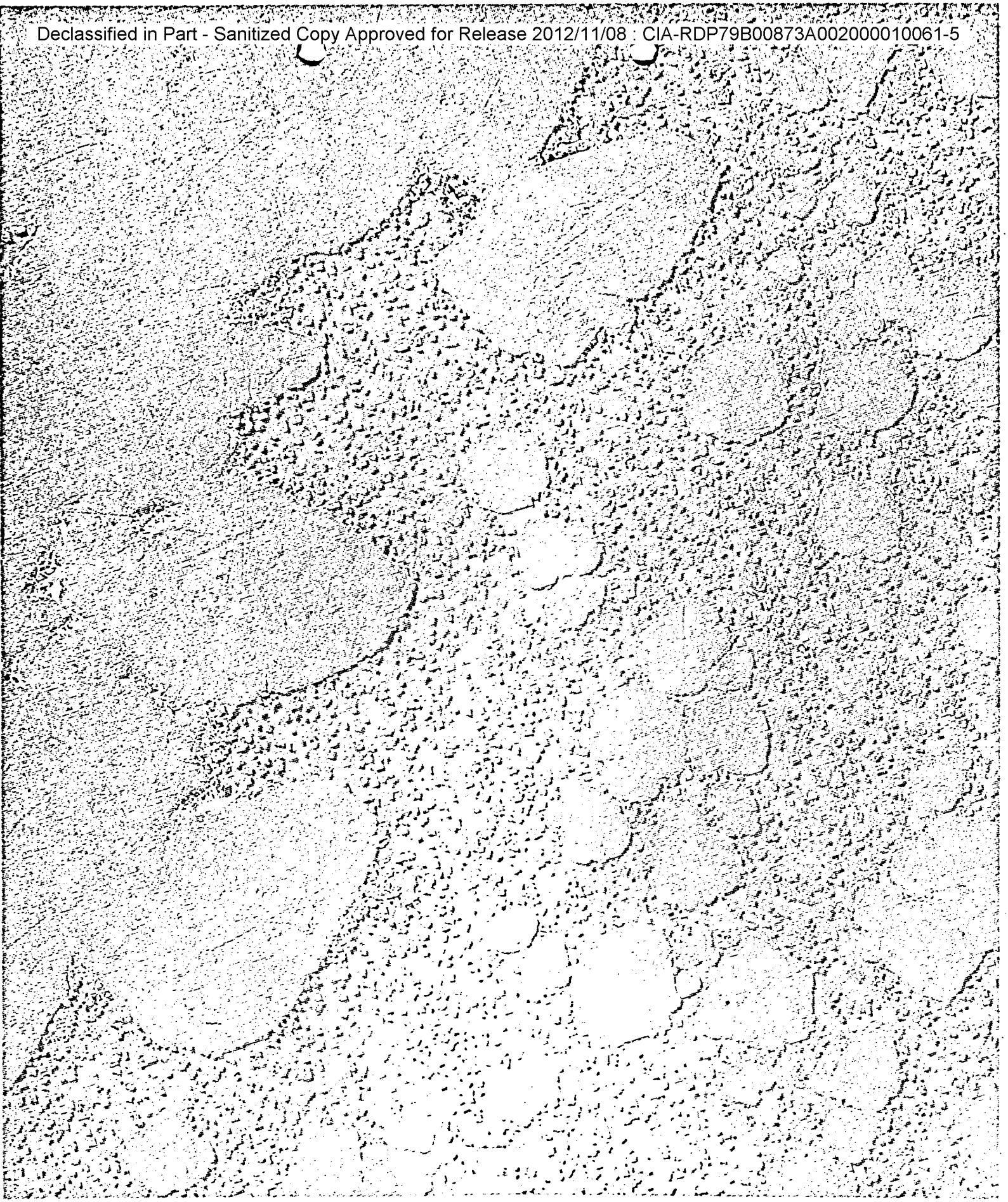

Figure 4. Photomicrograph of glass ceramic sample BB1A

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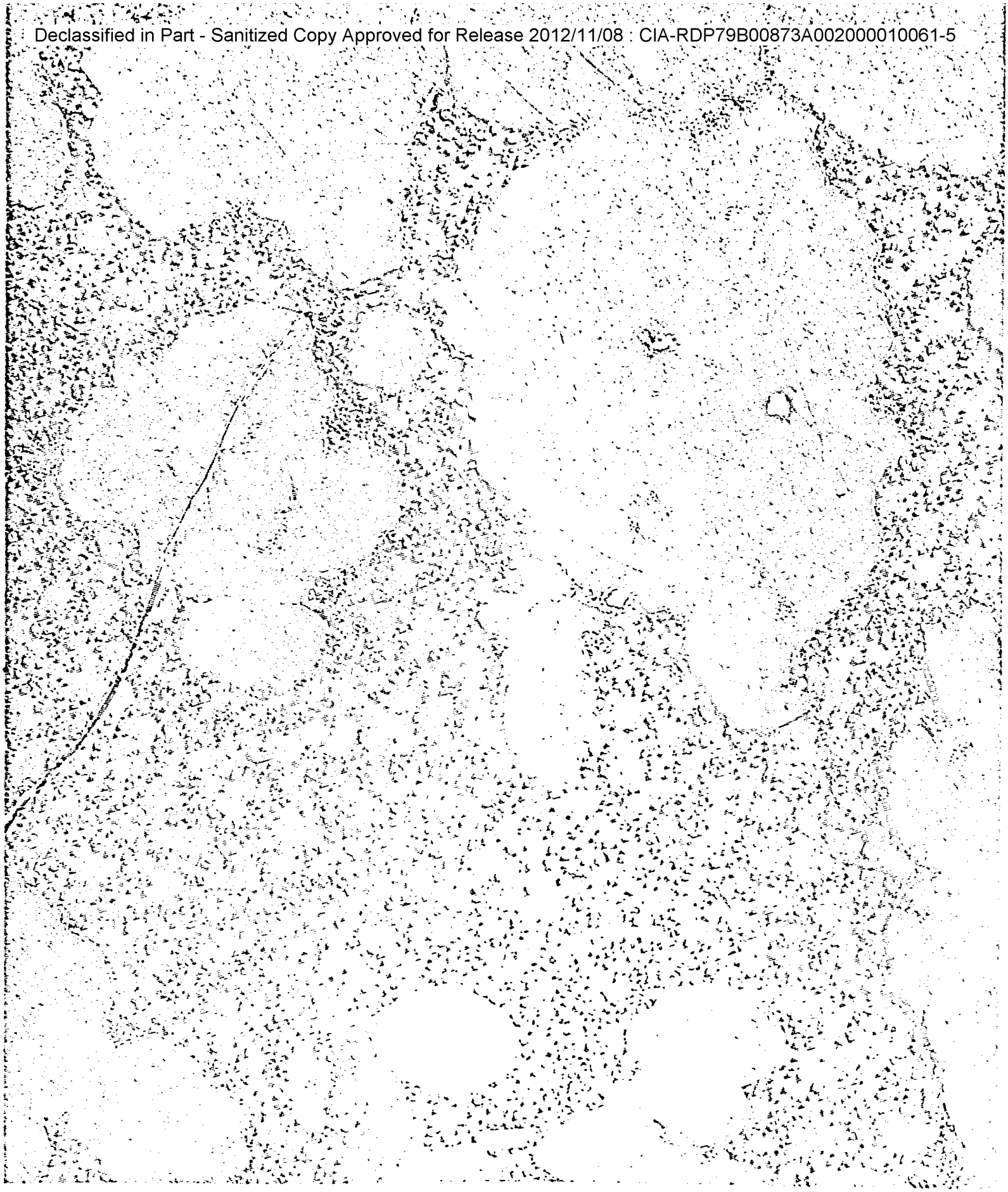

Figure 5. Photomicrograph of glass ceramic sample BB7A

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Figure 6. Photomicrograph of glass ceramic sample BB11A

