The Sural Group

White Paper

The SANGS™ process for Production of Neo-Globular structures

Introduction

The SANGS™[1] process enables the continuous production of a broad range of aluminum alloy bars and shapes, which possess superior microstructural characteristics and enhanced mechanical properties. More specifically, these bars or shapes have a neo-globular structure with little or no chemical inhomogeneities. The product has very fine grain structure, and hence lends to superior mechanical properties including yield, tensile, and fatigue strength, and elongation.

For brevity and clarity, in the following discussion "bars" shall be understood to include not only circular cross-sections, but also any solid or hollow shape.

Main Characteristics

The SANGS™ process allows for the production of 1" to 6" diameter bars having extremely fine grain structure (from 5 – 30 microns mean size, depending upon the alloy). The fine grain structure lends to superior mechanical properties and fatigue characteristics. The elongation of these bars is also superior to bars made by casting processes.

There is little to no variation of the major solute elements across the cross-section of the bars. For example, for casting alloys, the silicon and magnesium variation has been found to be orders of magnitude less than bars made from competing processes. As an example, the silicon variation was observed to be less than 0.03% across the cross-section of a 5" bar.

Elongations of over 21% have been observed for as-formed (not heat treated) for bars made of 356 alloy. Such elongations are extremely

desirable when forming structural parts such as one-piece aluminum wheels for the automotive industry.

[1] SANGS™ stands for SURAL Advanced Neo Globular Structure.

One of the most interesting characteristics of these bars is the observation of a unique neo-globular microstructure when these bars are heated (at the right conditions) to a temperature between the solidus and liquidus, and subsequently quenched. This microstructure allows for efficient semi-solid and semi-liquid forming of a range of alloys. The bars can therefore be heated by various means (induction, forced-air convection, radiation, etc.) to achieve a certain fraction liquid and then subsequently deformed to obtain a part.

The excellent chemical homogeneity of the bars allows for very uniform heating of the bars without any localized segregation. This is a huge economic benefit as it reduces the rejects at the heating stage.

The chemical homogeneity and the resulting uniform heating permits these bars to be deformed uniformly and with application of less pressure to deform them. Tests done on 356 bars at 585 C have shown the pressure at end of forming to be 200 *bar*, as compared to 500-700 *bar* for 356 bars made by competing technologies.

The bars thus produced by the process have extremely smooth surfaces with very good dimensional tolerances. The bars do not need any cleaning or surface treatment before additional mechanical working (e.g. injection or forging).

Bars can be produced at throughput rates of 0.75 to 2 tonnes per hour.

The bars thus produced have surface temperatures ranging from 400 C – 530 C, depending upon the following factors: effective diameter of the formed bar, machine throughput rate, and the type of alloy.

For certain alloys, an on-line quenching system can be employed, either before cutting or after cutting the bars.

For instances where the bar needs to be formed after cutting, the bar can be directed to a temperature stabilization furnace before the forming machine(s).

Primary Advantages

The SANGS™ process allows for the production of a large range of alloys, both wrought alloys and casting alloys. Competing processes that produce bars using casting processes and variations therefrom, and can produce only high-silicon alloys by casting. Other processes utilizing rolling or other sequences of solid forming processes to make bars are riddled with very high costs, low throughputs, and ability to make only small cross sections.

The biggest advantage of the SANGS™ process is the unique microstructure of the bars, with well-dispersed fine globular structure and very high chemical uniformity across the section (as well as longitudinally). This neo-globular microstructure allows the bars to be easily formed by solid and semi-solid forming technologies. In addition, the bars have excellent mechanical strength and fatigue properties.

The SANGS™ process has good throughput, and a single process installation allows production rates of 0.75 to 2.0 tonnes per hour, depending upon the alloy type, effective diameter of the product, and the shape of the product.

The SANGS™ process allows for environmentally friendly operation because the bar-producing stage is a solid forming process.

The SANGS™ process allows production of bars with better mechanical properties compared to the same alloy bars produced by the competing casting processes.

The flexibility of the process is inherent in the fact that the diameter of the bars produced can be changed readily, shape produced can be altered with minimum downtime, and the die-change process requires changing of die inserts rather then complete dies.

The SANGS™ bars have little to no chemical segregation, and exhibit very good chemical homogeneity.

The SANGS™ process produces bars with excellent surface finish, and very close dimensional tolerances. For shapes, very thin walls (up to 0.3 mm thickness) can be produced.

The SANGS™ process affords to easy automation and is a continuous process. Hence there are fewer process fluctuations and the system is less prone to operator error.

The SANGS™ process produces bars with surface temperature at or above 400 C. For instances where these bars have to be hot worked right after production, the system affords significant savings of energy.

The SANGS™ process is characterized by good reproducibility. The bars thus produced have been extensively tested.

The bars made by this process open the possibility, for the first time, for a wide application of various alloys to produce structural parts for the automotive and aerospace industry.

Uses

The bars and shapes produced by the SANGS™ process have been used as forming stock (e.g. forging, casting, stamping) and machining stock. Special shapes made from specific alloys can be used for unique applications in the automotive and aerospace sectors.

Niche applications include forming of composite bars using the SANGS™ process. The composites could be either two metallic alloys or a combination of a metallic alloys and non-metallic substances.

In addition to the above, the SANGS™ process also allows powder processing for novel applications.

Future Directions

Because this novel process has allowed production of such a wide range of alloys in bar form for the first time, studies are ongoing to study and characterize these bars. This is ongoing for both room temperature and at high temperatures.

The SANGS™ process will continue to produce new wrought alloys as well as casting-type alloys in order that the process' versatility is proven. At the same time, significant efforts are being expended in order to study the properties of the resulting bars and shapes.

Some Representative Figures

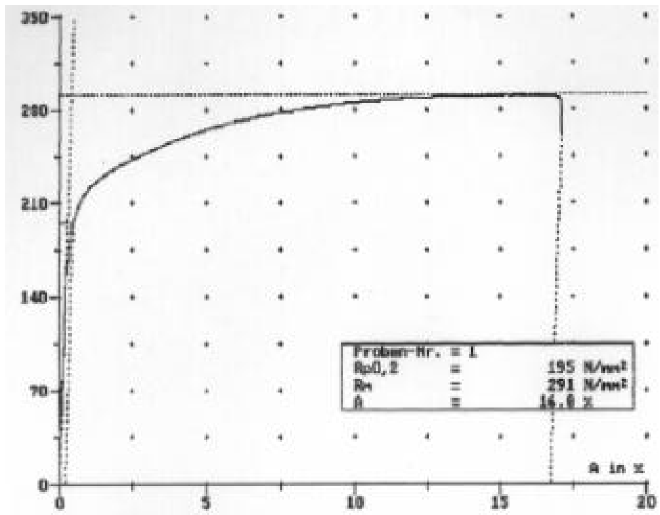
The figures attached to this paper are in order to depict some representative examples of products made by the SANGS™ process.

SOME MECHANICAL TESTS PERFORMED ON SANGS™ BARS

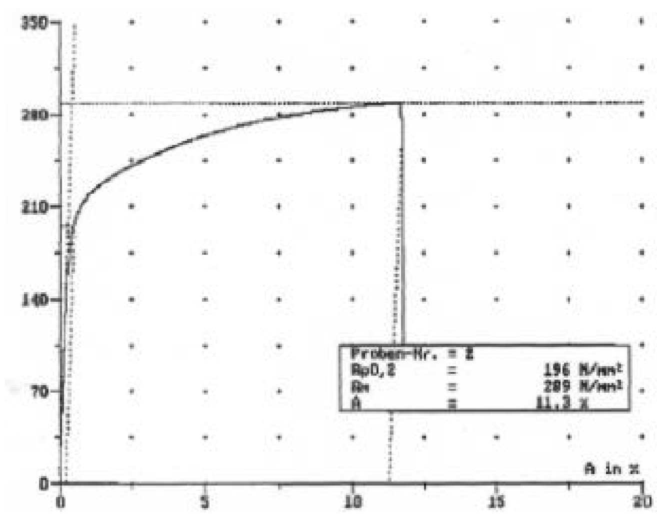
Sample No.	$P_{p0.2}$ (N/mm^2)	R_m (N/mm^2)	A (%)
1	195	291	168
2	196	289	11.3
3	185	278	15.0
4	189	276	9.1

5	196	292	20.6
6	189	282	11.6

Sample Curve A



Sample Curve B



SOME CHEMICAL TESTS PERFORMED ON SANGS™ BARS

A. Measurements at the Periphery

Element	Al2 %	Si %	Fe %	Cu %	Mn %	Mg %	Ni %
Median	92.39	6.696	0.103	0.000	0.005	0.373	0.001
Std. Dev	0.0144	0.0164	0.0008	0.0000	0.0002	0.0022	0.0000
Rel. Std. Dev. (%)	0.02	0.23	0.81		3.29	0.58	2.41

