calnano
materializing nano

GENERAL PRESENTATION

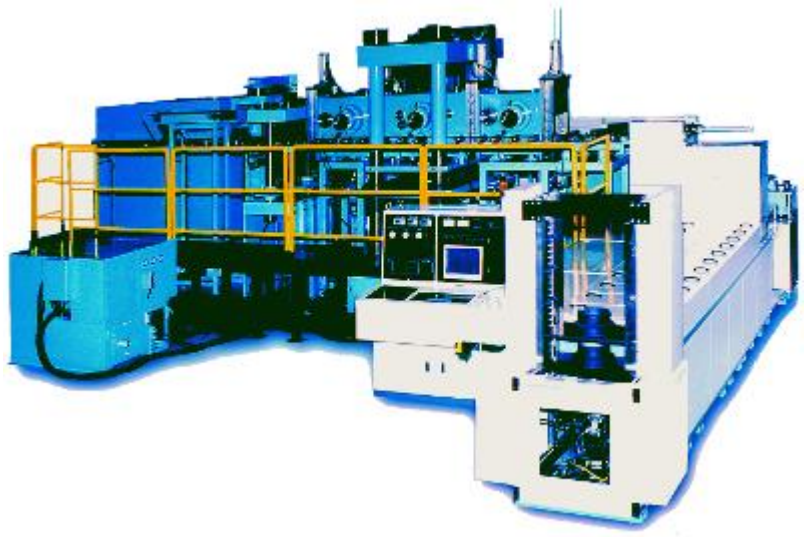
January 2021

17220 Edwards Road
Cerritos, CA 90703

Cal Nano Overview

Cal Nano's main technologies include Spark Plasma Sintering and Cryogenic Milling. Our goal is to provide toll services for large scale R&D programs and low-volume production for SPS and Cryomilling. Cal Nano is a publicly traded company with stock symbol – ***CANOF & CNO.V***.

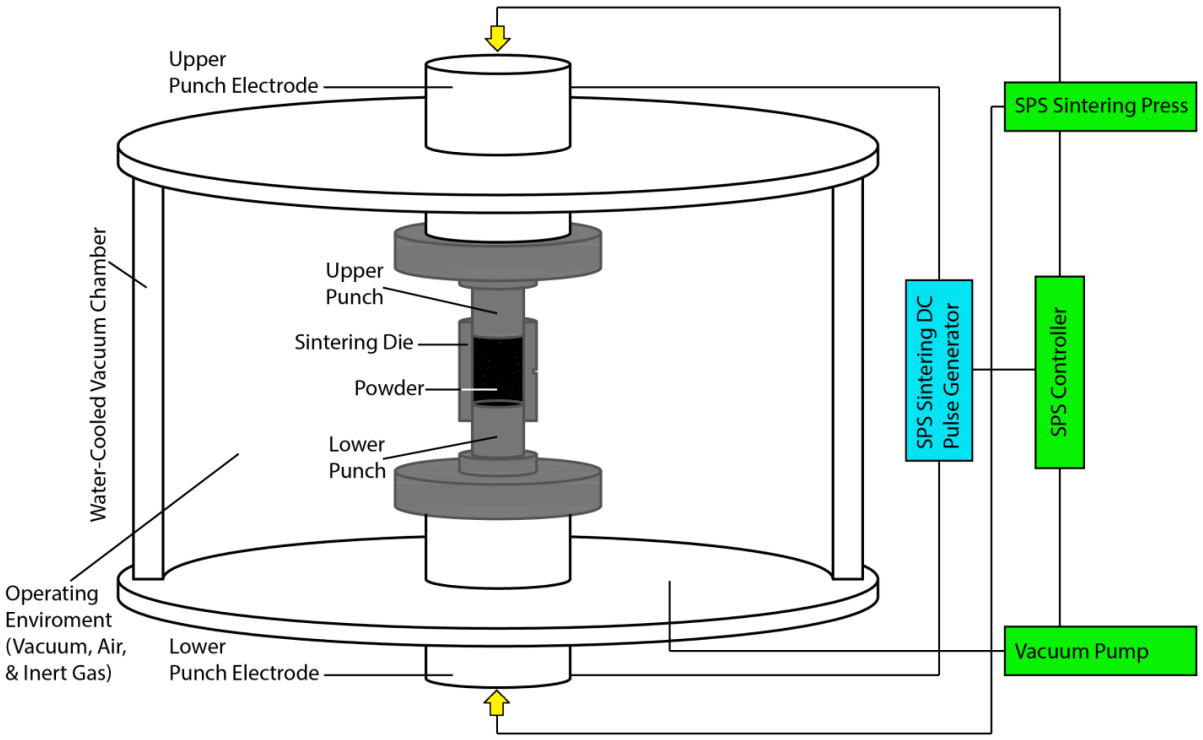
Cal Nano is also the official North American Technical Representatives of the Japanese manufacturer of SPS equipment, SUGA. We perform all installations, training and servicing of their SPS equipment in North America along with providing technical assistance to all SPS customers. SPS equipment is custom made for making small size samples to full-scale production system (shown in picture).



