

An Example: Chemical Vapor Deposition

Chemical vapor deposition (CVD) is a process currently employed throughout the semiconductor industry to produce integrated circuits. Most common electronic devices (computers, cell phones, calculators, Ipods, etc...) utilize integrated circuits. Hewlett-Packard here in Corvallis employs this process. Throughout the remainder of this course we will, from time to time, use the CVD process used in the production of integrated circuits as a context when discussing and learning class concepts.

In general, the goal of the CVD process is to deposit a uniform layer of silicon nitride (Si_3N_4) onto wafer surfaces within the furnace. Silicon nitride is useful for many reasons. For instance, because silicon nitride prevents oxidation, it can be used to mask off specific parts of a wafer allowing the construction of very small but complex integrated circuits. In the CVD process used when making integrated circuits, dichlorosilane (SiH_2Cl_2 , also abbreviated as DCS) and ammonia gas (NH_3) are injected into a furnace. These two chemicals react and produce the desired silicon nitride (Si_3N_4). Unfortunately, hydrochloric acid (HCl) and hydrogen gas (H_2) are also produced in this reaction.

1. Write a *balanced* chemical equation for the reaction between dichlorosilane and ammonia gas that forms silicon nitride, hydrochloric acid, and hydrogen gas.
2. If 8.342 grams of silicon nitride are required
 - a) How many grams of dichlorosilane are needed?
 - b) How many grams of ammonia gas are needed?
 - c) How many liters of ammonia gas at STP is this?

Unfortunately, as this first reaction takes place, a second reaction begins immediately between the hydrochloric acid and ammonia gas. In this second reaction, ammonium chloride is produced.

3. Write a *balanced* chemical equation for this secondary reaction between the hydrochloric acid produced from the first reaction and additional ammonia gas.
4. If all of the hydrochloric acid produced from the first reaction also reacts with ammonia gas, how many additional grams of ammonia gas will be required to still produce the 8.342 grams of silicon nitride?
5. Now the challenge. If 14.251 grams of dichlorosilane and 25.888 grams of ammonia gas are placed in the furnace at the same time,
 - a) Which reactant runs out first?
 - b) How much (grams) silicon nitride can be produced?

Answers:

1. $3 \text{SiH}_2\text{Cl}_2 + 4 \text{NH}_3 \rightarrow \text{Si}_3\text{N}_4 + 6 \text{HCl} + 6 \text{H}_2$
- 2a. 18.02 g DCS
- 2b. 4.051 g NH_3
- 2c. 5.328 L NH_3
3. $\text{HCl} + \text{NH}_3 \rightarrow \text{NH}_4\text{Cl}$
4. 6.076 g NH_3
- 5a. DCS runs out first.
- 5b. 6.597 g Si_3N_4