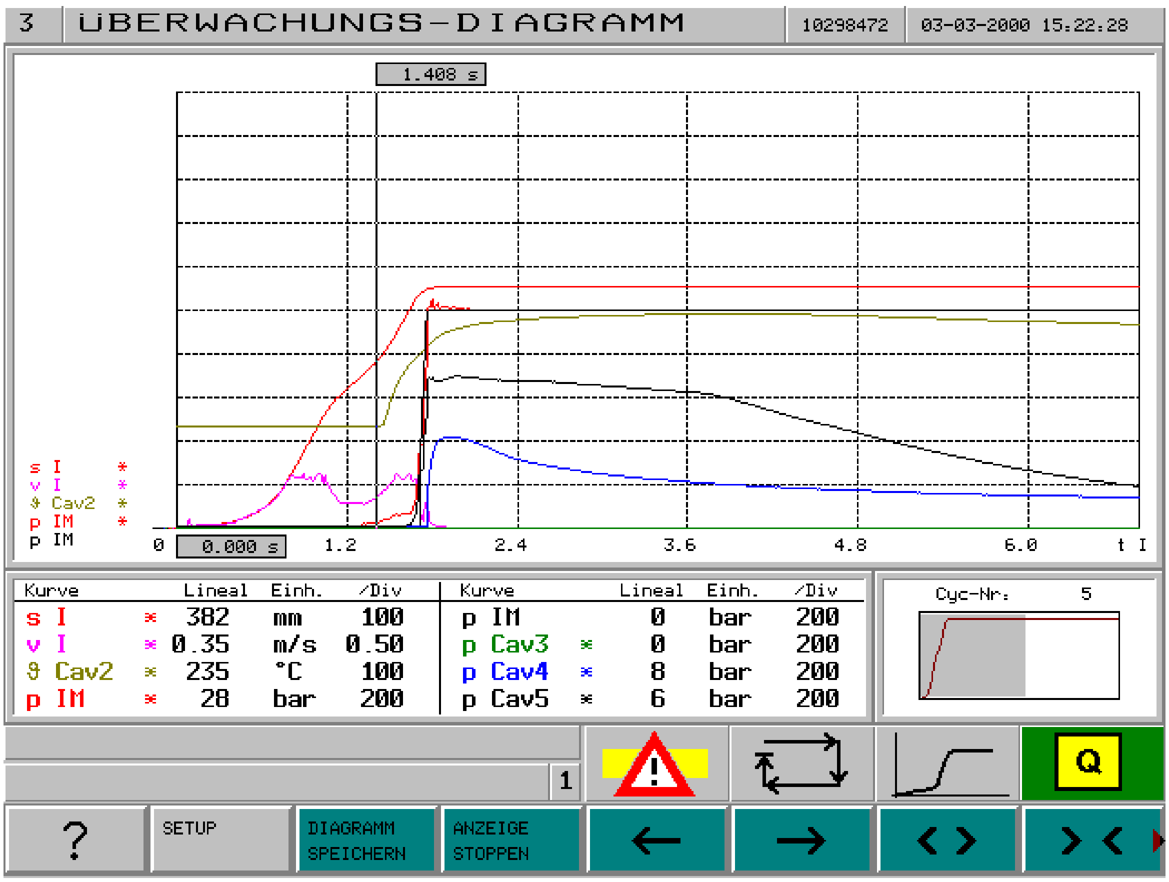
Zn %	Pb %	Sn %	Be %	Sr %	Ti %	Sb %
0.020	0.004	0.000	0.000	0.022	0.110	0.016
0.0011	0.0004	0.0000	0.0001	0.0003	0.0006	0.0006
5.63	8.37		18.18	1.56	0.51	3.96

B. Measurements close to Center

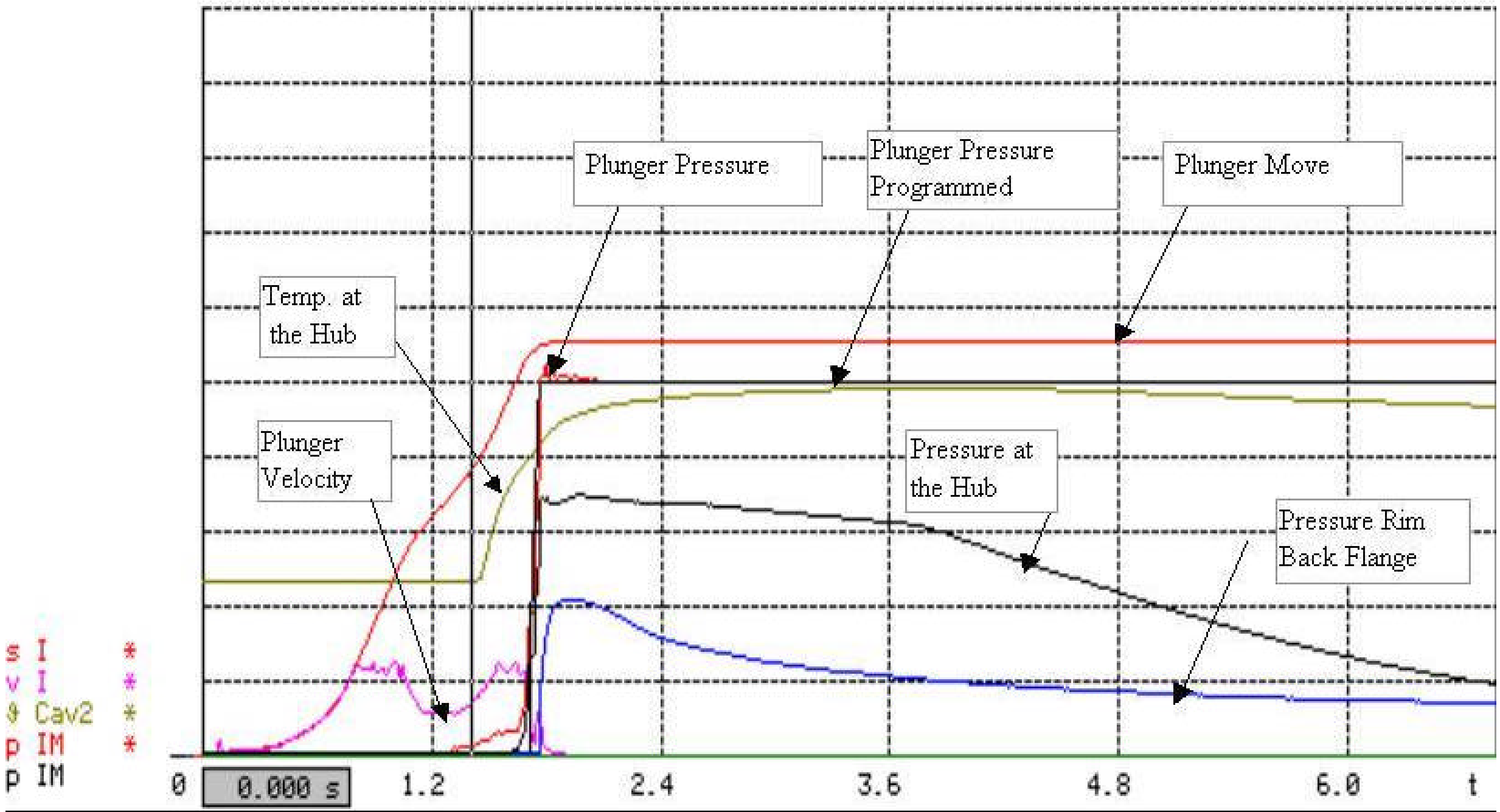
Element	Al2 %	Si %	Fe %	Cu %	Mn %	Mg %	Ni %
Median	92.36	6.996	0.103	0.000	0.003	0.372	0.001
Std. Dev	0.0604	0.0638	0.0004	0.0000	0.0003	0.0003	0.0001
Rel. Std. Dev. (%)	0.07	0.91	0.41		9.62	0.08	17.61

Zn %	Pb %	Sn %	Be %	Sr %	Ti %	Sb %
0.017	0.003	0.000	0.000	0.021	0.111	0.013
0.0006	0.0003	0.0000	0.0000	0.0000	0.0025	0.0007
3.73	10.24		28.72	0.20	2.29	5.38

PROCESS PARAMETERS WHEN FORMING A356 ALUMINUM WHEELS USING SANGS™ MATERIAL



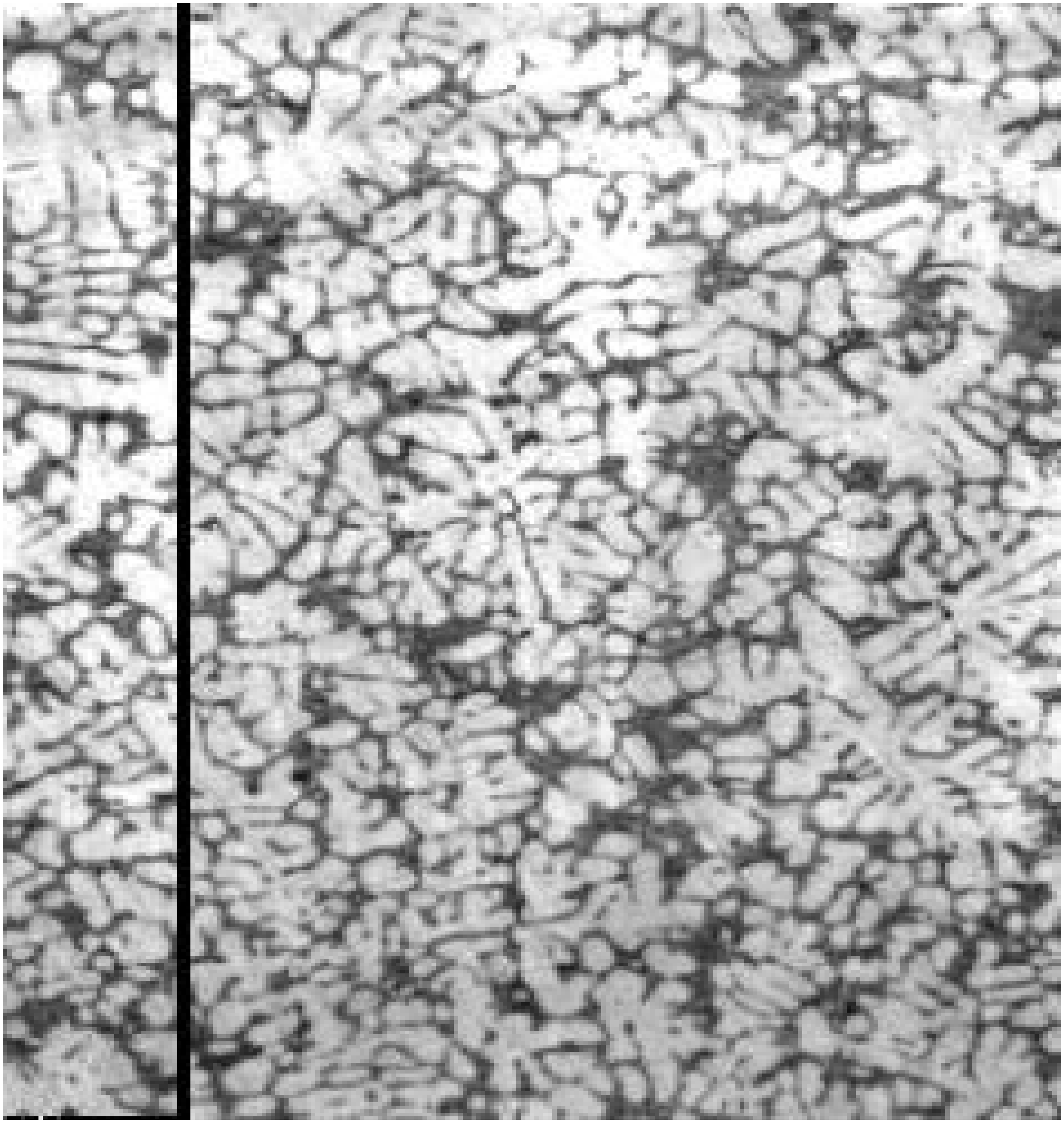
Forming Machine Performance During Semi-solid Casting of A356 Wheel