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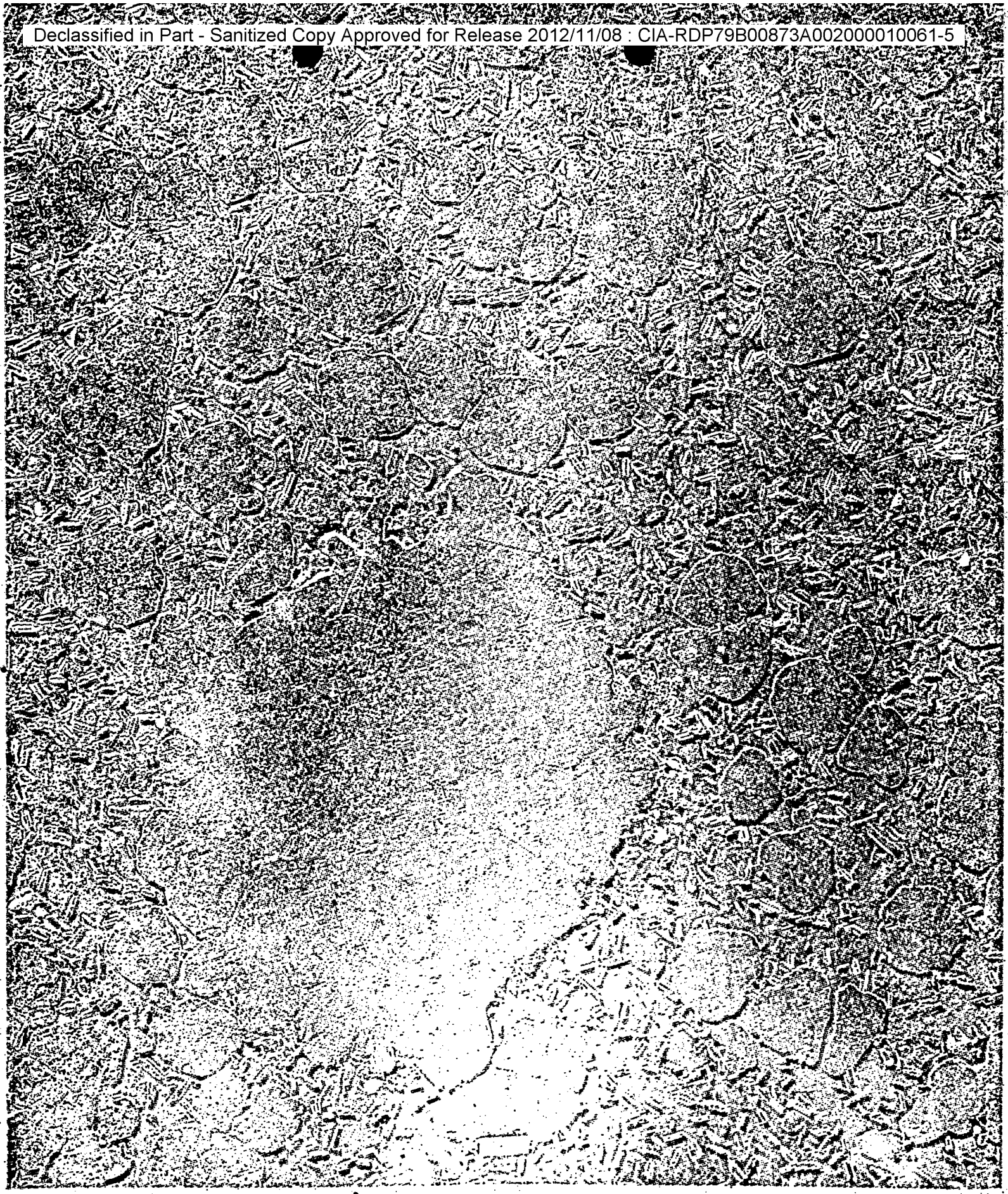