Fully Automated Production SPS System

Spark Plasma Sintering "SPS"

SPS allows for the rapid application of temperature and pressure via high-density pulsed current within a controlled atmosphere. SPS is the ideal consolidation method for most material



SPS Applications:

- Semiconductors
- Fine Ceramics
- Thermoelectrics
- Functionally Graded Materials
- Electronics
- Nanophases
- Hard Alloy Tools
- Diamond Tools
- Biomaterials
- Porous Materials
- Molds and Dies

Spark Plasma Sintering Capabilities

SPS-515

- Specs - 1500 A/50 kN
- ~ 1” diameter samples
- Has been used for R&D at Cal Nano for 10+ years
- Over 6,000 SPS runs performed
- Vacuum/N/Ar atmosphere

SPS 7.40 Mk IV

- Specs - 10000 A/1000 kN
- ~ 5-6” diameter samples
- Installed in Fall 2017 for larger R&D and pilot scale SPS programs
- Vacuum/N/Ar atmosphere

- Inert Glove Box Handling available for materials that require it (Ar/N)

Spark Plasma Sintering - Materials

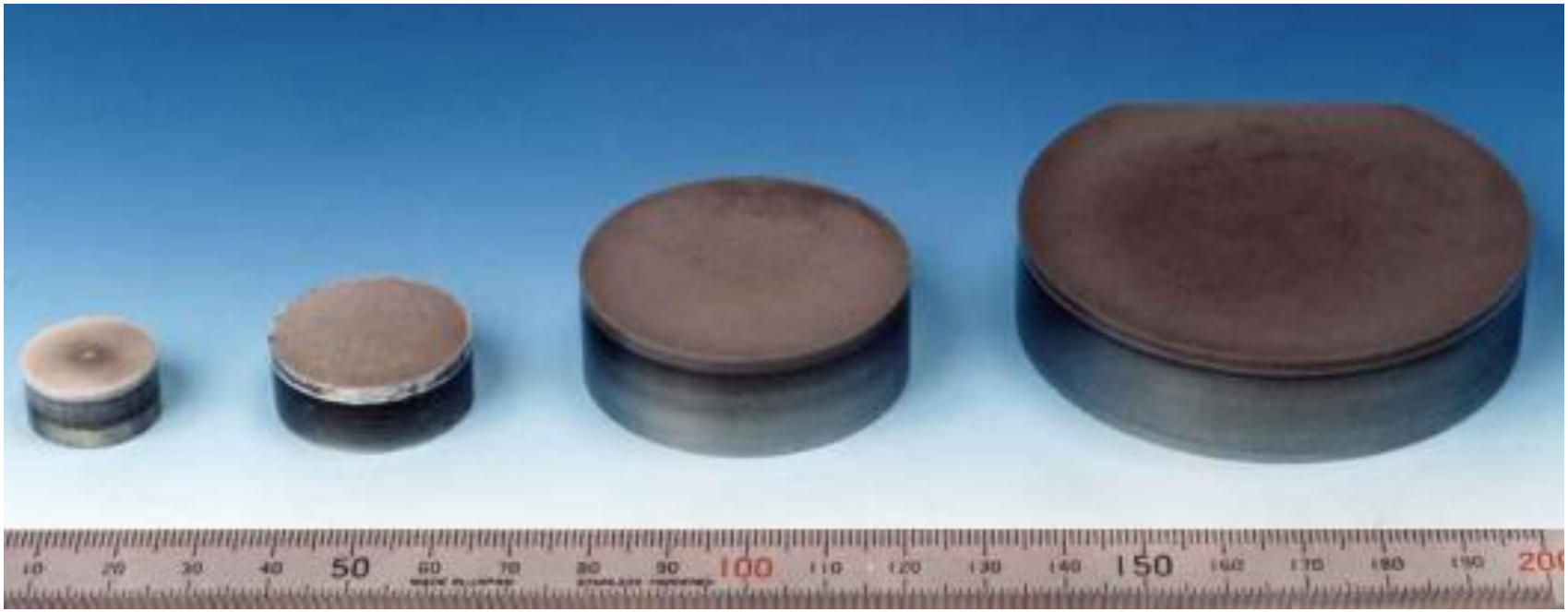
Classification		Materials for SPS processing
Metals		Fe, Cu, Al, Au, Ag, Ni / Cr, Mo, Sn, Ti, W, Be — Virtually any metals possible
Ceramics	Oxides	Al_2O_3, Mulite, ZrO_2, MgO, SiO_2, TiO_2, HfO_2
	Carbides	SiC, B_4C, TaC, TiC, WC, ZrC, VC
	Nitrides	Si_3N_4, TaN, TiN, AlN, ZrN, VN
	Borides	TiB_2, HfB_2, LaB_6, ZrB_2, VB_2
	Flourides	LiF, CaF_2, MgF_2
Cermets		Si_3N_4+Ni, Al_2O_3+Ni, ZrO_2+Ni
		Al_2O_3+TiC, SUS+ZrO_2, Al_2O_3+SUS
		SUS+WC/Co, BN+Fe, WC+Co+Fe
Intermetalic compounds		TiAl, $MoSi_2$, Si_3Zr_5, NiAl
		NbCo, NbAl, $LaBaCuSO_4$, Sm_2Co_{17}
Other materials		Organic materials (polyimide, etc.), compositematerials