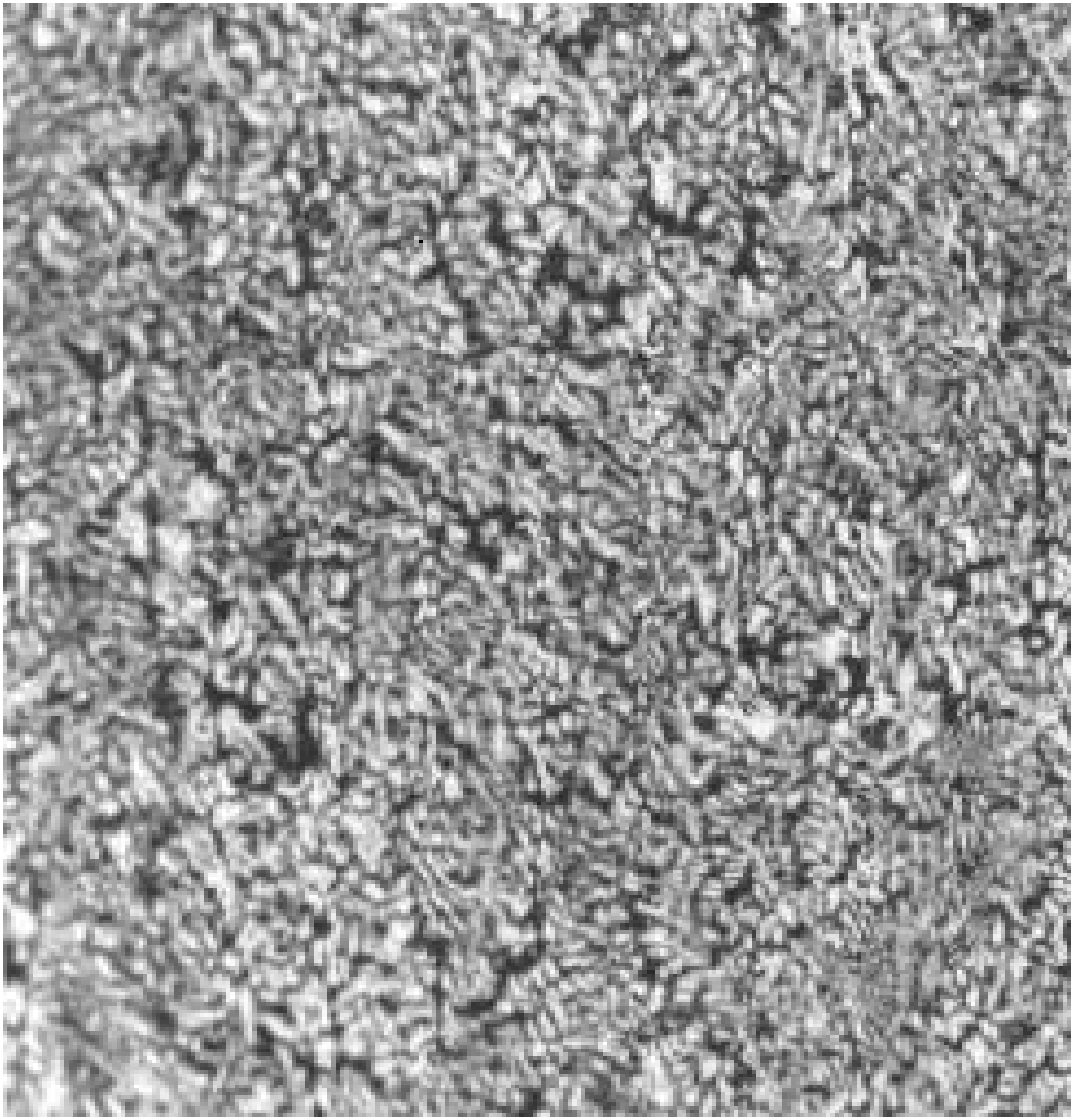
		Lineal	Unit	Division
Plunger Move	*	382	mm	100
Plunger Velocity	*	0.35	m/s	0.50
Temperature at the Hub	*	235	°C	100
Plunger Pressure	*	28	bar	200

		Lineal	Unit	Division
Plunger Pressure Programmed		0	bar	200
Pressure Rim Back Flange	*	0	bar	200
Pressure Rim Front Flange	*	8	bar	200
Pressure At the Hub	*	6	bar	200

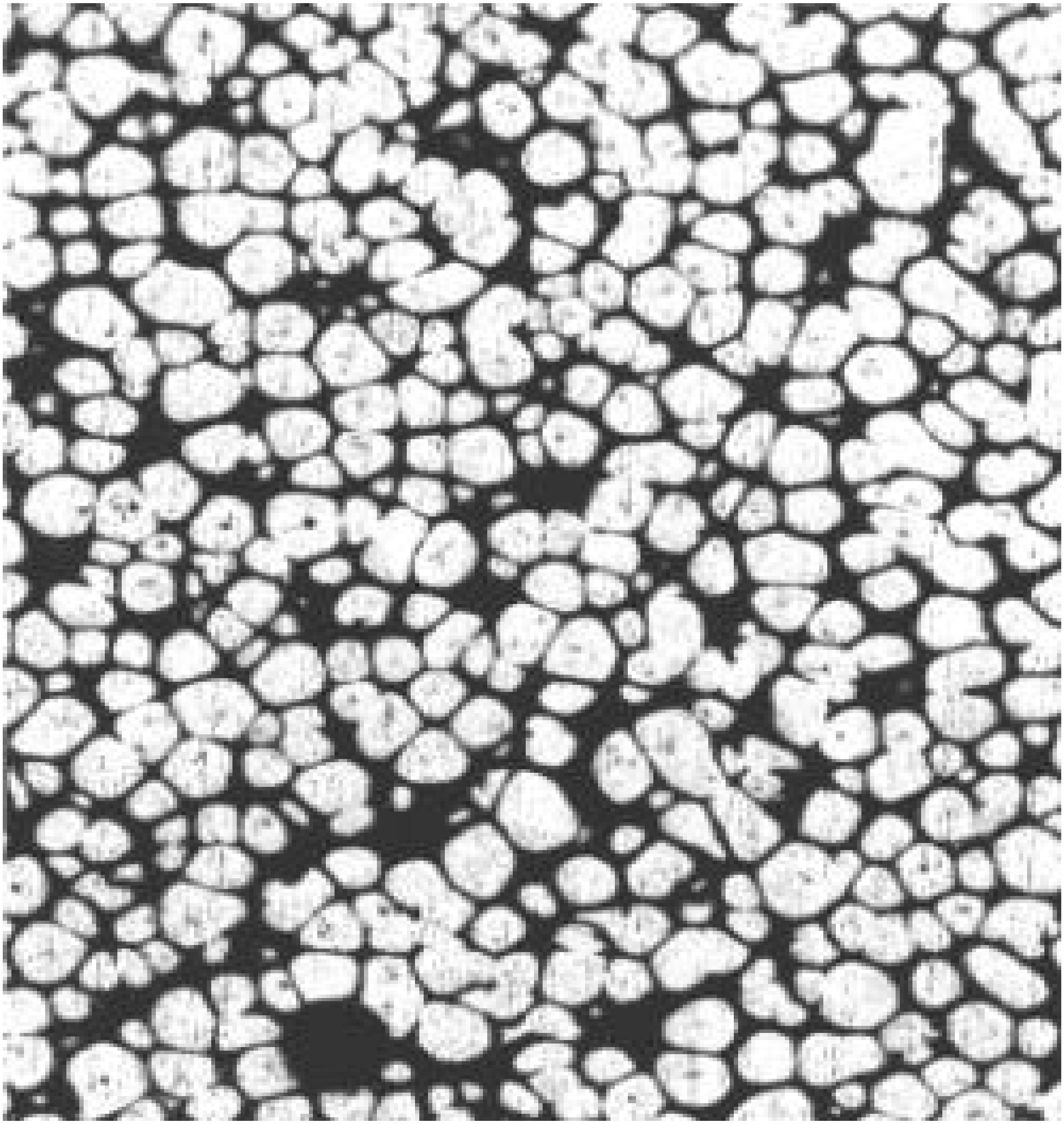
SANGS™ billets of various size and alloys possess unique thixotropic properties when reheated under ideal conditions, ideal for thixoforming of auto-parts.



