High-K precursor materials for the electronics industry

Albemarle's organometallic products are used in many applications, with the largest volume used as catalysts or cocatalysts in the polyolefin industry. But organometallics are also used for industrial organic syntheses in pharmaceuticals and fine chemicals, as well as in the electronics industry.

We have commercially produced numerous aluminum alkyl products since the 1960s. Trimethylaluminum (TMA) is an important product of the aluminum alkyl family. It is used in polyolefin applications but is also sold as a starting material to the semiconductor industry and is a key raw material in the production of other metal alkyls, such as trimethylgallium (TMG) and trimethylindium (TMI).

Over the past 10 years, we have built on our core strength of supplying aluminum alkyls and committed ourselves to improving product specifications to meet the stringent requirements of the electronics industry. This has led to different purity grades of TMA products, including an Electronic Grade or E-TMA and TMA-HP. Each of these products provides further reduction of metal impurities to meet the requirements of electronic applications.

TMA-HP was developed specifically for the direct deposition of dielectric films of aluminum oxide, using chemical vapor deposition (CVD) or atomic layer deposition (ALD). See Figure 1 for HfO_2. Development of TMA-HP required close interaction with our customers to develop a product which met the low trace-metals specifications.

The semiconductor industry continues to face pressure to shrink the size of components while improving performance. Silicon remains the primary semiconductor material in the marketplace and integrated circuit technology on silicon wafers is currently undergoing dramatic technology and material changes.

For transistors to continue to improve in performance while shrinking in size, new gate dielectric materials must be developed and implemented. Traditional transistor gate technology is limited by substantial current leakage problems, which waste energy and produce heat that can adversely affect device performance.

With higher-K materials (relative to SiO_2), thicker layers can be deposited to simultaneously improve performance and reduce current leakage. The K value of an inorganic dielectric material (Table 1) is proportional to its capacitance. In order to produce the high-K gate materials, high-purity volatile precursors of transition metal complexes will be required.

Material	ϵ_r or k	Precursor
SiO_2	4.5	
Al_2O_3	9-11	TMA-HP & E-TMA
$Hf_xSi_{1-x}O_y$	11	
$Zr_xSi_{1-x}O_y$	12	
ZrO_2	14-25	TEMAZ
HfO_2	15-26	TEMAH
TiO_2	50-80	TDEAT

Table 1: K value of inorganic dielectric materials.

These precursors are a natural extension of Albemarle's process technology, equipment, and raw materials used for making metallocenes, a class of catalyst components. As a result, we have recently developed a proprietary process to produce metal amide materials including TEMAH {$Hf(NEtMe)_4$} and TEMAZ {$Zr(NEtMe)_4$}. This process was successfully demonstrated on pilot plant scale to make high purity TEMAH in late 2007.

Albemarle continues to seek opportunities in the electronics industry that allow us to combine our strengths in organometallics chemistry and scale up technology. We can provide highly refined products to meet customer specifications.

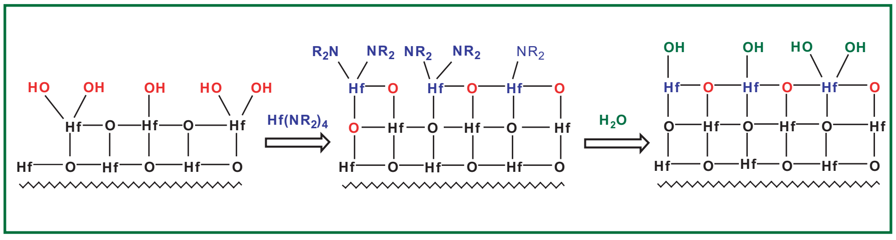

Figure 1: Atomic layer deposition of hafnium oxide.

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