Pure Nano SiC (30nm → 100nm)
R.D : 99.4%
mHv : 2380

Transparent ceramics

Spark Plasma Sintering – Functionally Graded Materials

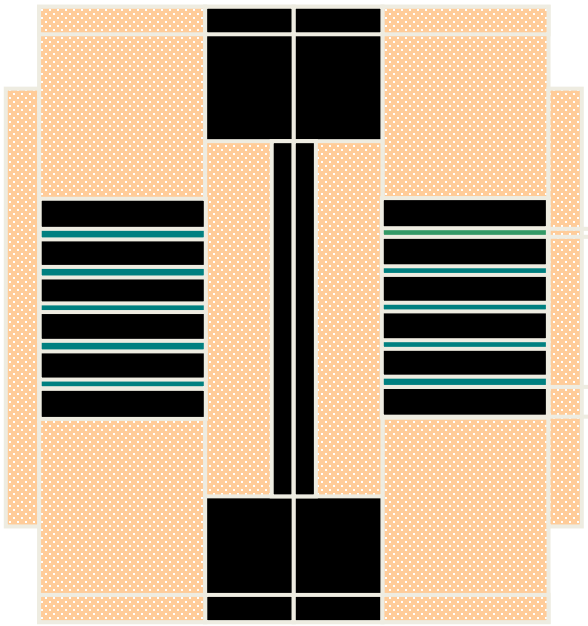
ZrO_2(3Y)/Stainless Steel FGM



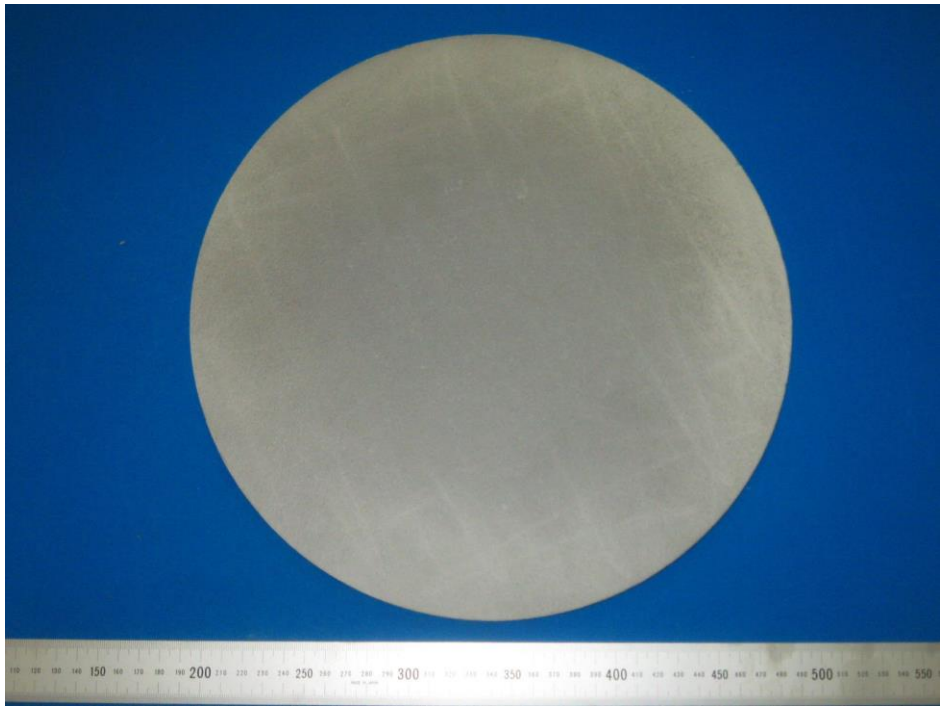
Spark Plasma Sintering – Multi-sample

WC/Co Diamond Cutting Blade by SPS

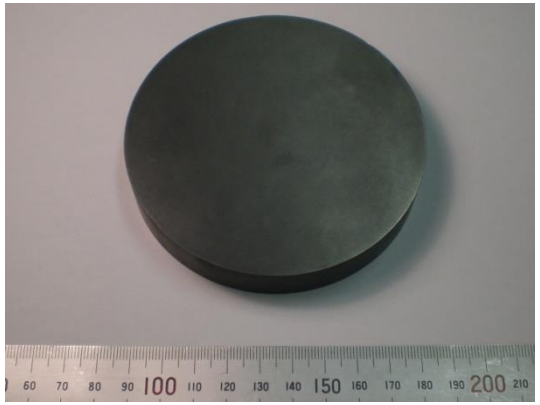
Outer Diameter	Φ100 mm
Inner Diameter	Φ40 mm
Thickness	0.35/0.4mm



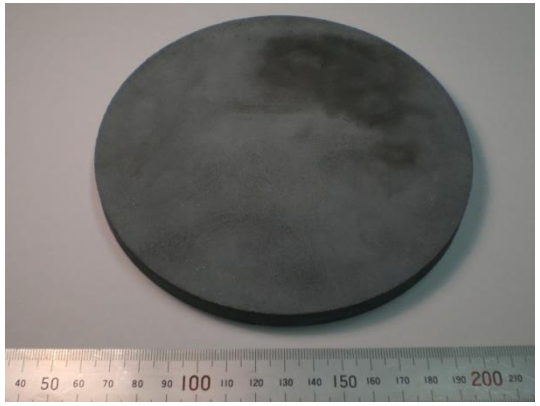
Spark Plasma Sintering – Large Ceramics



Material: Al_2O_3
R.D: Approx 99%



Material: WC (no additives)
R.D : 99-100%