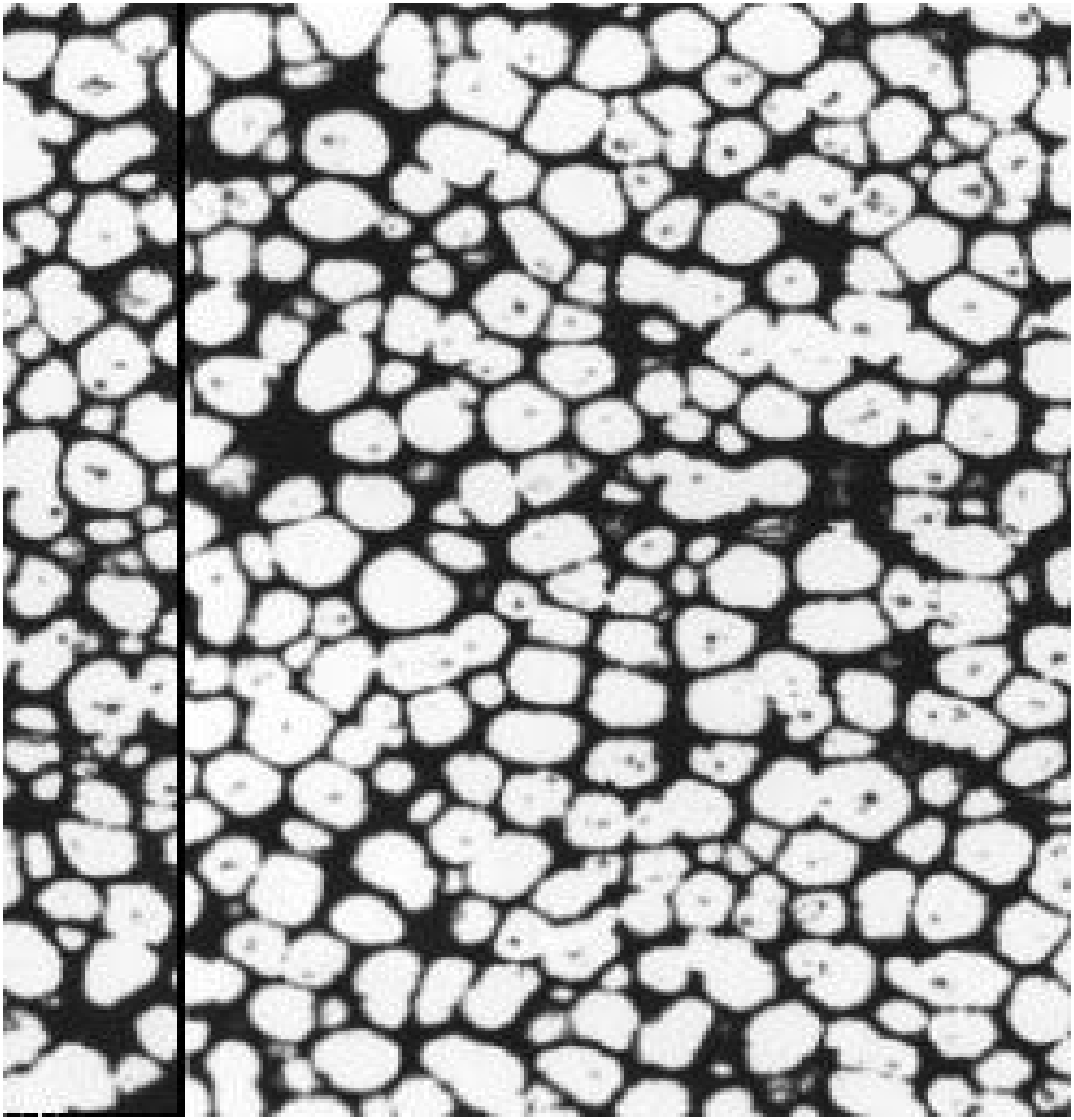
Microstructure of A356 feed material used for the production of SANGS™ bars: X200.



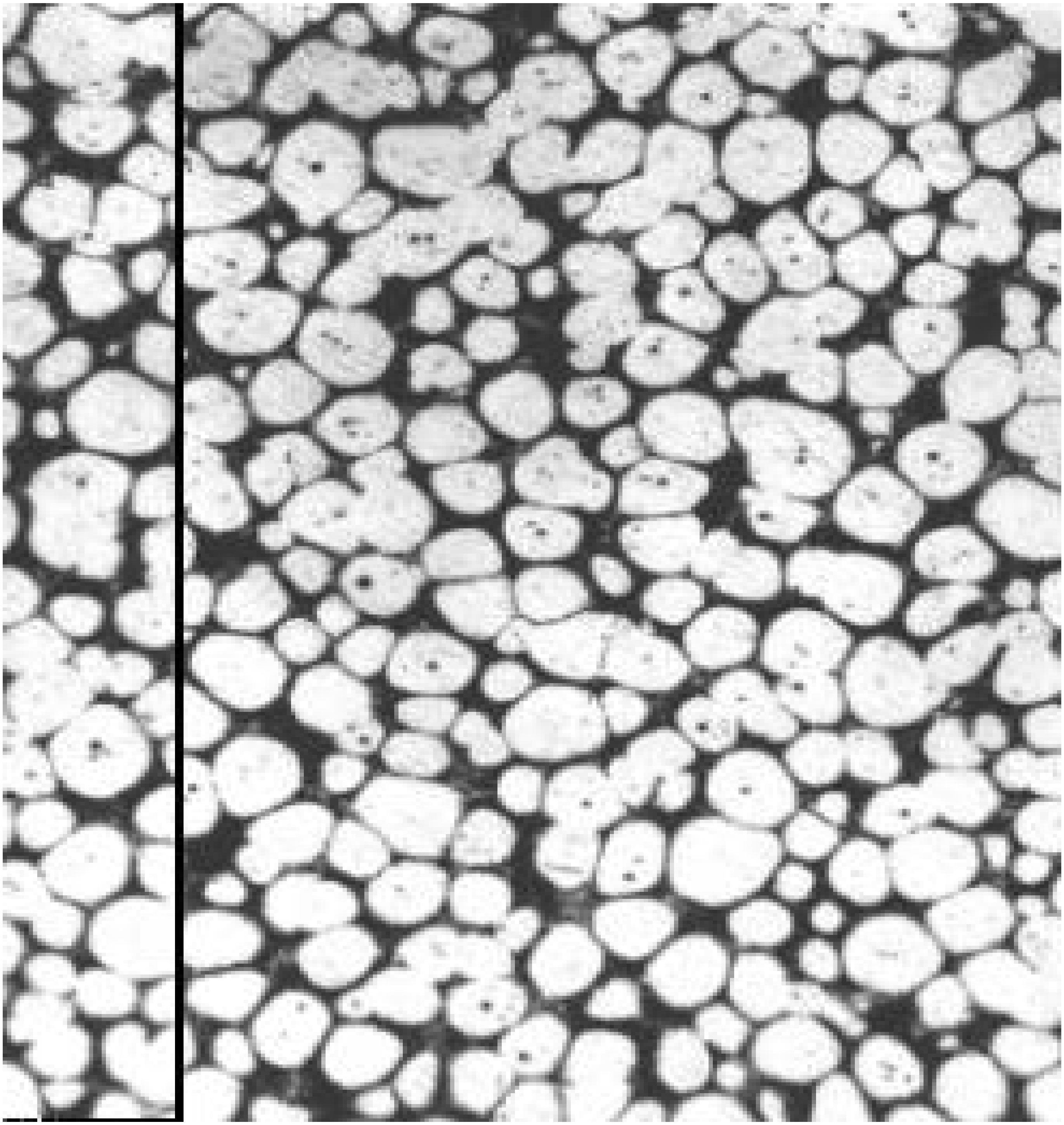
Microstructure of as-formed A356 SANGS™ bar (cross-sectional view): X100



