Cost saving of using a metallurgical grade silicon with higher trichlorosilane yield in the hydrochlorination based polysilicon process

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Abstract

Synthesis of trichlorosilane (TCS) by hydrochlorination (HC; $Si + H_2 + SiCl_4$) has become a favored commercial source of TCS for TCS-Siemens based stand alone polysilicon plants. TCS from the HC unit can also be converted to silane (SiH_4). Silane can be sold or converted to polysilicon via silane-Siemens or silane-fluid bed reactor (FBR). Solar-grade polysilicon has become a highly specialized low-margin commodity material. Commercial HC plant operators need to place high emphasis on all methods to reduce plant operating costs.

Decreasing TCS yield from the HC fluid bed reactor results in higher energy input costs for a plant producing a fixed amount of polysilicon. Laboratory HC reactor results show that metallurgical grade silicon composition can have a strong influence on TCS yield. This paper provides information about chemistry, process design, commercial process operation, energy input and parameters that influence overall TCS yield of the HC process. The discussions are applicable for a commercial HC process unit used to produce polysilicon-grade TCS or silane (SiH_4).

Not discussed in this paper are additional areas of commercial HC plant operation that impact operating costs. These areas focus on plant reliability. Reliability is achieved through optimization of process design, operating strategy and operating experience. Poor plant reliability can result in higher differential operating costs than differential costs resulting from low TCS yield.

Hydrochlorination Chemistry and Basic Information

The process to produce trichlorosilane (TCS) by reaction of ground metallurgical grade silicon (MGS), hydrogen and silicon tetrachloride (STC) has been given several names. Hydrochlorination (HC) has become the most widely used name and is used in this paper. The HC reaction is comprised of parallel reaction steps. The overall equilibrium reaction is written:

$$Si\ (s) + 2H_2\ (g) + 3SiCl_4\ (g) = 4HSiCl_3\ (g) \qquad (1)$$