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Gas recycling in a stacked susceptor epitaxial reactor

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Abstract

Gas recycling in a previously patented silicon epitaxial reactor is described. As far as HCl content is kept under certain limits to avoid Si etching during deposition, simple gas recycling has two main advantages: an important reduction in carrier gas waste, and, in some cases, also an increase in the deposition efficiency. A further step, also discussed here, is to avoid using source gases as such, but to produce them in-situ in a closed loop, by means of etching electronic grade Si in a separate chamber, to deposit it afterwards in the epitaxial chamber. This solution avoids carrier gas waste, which has to be introduced only initially, and gives theoretical efficiencies of 100%, which is a big difference with usual epitaxial reactors nowadays.

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1. Introduction

The photovoltaic (PV) industry relies nowadays on high-purity silicon feedstock as used by the microelectronic industry. This situation is not desirable in the long term because the material is very expensive, due to the requirements of microelectronics, which are not the same as for photovoltaics. But, more urgently, this dependency might result very detrimental in the short term for the sustained growth of PV due to the threat of a silicon shortage [1], perhaps preventing further development.

In parallel with the search of independent silicon sources (the so-called solar grade silicon), different approaches for making thin-film solar cells have been conceived [2] that, by using less feedstock material, can alleviate these problems. Among the candidate technologies, it has been proposed to grow a thin epitaxial layer on a cheap substrate by chemical vapour deposition (CVD) following the well-known techniques of microelectronics.

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However, in order to make costs adequate for photovoltaics, novel high throughput reactors must be invented and the consumption of gases and energy must be minimized.

Some proposals of high throughput CVD reactors have been made in the past [3,4]. Luque et al. [5] patented a high throughput epitaxial reactor of up to 250 wafers per batch, the so-called stacked susceptor epitaxial reactor (SER). It is based on graphite stacked susceptors, heated by Joule effect. In this reactor, and to avoid excessive heating, the gases must be blown at a high velocity. This means that the consumption of pure carrier gases (hydrogen, nitrogen, etc.) in this reactor can become a large component of the cost of an epitaxy. It was then proposed to decrease it by recycling or recirculating the gases during the process [5]. This idea is rather unexplored for CVD reactors, and has seldom been considered [5,6].

Some 12 years later, the European Project, EPIMETSI, partially intends to make this reactor become a reality. Construction of a prototype is on its way. The first part of this project has been to make a thorough revision, update and modifications, where necessary, of the design made in 1989. This paper deals with the results found in this revision, as far as recirculation of gases is concerned. It is based on the models used at that time, and some new results are also shown.

In this paper, we will analyze gas recycling in a silicon CVD system using silane or chlorosilanes as source gases. Though with a special focus on the SER operation, the formalism can be applied to any reactor and many of the conclusions will hold for conventional equipment. A first approach to recirculation consists simply in recycling the exhaust gases; we call this approach "external gas recycling" and will be studied in Sections 2 and 3. A further step is to produce the source gas in the recycle line by etching solid silicon. This approach is referred to here as "epitaxy growth by mass transport" and is dealt with in Section 4. Finally, conclusions are presented in Section 5.

2. External gas recycling

External gas recycling is a good way to make a better use of the hot gases vented from the reactor: to cool them down and to feed them back in. In doing so, the source gas would eventually be exhausted and the recycled gas would become rich in reaction products in the epitaxial chamber. However, if a fraction of the extracted gas is vented and the same amount of fresh gas with the appropriate source concentration is fed, a stationary condition can be met in which the concentration of reactants and products of reaction in the epitaxial chamber is kept within the required ratios.

Fig. 1 represents the recycling system. Magnitudes with subindex g refer to the output of the epitaxial chamber, where the deposition takes place at high temperature; subindex r denote the output of the cooling chamber, where the gas is

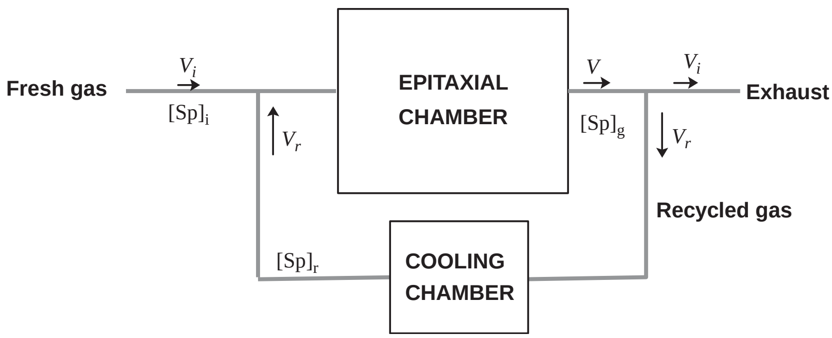

Fig. 1. Recycling system with epitaxial chamber and cooling chamber. [Sp] stands for the concentration at standard conditions of a given species. V stands for gas flow velocity. Subindex i means initial (fresh) stream, r means recycled stream and g refers to the flow out of the epitaxial chamber.