Analysis of Brandonite® 4210 Liquid Castable Composites As A Cost-Effective, Non-Toxic Replacement For Parts Containing Lead or Lead Oxides

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EXECUTIVE SUMMARY

Globe Composite Solutions has developed a cost-effective lead-free liquid-castable material to meet a wide variety of applications currently being filled by lead. Unlike lead, Brandonite® 4210 (patents pending) meets the EU RoHS Directive. Essentially inert chemically, the new material poses no toxic or ecological threat and can be successfully (and safely) disposed at the end of a product's life cycle.

Brandonite® 4210 is a polymer-metal (poly metal) composite that is dispensed as a liquid, requiring less expensive tooling than injection molding and providing product developers more design and manufacturing flexibility for virtually any size or part geometry. Additionally, research conducted at Globe and with independent testing laboratories indicates that Brandonite® 4210 provides essentially the same or better radiographic shielding capabilities and greater arc resistance when compared to other lead-based materials.

Globe's introduction of a non-toxic high gravity composite material coincides with increasing scrutiny and regulatory oversight of lead and lead-based products. There is a real and growing concern as to the future sustained availability of lead or lead-based materials. Since many manufacturers operate on a just-in-time basis, any supply chain interruption due to the cessation of lead-based raw materials would have costly and disastrous consequences to its business.

BACKGROUND

The use of lead has come under increasing oversight and concern worldwide. U.S. consumption of lead in 2009 was 1.4 million metric tons and world mine production of lead increased by 165,000 tons, or about 4% to 3.84 million tons, from that of 2007. China was the leading producer with about 39% of the world total mine production.[1] Lead consumption was expected to increase by 3% in 2009 worldwide owing to a nearly 25% increase in Chinese lead consumption, which was driven by growth in the automobile and electric bicycle markets. Worldwide, approximately 8.9 billion pounds of lead were produced and 881 million pounds of material containing lead are absorbed into the environment every year.[2]

Due to the inherent hazards of lead, there has been increased public awareness of the toxicity and its impact upon humans and the eco-structure. A sampling of recent news reports is a testament to the increased sensitivity associated with lead:

- Hundreds suffer lead poisoning in China. Latest pollution disaster caused by smelter in poverty-stricken Gansu [3]
- China exports lead poisoning: From eye shadow to glazed pottery, products pose danger to U.S. kids [4]
- Toy recall puts attention on lead poisoning [5]
- Hundreds of Thousands of U.S. Children Poisoned from Lead in Paint, Not Toys [6]

Increasingly, lead usage has been restricted – in fact, virtually prohibited in any case of direct human or animal contact – by an ever-tightening set of regulations within the US and abroad.

California requires public notification of hazardous substances (lead compounds are explicitly included) in products produced or shipped within its borders, under its Environmental Protection Agency Proposition 65. Effective January 1, 2007, the California Electronic Waste Recycling Act of 2003 (SB20) restricts the use of lead. Historically, such action by California has preceded similar action by other states and by the U.S. on a federal level. Maine, Rhode Island, Texas, Vermont and Washington all have enacted legislation restricting the use of lead.

In October 2009, the EPA strengthened the national ambient air quality standards for lead. The revised standards were about 10 times more stringent than the previous standards which dated back to 1978. The EPA revised the level of the primary standard to 0.15 micrograms of lead per cubic meter ($\mu g/m^3$) from 1.5 ($\mu g/m^3$) measured as total suspended particles. Since the previous standard had been issued, more than 6,000 studies on lead health effects, environmental effects, and lead in the air have been published.

The European Union promulgated stringent controls upon lead and other hazardous materials with the adoption of the Restrictions of Hazardous Substances (aka RoHS) Act in February 2003[3] which became effective on July 1, 2006. *Medical device manufacturers (known as Category 8 goods) and manufacturers of industrial and test equipment (Category 9 goods) have been exempted from compliance until 2012.* Other countries adopting the EU RoHS Directive are Australia, Canada, Korea and Taiwan. The Japan Green Procurement Survey Standardization Initiative (JGPSSI) restricts the use of lead and was implemented July 1, 2006.[7]

Several of Globe's existing customers are targeting full RoHS compliance by no later than 2012. There are few commercially feasible lead-free radiographic shielding alternatives available for medical device and other manufacturers currently using lead or lead-based materials. As a result, some medical device manufacturers risk the removal of their products from the market when RoHS is implemented.

Additionally, OSHA has increased its surveillance efforts to restrict the handling of lead-based materials in the workplace. In 2009, OSHA implemented a special emphasis program aimed at reducing occupational exposure to lead. "Occupational exposure to lead continues to be one of the most prevalent overexposures found throughout industry," said Charles E. Adkins, OSHA's regional administrator in Kansas City. "It is imperative we do all we can to reduce that exposure to workers. This special regional emphasis program will serve to amplify OSHA's commitment to ensuring the safety and health of workers in all occupations."[8]

As shown below, the cost to store, handle and manufacture lead has had a marketed impact on the price of lead, rising almost 50% in the past five years. Additionally, there is a high degree of volatility in the price, having increased 250% and 110% during two nine-month periods during the same five year span.

