Deposition Patterns in Reactant Fabrication

TECHNICAL AREA:

The present disclosure describes masking techniques used during vapor deposition for creating specific geometries of materials in the building of reactant devices utilized in exothermic reactions. The geometry of the deposited material is key to the efficiency of the exothermic reactions.

BACKGROUND:

Vapor deposition (PVD or CVD) is a process by which a target material is vaporized and is transported and condensed onto a substrate where it forms a thin film.

EXISTING TECHNOLOGIES:

Significant research in the generation of excess heat with hydrogen absorbing materials has focused on electrolysis and gas-based experiments which often require one or more of the following elements in the reaction cell: a first electrode made of a transition metal, such as palladium or nickel, a second electrode made of an inert metal, such as platinum or gold, a working fluid or medium, such as heavy water or deuterium gas, and sometimes an electrolyte, such as lithium deuteroxide. The ability to induce a current in the cell is dependent on the working fluid that creates a path for the current flowing between the electrodes.

PROBLEMS WITH EXISTING TECHNOLOGIES:

Current research in clean energy technologies utilizing hydrogen absorbing materials lacks reproducibility, potentially from a materials standpoint. The production of the devices used in these research reactions is not easily scalable and does not allow precise control of the final material.

SUMMARY OF THE PROPOSED SOLUTION AND THE ADVANTAGES THE PROPOSED SOLUTION PROVIDES:

Vapor deposition offers a solution for building complex geometries and multi-layer structures for high-volume devices used in energy generation. The careful regulation of process parameters such as temperature, overall pressure, introduction of specific partial pressures, substrate, etc. allow the growth of specific films of pure metals and alloys. Using a mask, complex geometries can be created for devices. Several types of masks exist, and the choice depends on the scale of the features. For example, a metal stencil can be used for larger features while a photoresist mask might be chosen for smaller resolution features. Lift-off masks can be manufactured with micro- and even nano-scale features, but in deciding between additive and lift-off techniques, cost and ease of manufacturability must be taken into account.

The control of process parameters and the clean environment allows for better precision and reproducibility in the manufacture of these devices. For reactions where absorption plays a role, increasing the surface area of reactants would provide better efficiency. Techniques to increase surface area on films include building structures and creating roughness.

To build specific structures of materials, masking can be used during the deposition process. A stencil mask is created using an appropriate technique suited to the resolution of the desired features. Care must be taken when dimensioning the apertures on the mask as blurring will occur during deposition (enlargement of deposited material due to gap between mask and substrate). Blurring is largely dependent on the gap between the stencil and the substrate which is determined by both the stencil and the geometry being deposited.

The mask can be held in a fixed position throughout the deposition process or it may be moved to create variable thickness and therefore a degree of roughness. When a dynamic process is used, the thickness (or height) of the deposited material depends on the time the mask stays at a given position, shown by the equation below.

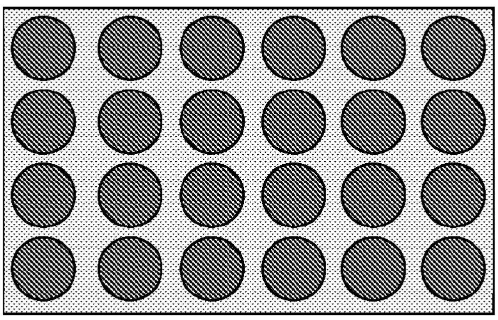
$$h(x) = c \int t(x')M(x - x')dx'$$

where *t(x)* is the dwell time of the mask and *x* is the longitudinal position of the mask