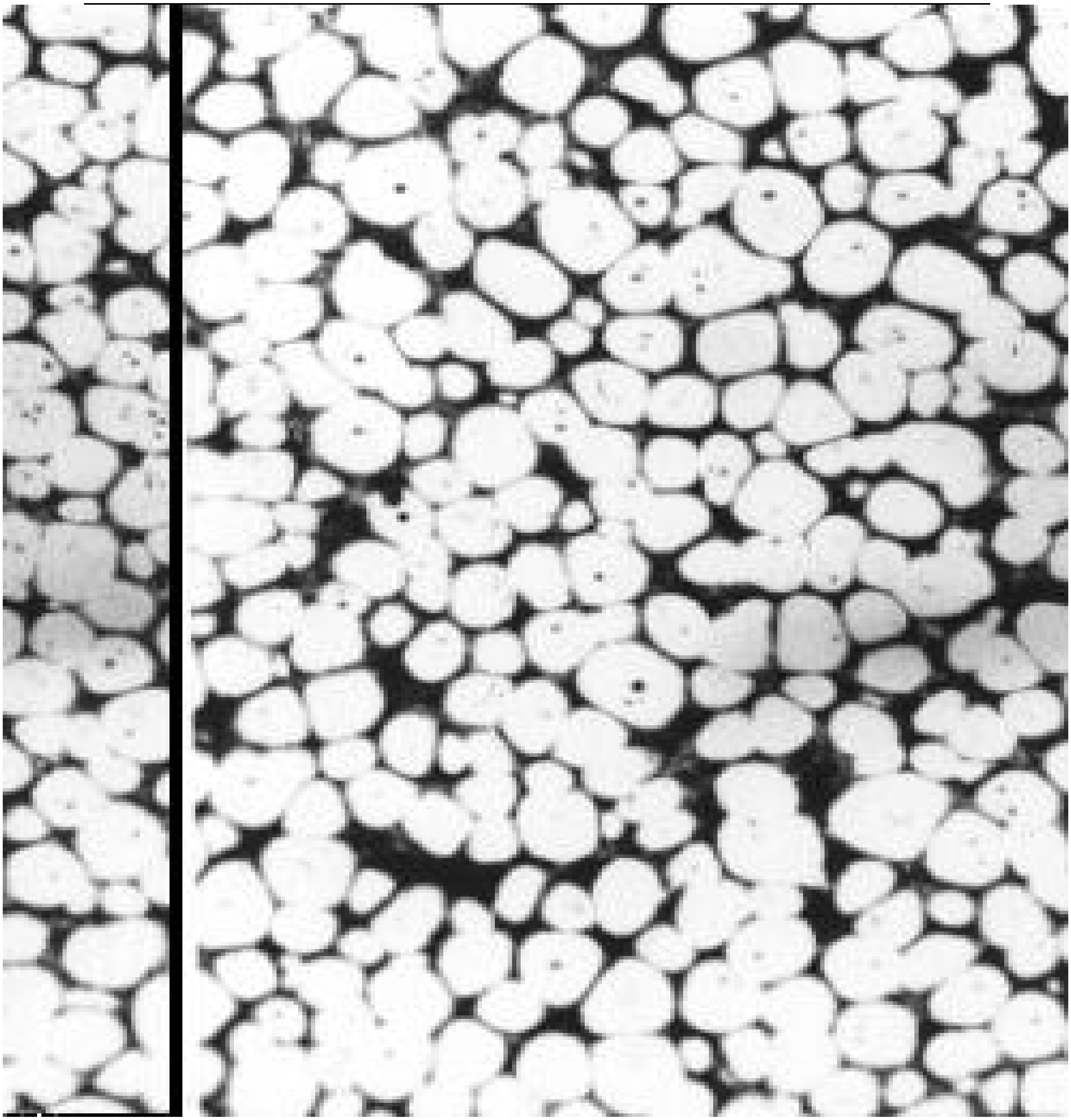
Bulk microstructure of 2” diameter A356 SANGS™ bar, reheated at 595ºC for 4 minutes (& quenched): X100.



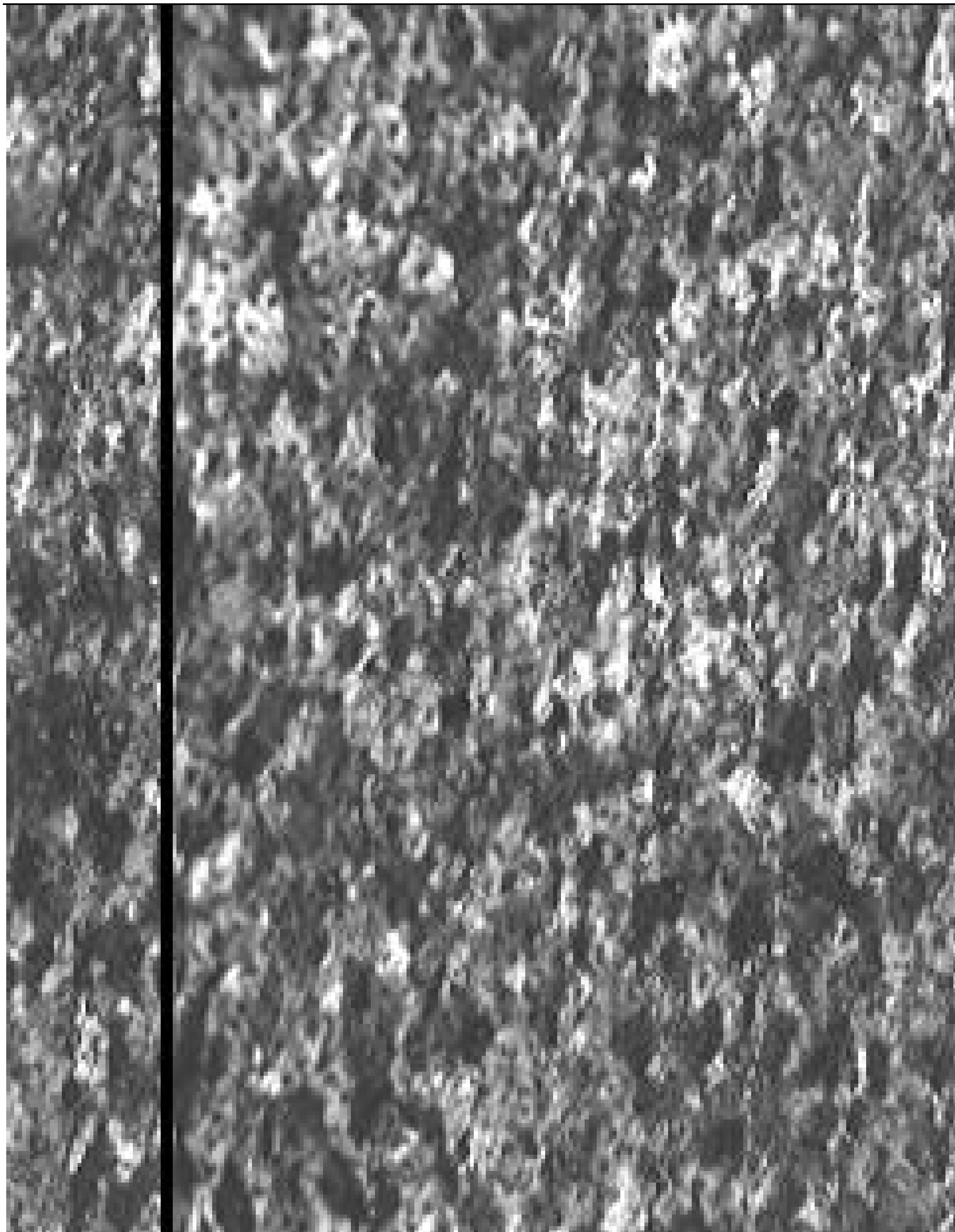
Bulk microstructure of 2” A356 SANGS™ bar, reheated at 585ºC for 15 minutes (& quenched): X100.



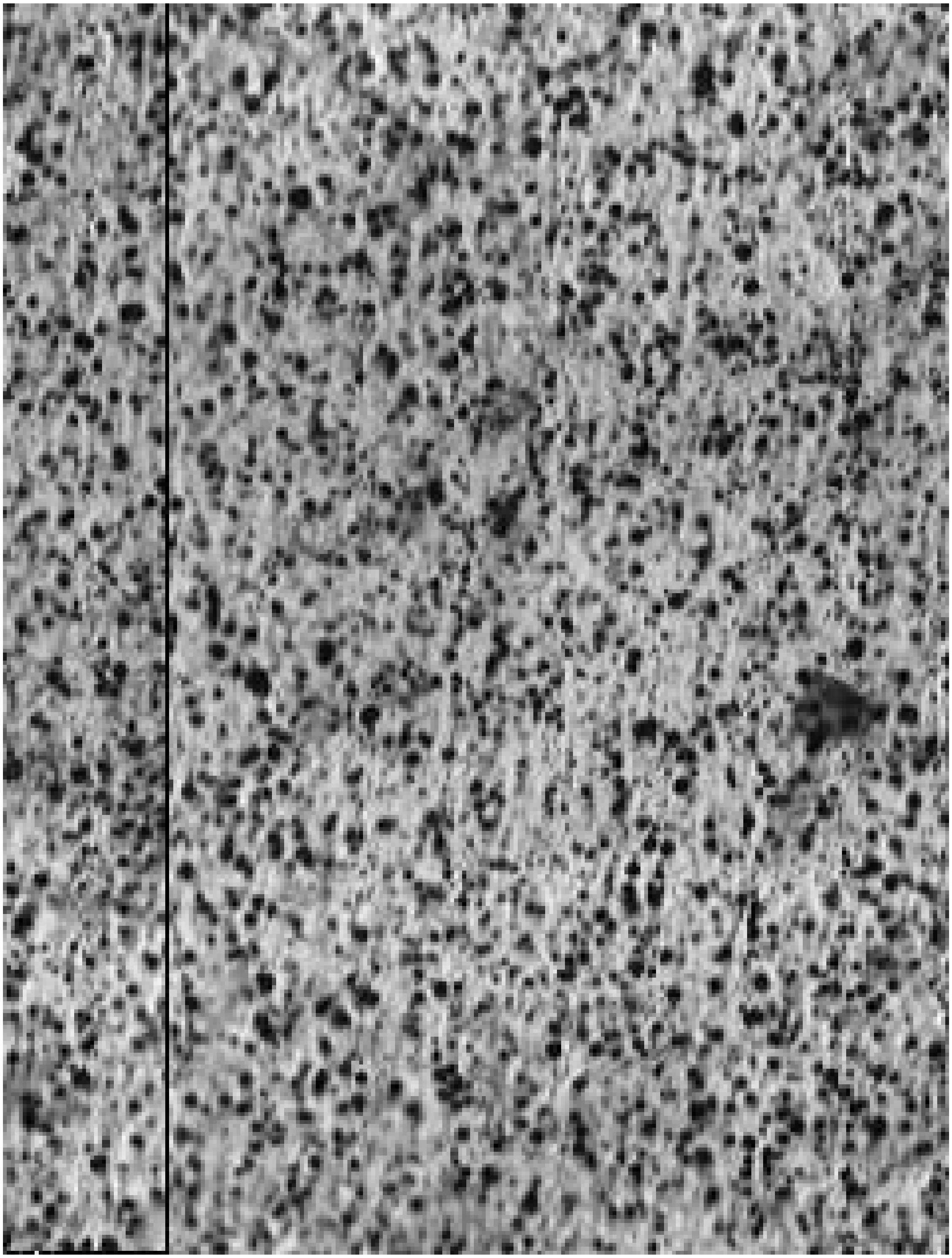
10 mm to surface –microstructure of 5” A356 SANGS™ bar, reheated at 595ºC for 5 minutes (& quenched): X100.