Figure 7. Photomicrograph of glass ceramic sample BB16A

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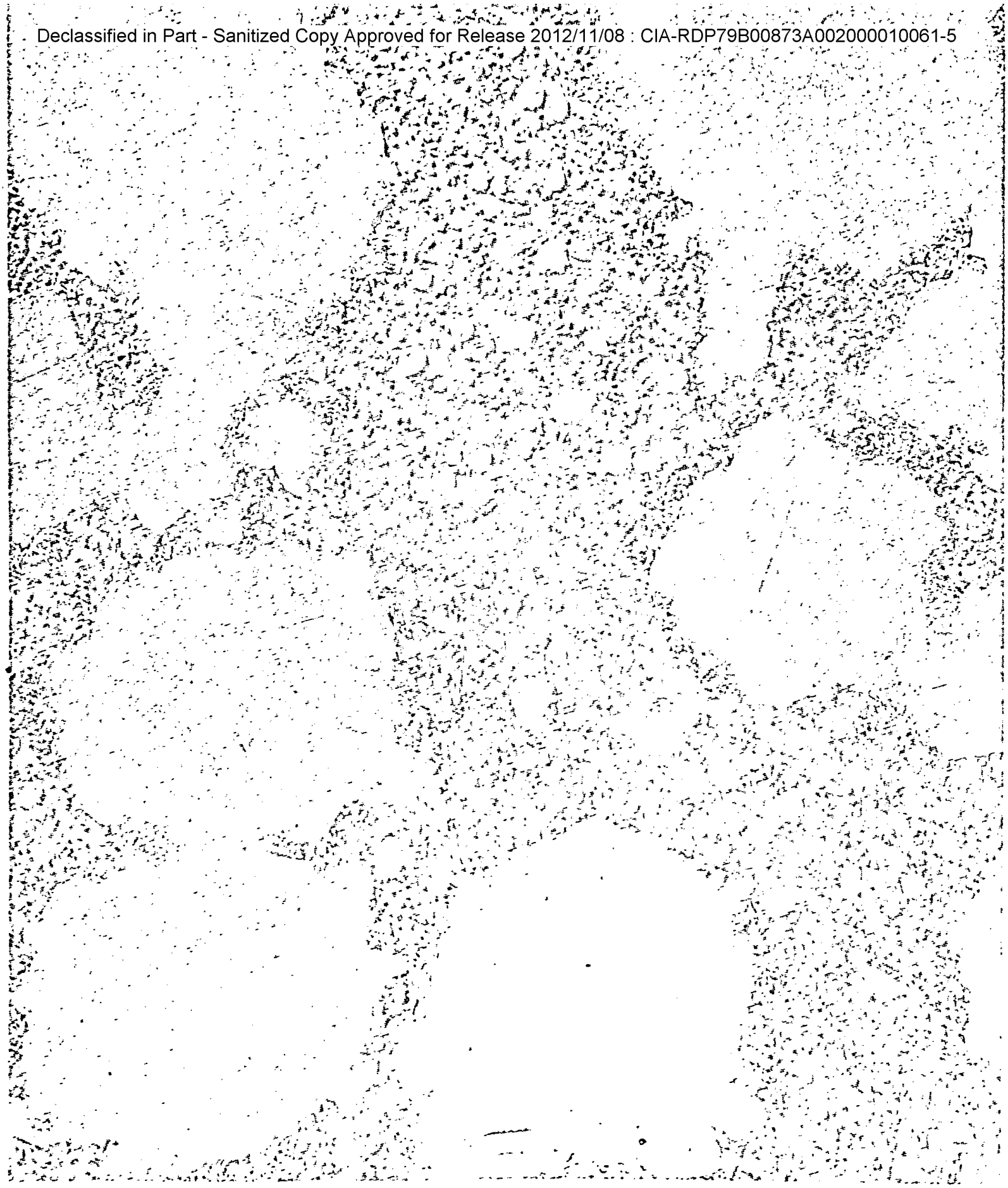