ALTERNATIVE MATERIALS

Lead, because of its relatively low acquisition cost and excellent radiation shielding capacity, has traditionally been used in medical settings for technician and patient protection in X-ray facilities, nuclear medicine, and for equipment containers and housings. Lead-encapsulated epoxy resins ("litharge") have gained recent acceptance in the marketplace due to the castable aspect of this liquid resin which has allowed manufacturers to produce parts with unique design configurations. Unfortunately, litharge has poor mechanical properties, is toxic and has experienced a 161% increase in cost over the past 2 ½ years.

Globe Composite Solutions, Ltd. initiated a research project to evaluate alternative sources of high-gravity and/or radiographic shielding material that would have similar cost and performance characteristics as lead. Globe's *research indicated that only thermoplastic injection-moldable materials are available to replace lead or litharge. Although thermoplastic materials are able to achieve higher densities, the injection-molding process requires high initial tooling costs, appeals to large (10,000+ parts per year) production quantities and is limited to relatively small part sizes and geometries:*

	Dispensing Method	Tooling Cost	Part Size or Geometry	Volume Requirement	Density Range
Brandonite®	Liquid	Low	High	Low	2.0 – 5.7 g/cc
Thermoplastics	Injection	High	Low	High	2.0- 11.0 g/cc

BRANDONITE® 4210 PROPERTIES

Comprised primarily of tungsten plus a variety of polymer binders, *the new poly metal composite is fully capable of being processed with conventional thermoset resin equipment*. Globe compared the physical performance of its Brandonite® 4210 material with pure lead as well as commercially available litharge products. A comparison of physical, electrical and thermal properties reveal that Brandonite® 4210 provides essentially equivalent or greater physical attributes than either lead or lead-based litharge.

The gamma and X-ray shielding properties of Brandonite® 4210 is a function of the power level and the density of the Brandonite® 4210 material. *An independent testing facility has confirmed that Brandonite® 4210 shielding properties are essentially the same as lead:*

			Radiation Shielding As % of Lead				
SAMPLE							
Thickness (Inches)	Density (g/cc)	Power Level	300 kV/3 mA	140 kV/3 mA	140 kV/3 mA	76 kV/3 mA	76 kV/5 mA
		Duration (minutes)	1.3	2.6	5.2	5.2	5.2
0.25	2.4	GCS Brandonite 4210-d24			29.7%		
0.25	2.6	GCS Brandonite 4210-d26			42.8%		
0.25	2.7	GCS Brandonite 4210-d27			77.9%	99.6%	99.5%
0.25	3.0	GCS Brandonite 4210-d30			87.1%	99.7%	99.8%
0.25	3.2	GCS Brandonite 4210-d32	24.4%		91.1%		
0.25	3.4	GCS Brandonite 4210-d34	37.7%	98.5%	92.4%		
0.25	3.5	GCS Brandonite 4210-d35	56.5%			100.1%	
0.25	4.3	GCS Brandonite 4210-d43				100.2%	
0.25	4.7	GCS Brandonite 4210-d47	77.5%		98.2%	100.1%	
0.50	5.7	GCS Brandonite 4210-d57	98.5%	99.9%	99.3%		

Brandonite exhibited significantly greater arc resistance than the litharge material (Lord Circalok #6015 and #6013) when used for certain radiation shielding applications. Testing was performed by a well-known independent testing laboratory, ELTEK International Laboratories, located in St. Louis MO. The testing was conducted according to ASTM D-495 & UL 746A, which is appropriate for this application environment.

	Lord #6015	Lord #6013	Brandonite 4210-d30	Brandonite 4210-d32	Brandonite 4210-d42
Density (sp gr 23/23ºC)	2.92	4.2	3	3.2	4.2
Arc Resistance (secs)	10	78	133	184	185

ASTM D-495 & UL 746A testing is intended to differentiate among similar materials with respect to their resistance to high-voltage, low-current arcing of the material close to the surface of insulation. Low arc resistance will deteriorate the surface of the insulating material, thereby causing surface electric discharge. This electrical discharge will eventually lead to part failure when too much insulating material has been worn away. Certain radiographic shielding components require frequent replacement, approximately once every 2-4 years. This may be due to the low arc resistance of litharge material.

Different formulations of Brandonite® 4210 yield composites that emulate the key physical properties of lead. The densities of Brandonite® 4210 range from 2.6g/cc to 5.7g/cc. It is in the higher density forms this composite is similar in behavior to that of heavy metals, primarily lead, but also lead alloys, zinc, brass, silver, and molybdenum.