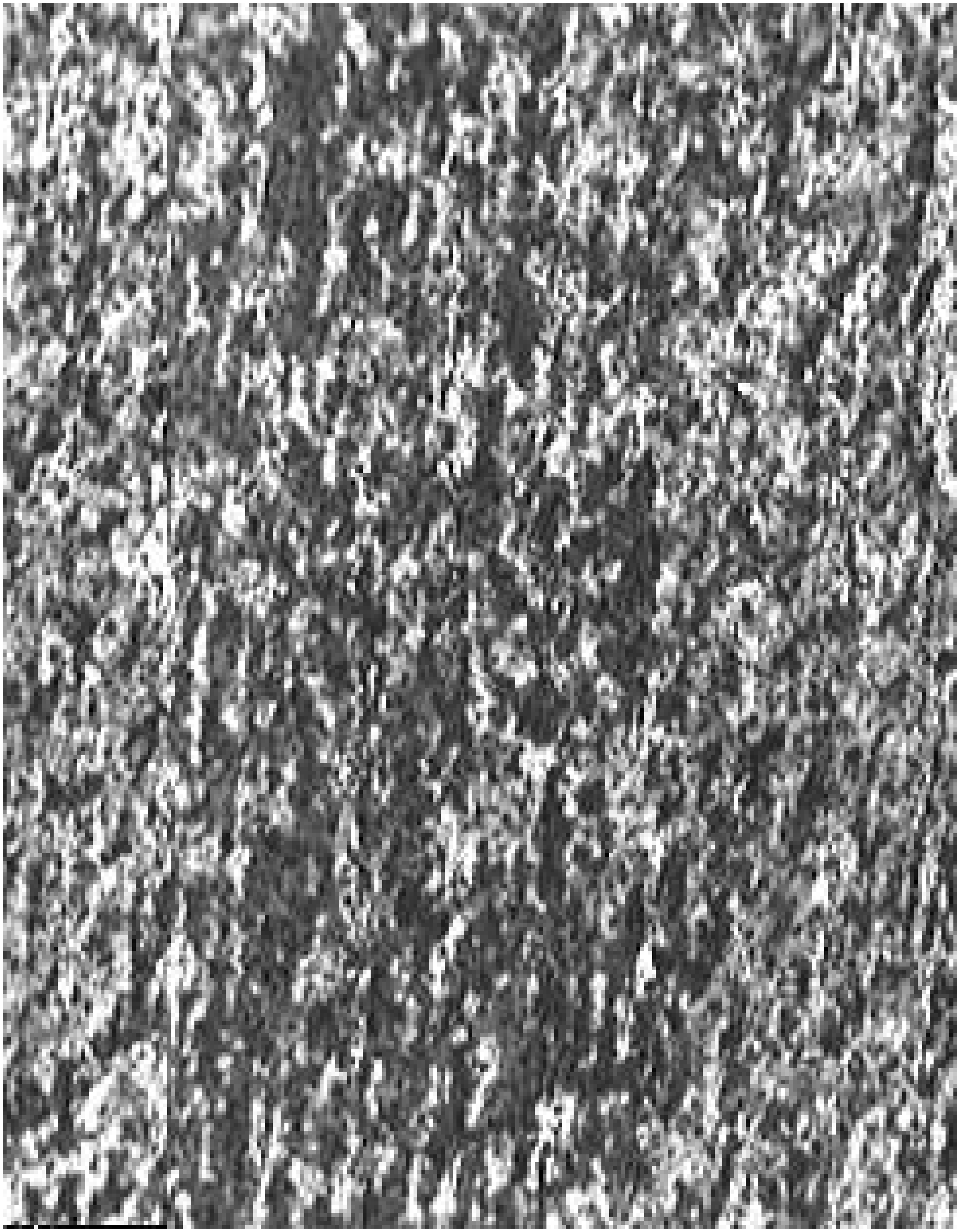
30 mm to surface – (center) microstruture of 5" A356 SANGS™ bar reheated at 595ºC for 5 minutes (& quenched): X100.



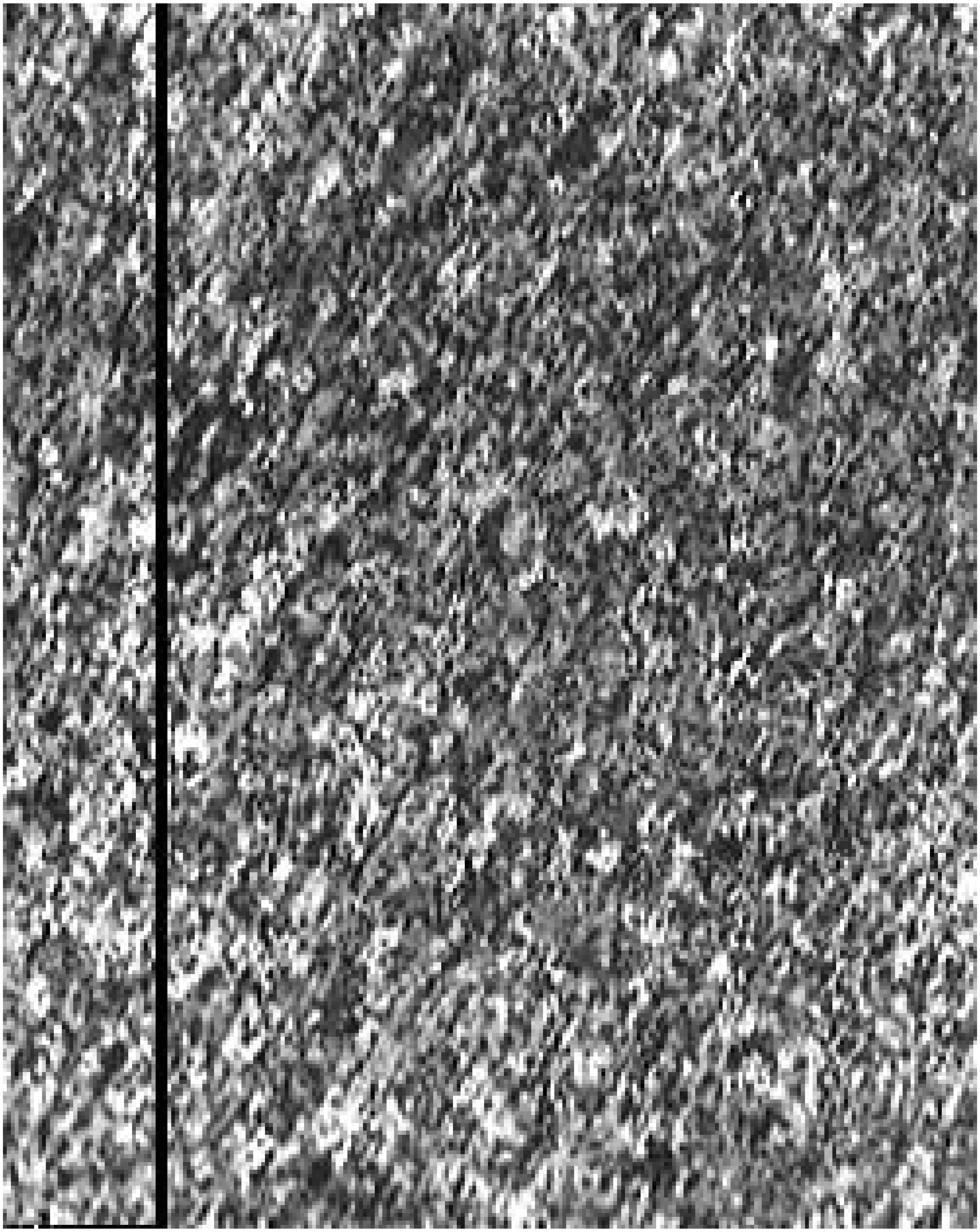
10 mm to surface microstructure of SANGS™ AA 6061 as-formed bar of diameter 3-1/2” (cross-sectional view, X200)