Figure 8. Photomicrograph of glass ceramic sample BB18A

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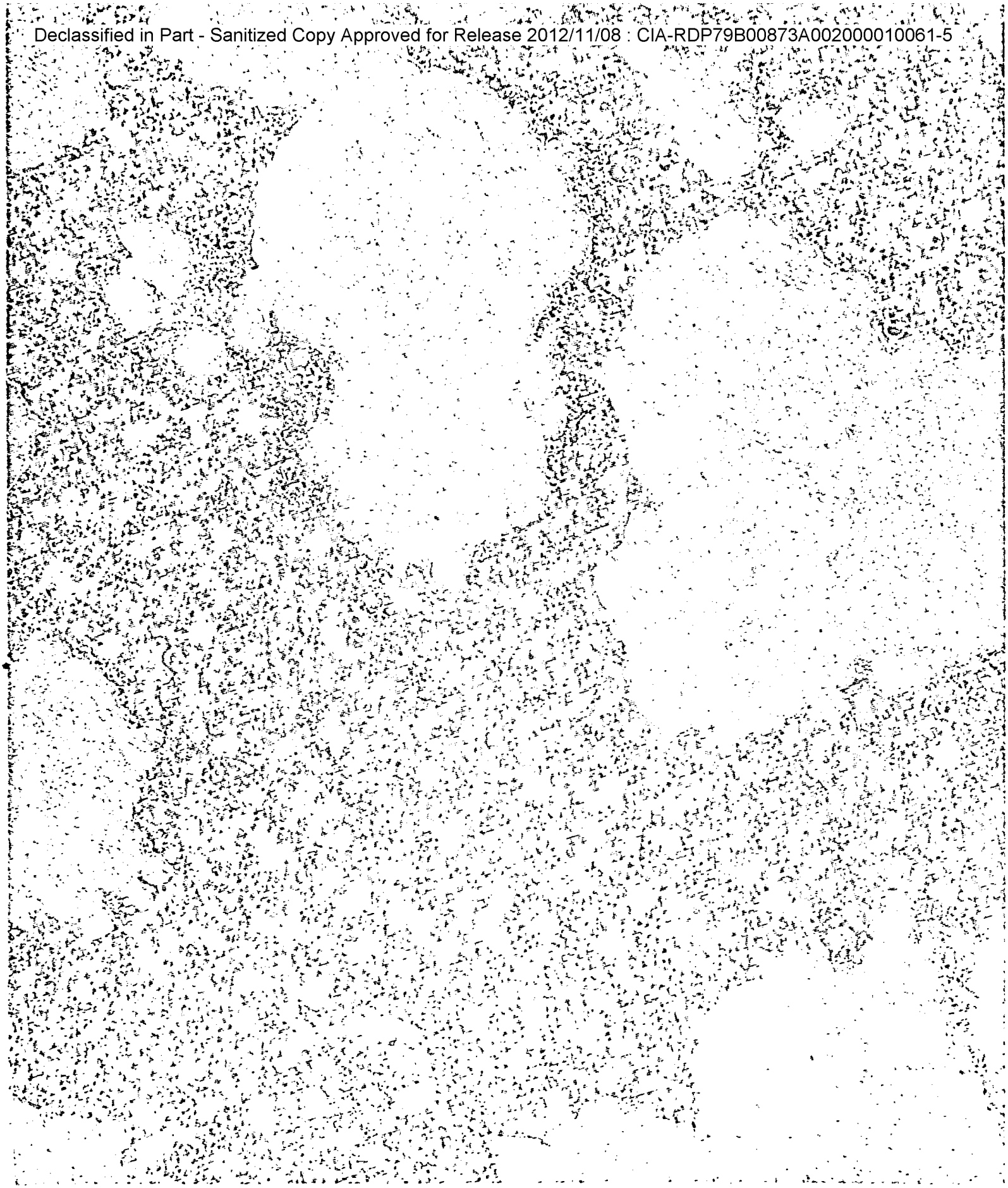

Figure 9. Photomicrograph of glass ceramic sample BB19A

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Figure 10. Number density and average particle size data for some Corning glass ceramics.

Sample	Number/cm^3	Average Particle Size (microns)
BB1A	2.6×10^{13}	0.18
BB7A	3.4×10^{13}	0.15
BB11A	1.7×10^{13}	0.17
BB16A	6.3×10^{12}	0.53
BB18A	4.8×10^{13}	0.12
BB19A	1.1×10^{14}	0.13

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Figure 11. ANGULAR GAIN FUNCTION FOR SAMPLE CERAMIC POWDER 105

FRACTION OF POWER INSIDE 90 DEGREES = .736

FRACTION OF POWER INSIDE 45 DEGREES = .629

BRIGHTNESS VARIATION = +- .84466

SPECULAR TRANSMITTANCE = 0

R_d = 6.5%

ANGLE K	I[K]	GAIN[K]
0	.95	9.928
5	.747	7.838
10	.571	6.061
15	.435	4.703
20	.301	3.344
25	.227	2.613
30	.173	2.09
35	.102	1.306
40	.077	1.045
45	.057	.836
50	.039	.627
55	.023	.418
60	.018	.366
65	.015	.366
70	.01	.314
75	.006	.261
80	.003	.209
85	.001	.105
90	0.00	0.00

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Figure 12. ANGULAR GAIN FUNCTION FOR SAMPLE LS75G

FRACTION OF POWER INSIDE 90 DEGREES = .597

FRACTION OF POWER INSIDE 45 DEGREES = .53

BRIGHTNESS VARIATION = +- .395735

SPECULAR TRANSMITTANCE = 0

R_d = 5.4%

ANGLE K	I[K]	GAIN[K]
0	1	8.553
5	.872	7.484
10	.709	6.158
15	.493	4.362
20	.324	2.951
25	.216	2.036
30	.139	1.368
35	.098	1.026
40	.065	.727
45	.039	.47
50	.026	.342
55	.022	.325
60	.016	.308
65	.013	.257
70	.007	.171
75	.003	.103
80	.002	.086
85	0	.043
90	0.00	0.00