Brandonite® 4210 Product Availability Summary

Brandonite® Designation	4210-d26	4210-d30	4210-d32	4210-d35	4210-d44	4210-d47
	(Patent Pending)	(Patent Pending)	(Patent Pending)	(Patent Pending)	(Patent Pending)	(Patent Pending)
Hardness, D scale	95D	89D	92D	94D	94D	95D
Density, g/cc	2.6	3	3.2	3.5	4.4	4.7
Izod impact strength, ft-lb/in	0.4	0.44	0.48	0.54	0.63	0.66
Tensile strength, psi	4,190	4,780	7,380	6,300	5,848	11,300
Elongation, %	0.5	1.0	1.0	0.5	0.7	1.0
Flexural strength, psi	9190	11,700	13,630	13,400	13,450	14,900
Flexural modulus, psi (k)	1,340	1,190	1,092	929	875	855
Volume resistivity Ohm-cm, x10^15	7.1	7.05	6.8	6.45	5.1	0.457
Dielectric constant	5.86	7.94	9	11.5	22	29.5
Dissipation factor	0.009	0.01	0.011	0.014	0.026	0.033
Dielectric strength, V/mil	384	130	72	42	10	2
Thermal conductivity						
BTU in/hr ft^2 F	3.114	3.712	3.712	4.56	6.34	6.952
W/m k	0.449	0.535	0.535	0.658	0.915	1.003
Contains Pb?	NO	NO	NO	NO	NO	NO

BRANDONITE® 4210 BENEFITS

Benefit 1: Material Availability

Globe's Brandonite® 4210 family of high-gravity composites are formulated using a variety of commercially available materials from numerous primary and secondary sources. There are numerous advantages associated with the presence of multiple suppliers. First, *it allows a consistent and uninterrupted supply of product for any customer that employs a just-in-time product delivery.* Secondly, the presence of multiple suppliers for the basic ingredients of

Brandonite® 4210 *allows Globe to aggressively negotiate material costs thereby assuring customers that it will receive the lowest possible price for its components.*

Benefit 2: Environmentally-Friendly

Brandonite® 4210 materials are fully RoHS compliant which helps customers achieve its mandated RoHS compliance requirement and allows US-based companies to further expand its reach into heavily regulated markets by offering RoHS compliance products. Additionally, t*he use of this non-toxic material may also allow customers to establish or reinforces its brand positioning as being an environmentally-friendly manufacturer.*

Benefit 3: Lower Tooling Cost

A primary advantage of this material is that it can be processed using Globe Composite Solutions' conventional liquid casting equipment, enabling customers improved design flexibility and significantly reducing/eliminating costly secondary machining operations. As a result, lower cost tooling can be deployed, thereby reducing the initial costs to convert to this material.

Benefit 4: Part Size/Part Geometry

Since the material is dispensed as a liquid, rather than injection molding, parts can now be made in almost any geometry or part size. As shown below, this allows the customer a broader range of design possibilities as well as the opportunity to incorporate many features and functions into a single part.

Benefit 5: Cost-Effective Material

Since Brandonite® 4210 is available in a wide spectrum of densities, ranging from 2.6 g/cc to 5.7 g/cc, the material can be matched to the specific product application, thereby assuring that customer that it is using the most cost-effective formulation. We have encountered numerous instances in x-ray/gamma-ray shielding or ballast applications where the use of lead or lead-derivatives exceeds the amount of shielding or weight requirements. Now, material can be configured for the appropriate density or other physical characteristics to minimize unnecessary expense.

APPLICATIONS

Due to the continually evolving demand for this product (and the inherent flexibility of the base material to accommodate different fillers), *Brandonite® 4210 can be used for weight-related applications (i.e., balance or ballasting) as well as gamma and x-ray shielding applications. In*

almost any situation where high density material is required, Brandonite® 4210 can be used without the environmental health or toxicity concerns of lead.

Specifically, *Brandonite® 4210 can be formulated to provide optimal x-ray and gamma ray shielding properties similar to lead or lead-encapsulated resins* (litharge) for medical device applications requiring radiation shielding. This product is castable and has similar radiation-shielding properties as lead without the attending toxicity and disposal issues. Target applications include X-ray tube housings, radioisotope containers, syringe shields, bitewing dental X-ray packets, and shielding for technicians and patients.

There are numerous non-medical uses for this material as well. As an example, Brandonite® 4210 can be formulated in various densities to achieve optimal ballast configurations for towed arrays, water-quality sampling equipment, submersible probes and other marine applications. Recently, Globe developed a new non-toxic ballast control mechanism for freshwater reservoir monitoring equipment.

SUMMARY

Brandonite® 4210 is a new cost-effective polymer-metal composite that has been developed to replace lead and lead-encapsulated epoxy. Brandonite® 4210 is available in densities ranging from 2.6 g/cc to 5.7 g/cc and c*an provide equivalent x-ray shielding properties to lead or litharge while possessing essentially the same physical, mechanical, electrical and thermal properties.*

Brandonite® 4210 is generally available at lower costs when compared with alternative high-gravity materials and may provide customers with numerous secondary benefits. This material could be an effective hedge against recent lead and litharge price increases. Additionally, *Brandonite® 4210 provides an excellent material to protect customers against the possible removal of lead or lead-encapsulated litharge due to environmental concerns.*

Unlike lead, Brandonite® 4210 composites are nontoxic and meet some of the most demanding physical requirements utilizing a variety of polymers and metallic and non-metallic fillers. Brandonite® 4210 meets EU RoHS Directive and is lead-free (Pb-Free). Since this material can be liquid cast, tooling is far less-expensive that injection molding and product developers can enjoy even more design/manufacturing flexibility.

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