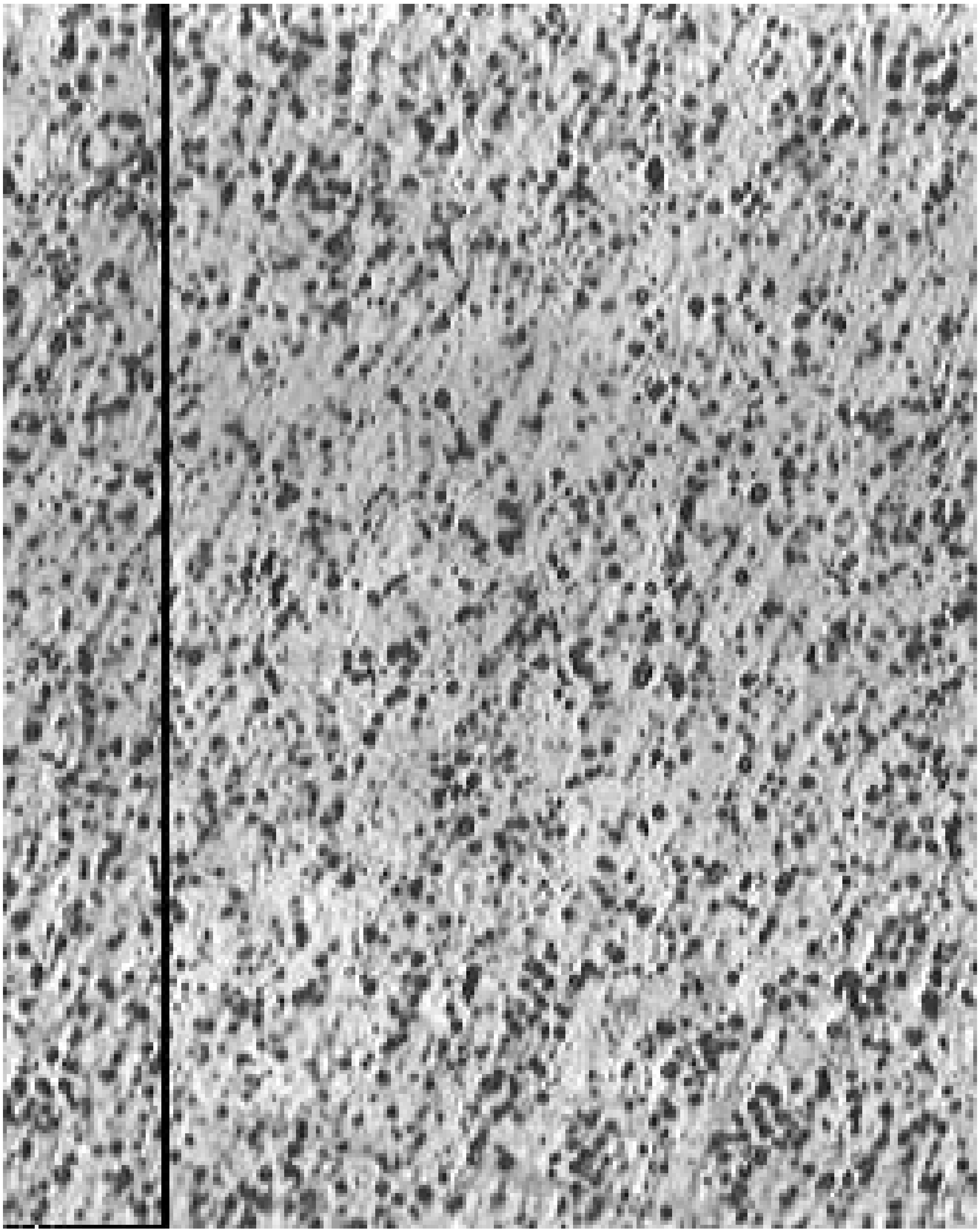
10 mm to surface precipitation of SANGS™ AA 6061 as-formed bar of diameter 3-1/2" (longitudinal view, X200)



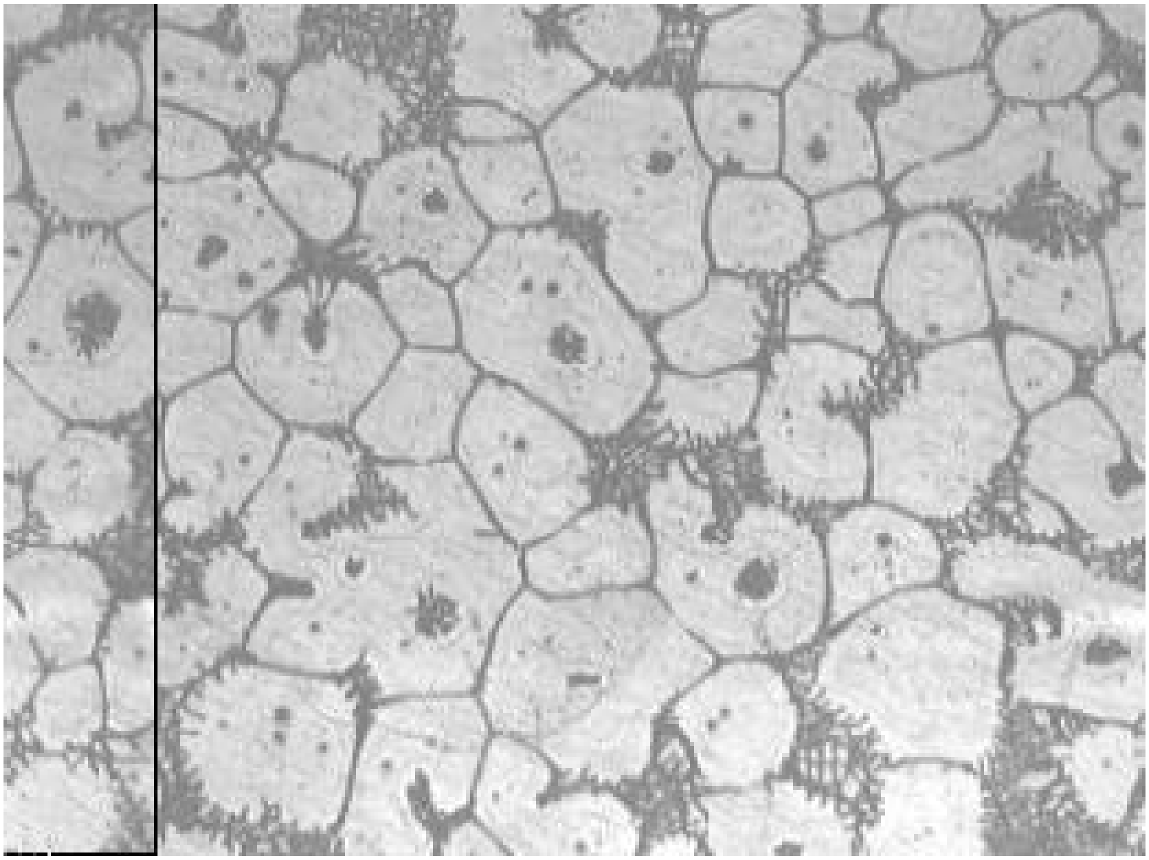
40 mm to surface (center) microstructure of SANGS™ AA 6061 as-formed bar of diameter 3-1/2" (above center-line, longitudinal view, X200)



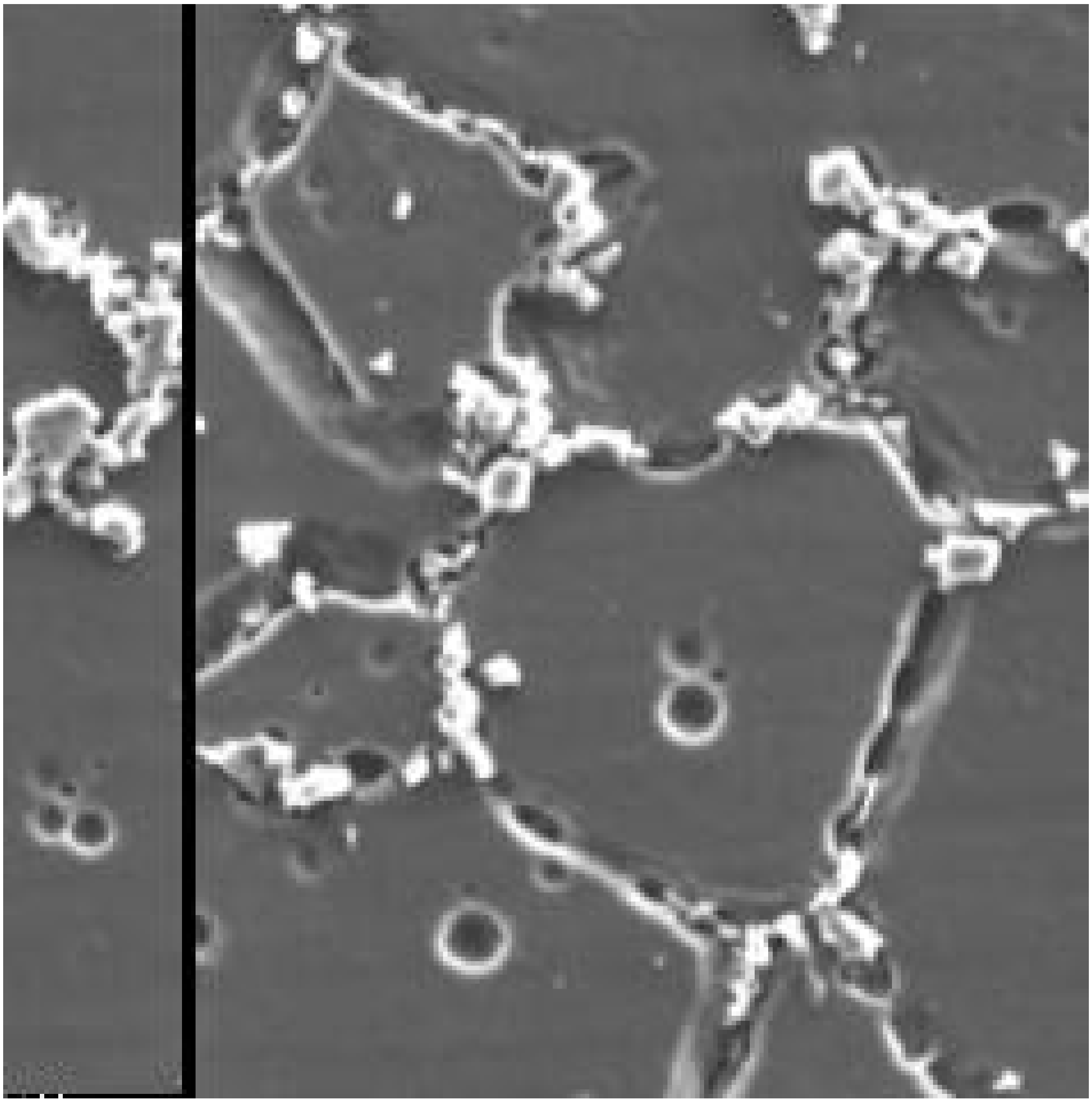
40 mm to surface (center) microstructure of SANGS™ AA 6061 as-formed bar of diameter 3-1/2” (below center-line, longitudinal view, X200)