Dimensions: ϕ100x16mm



Material: SiC (with additives)
R.D : 99-100%

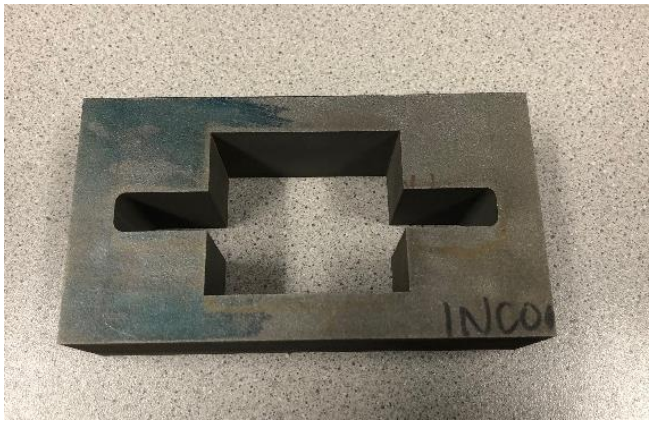
Cal Nano Machining Capabilities

Multiple Hardinge Lathes capable of machining up to ~6” OD parts

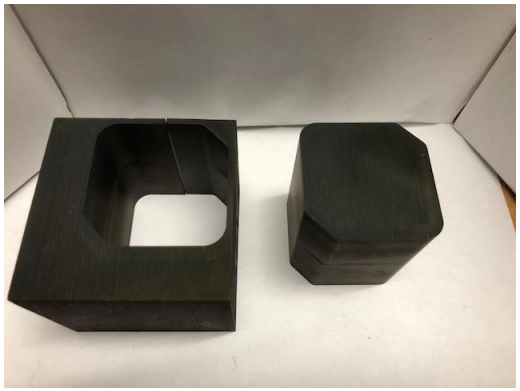
Wire EDM - precision cuts on pieces over 24” L x 24” W and ~8” Tall

Vertical Milling machine

Cal Nano Machining Capabilities



Custom design made with wire EDM of metallic alloy



Custom graphite tooling made with wire EDM

Standard SPS Graphite Tooling made with Lathe

Custom SPS WC Tooling

Mechanical Testing

Testing & Analysis Labs:

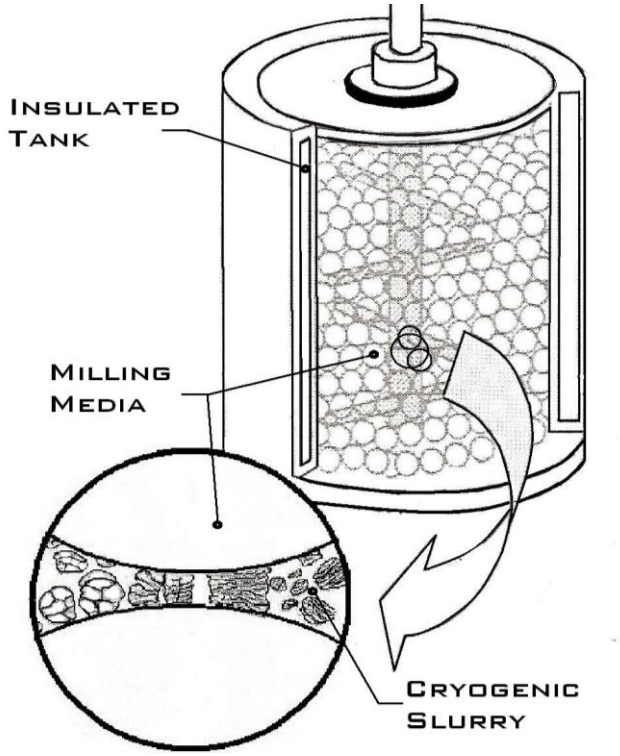
- Instron Unit - Tensile & Compression
- Standard Hardness & Micro Hardness
- Profilometer – Surface Roughness
- Laser Diffraction Particle Size Analyzer

  - 0.01 um- 3800 um range

Instron Machine

Cryogenic Milling

Cryogenic Milling is high energy attrition ball milling with the material and media submerged in cryogenic liquid. Cal Nano uses ¼" SS balls for media and either liquid nitrogen or liquid argon as the cryogenic liquid.

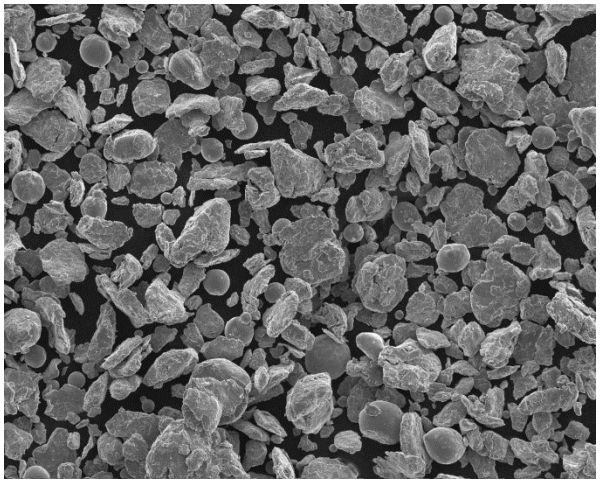


Currently three Cryomills at our facility:

- 500 gram powder capacity
- 1 kg powder capacity
- 7-10 kg powder capacity

Cryogenic Milling Benefits

- **Cryomilling is an effective means to produce nano-grained metals and alloying specialty materials including high entropy alloys, refractory materials and metal/ceramic composites.**
- Rapidly reduces particle size in materials that otherwise smear (plastics, low density metals, water soluble etc.)
- In many light alloys produces nano-scale nitrides resulting increased hardness, stiffness, and thermal stability.
- Solid state reactions during milling allows the formation of alloys beyond liquid melt limits
- Uniform distribution of added ceramic particles in MMCs etc.



Cal Nano has received a patent submission securing key techniques allowing for safe and cost effective large scale commercial cryomilling. 100's to 1000's of kg per week are achievable with cryomilling process.

Cryogenic Milling Benefits (cont'd)

Particle size reduction –

Ability to reduce polymer materials to sub 1 um size which is typically not possible with other methods. Material needs to start at a few hundred microns in order to achieve this.

Strength Improvement –

Cal Nano was able to double standard Al 6061 tensile strength simply by cryomilling. No additives or heat treatment needed. Similar results have been achieved with Iron, Ti and Ni-based alloy systems.

Moisture/Oxygen Sensitive materials–

During our cryomilling process the material is fully submerged in cryogenic liquid at all times. Along with that, Cal Nano handles material pre and post-milled materials in an inert glove box making it a great process for sensitive materials.

Mechanical Alloying –

Cal Nano was able to produce high entropy alloy systems (mixing 5+ elements) safely and in about 1/5 the time compared standard milling processes