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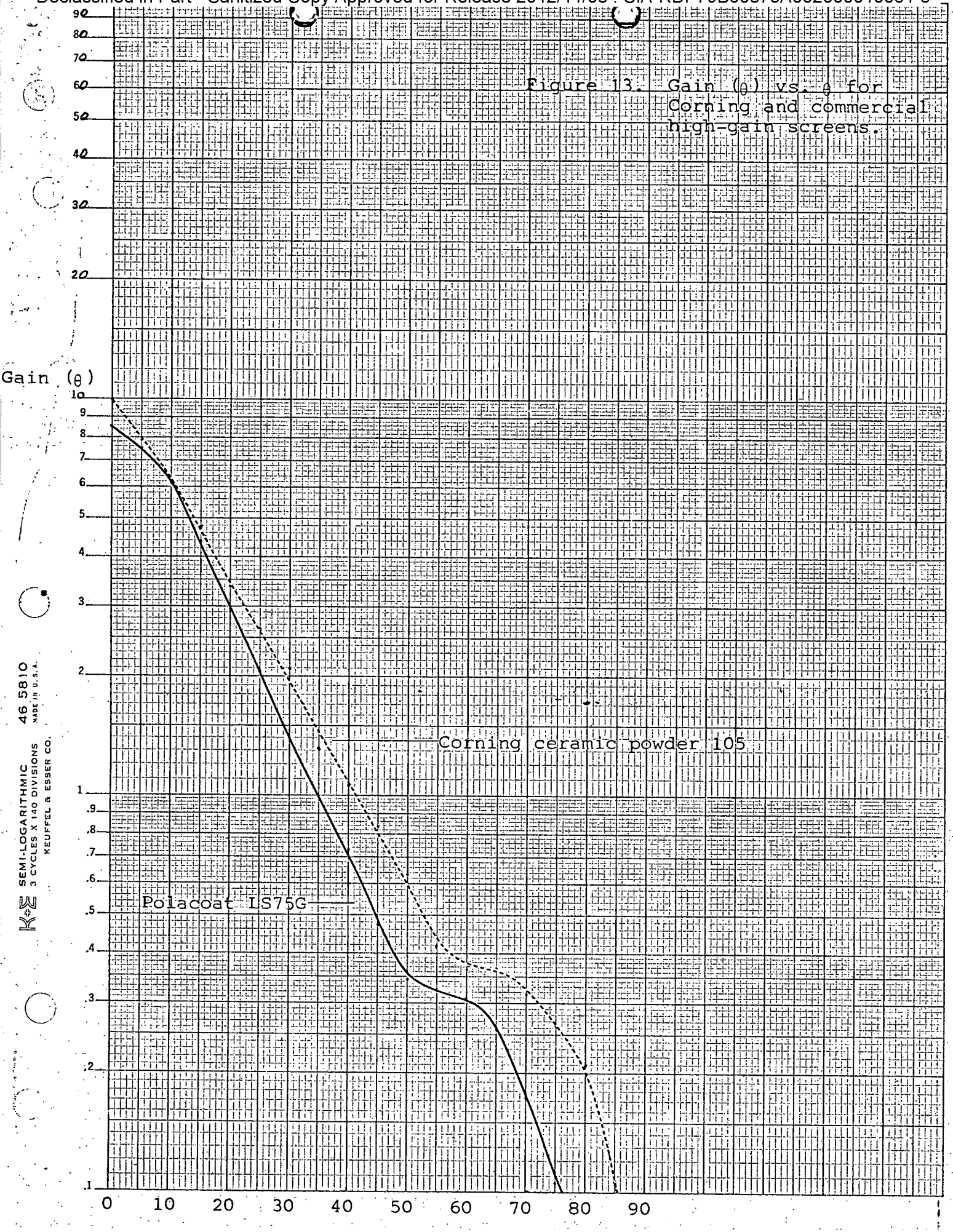

Figure 13. Gain (θ) vs. θ for Corning and commercial high-gain screens.

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