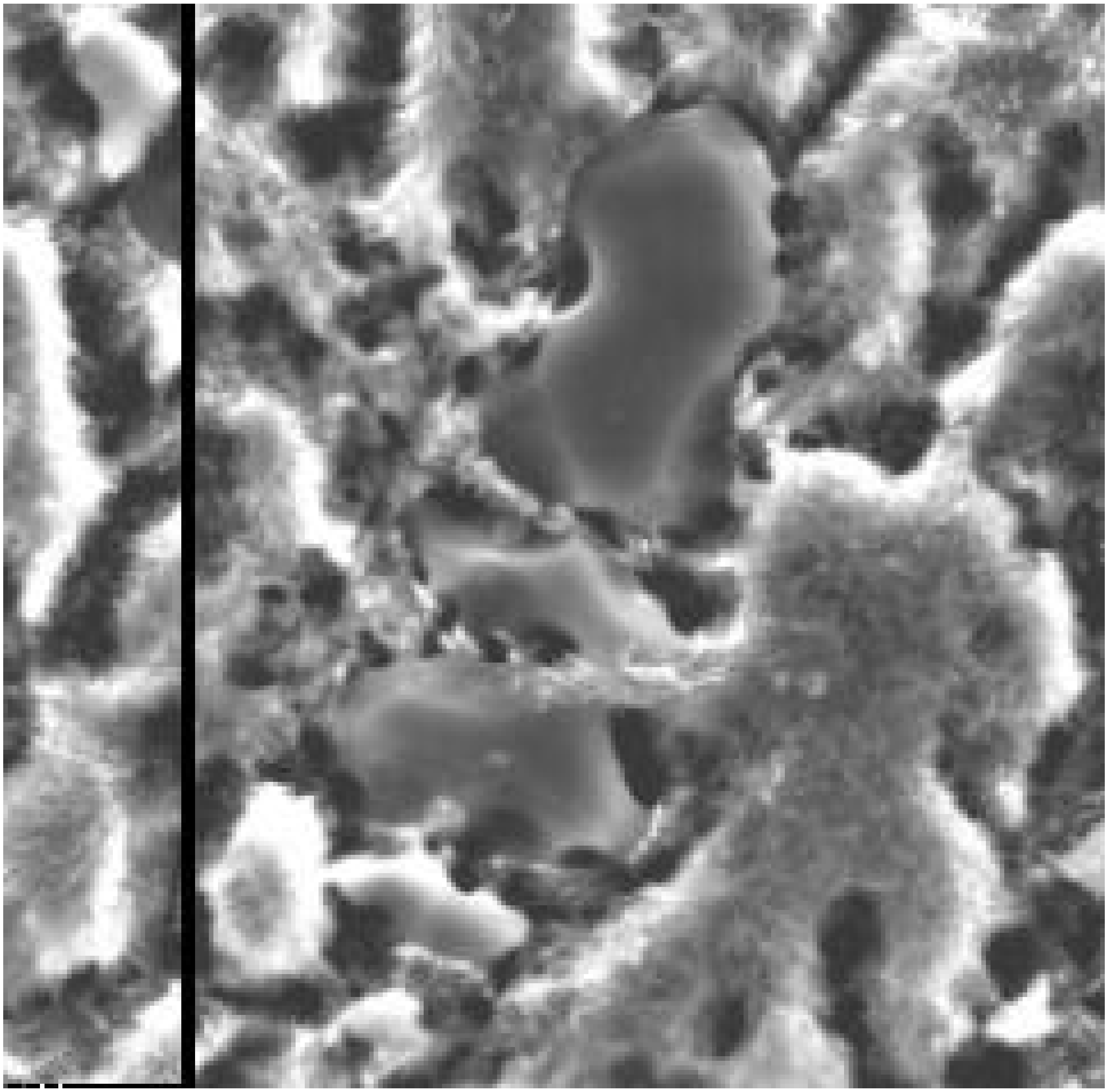
40 mm to surface (center) precipitation of SANGS™ AA 6061 as-formed bar of diameter 3-1/2” (longitudinal view, X200)



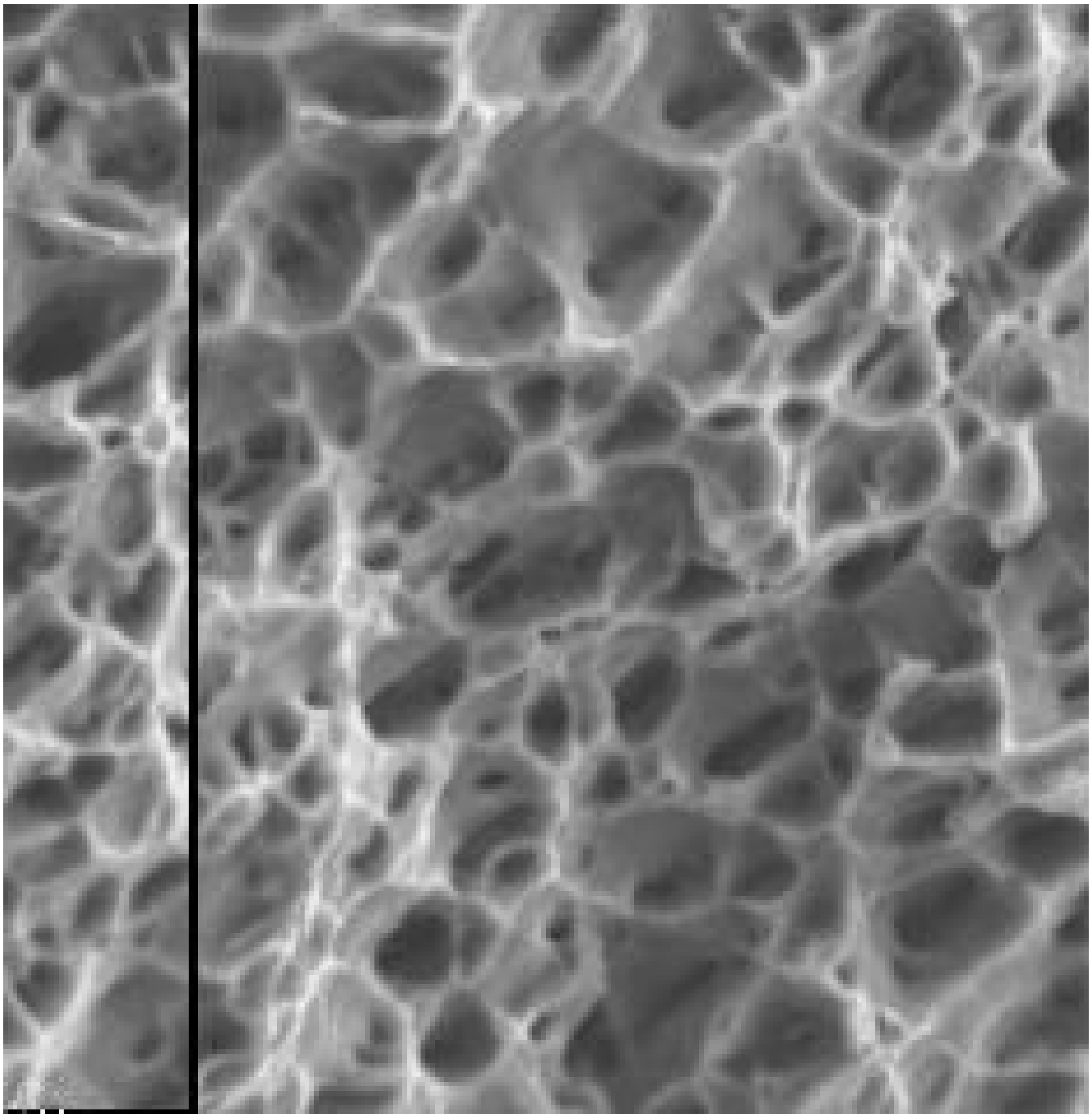
Microstructure of SANGS™ 3/8" AA 6061 bar after reheating at 640 C for 15 minutes, X100



SEM image of silicon-rich intermetallic compounds in the reheated microstructure of the SANGS™ 2” A356 bar (Soaking temperature: 595° C, soaking time: 5 mins.)



SEM image of the microstructure of the SANGS™ 2” A356 bar (Soaking temperature: 585° C, soaking time: 5 mins.)



SEM image of topography of fracture surface of a tensile bar of AA6061 SANGS™ bar. The uniform dimples seen in this high-integrity material explain the over 30% elongation achieved in this test sample.