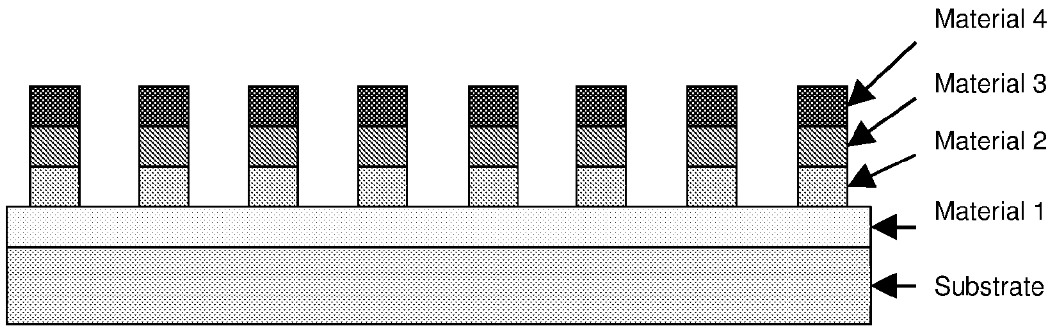
Stencil lithography provides an advantage for manufacturability as the stencil may be reused and the material created does not require subsequent processing. Using deposition processes to prepare the devices allows for better control of purity and morphology.

DETAILED DESCRIPTIONS OF THE PROPOSED SOLUTION AND FIGURES:

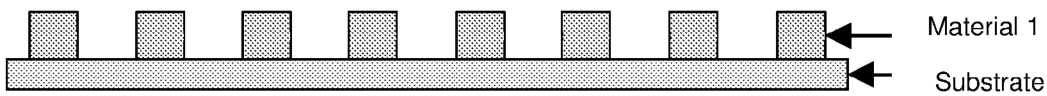
In the embodiment shown in Figure 1, a rigid stencil is held statically in the XY direction over the substrate. One or more materials can be deposited through the same stencil creating, for example, a columnar or layered columnar structured. The stencil can optionally be moved in the Z direction to create more complex geometries. The increase in surface area provided by a complex structure as opposed to a flat thin film allows for greater reactivity. The material selected can be different stable isotopes of palladium or nickel so that the final material contains an isotopic distribution distinctive from the naturally-occurring distribution (ref IH002).



Top view



Side View



Side View

Figure 1: Different views of columnar, multi-material and single material structures on substrates

In the embodiment shown in Figure 2, similar to the first, structures of one material are created using a stencil, and subsequently another material is layered on top of the first material without a stencil. This method is suited to the technique of co-deposition (IH008) where a hydrogen-absorbing metal is deposited first in the presence of a hydrogen isotope and a hydrogen-barrier material is layered on top to prevent the desorption of the hydrogen isotope in the first material. Example materials include palladium as the hydrogen-absorbing material and gold as the hydrogen-barrier material.

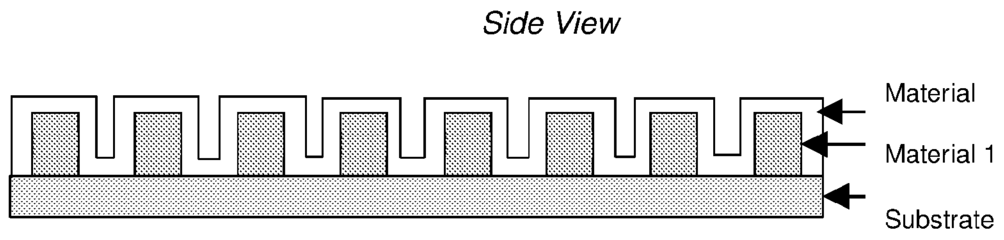


Figure 2: Depiction of columnar, multi-material and single material structures on substrates

In another embodiment, a rigid stencil is moved over the substrate, in the XY direction and/or the Z direction, during the deposition process. Layers with variable thickness can be created using this dynamic process which can provide a degree of surface roughness and an increase in surface area. Surface roughness is necessary for increasing both reactivity and efficiency in certain reactors. This method is suitable for use with platinum-group metals and additionally nickel. Similar to the first embodiment, a stable isotope or combination of stable isotopes of these metals can be used.

In the embodiment shown in Figure 3, a complex inter-layered structure of different materials is created using either multiple static stencils, one dynamic stencil, or any combination to achieve the desired structure. A layered structure may be necessary for tailoring certain reactions as the interface between materials can provide active reaction sites, so increasing the overall area of interfaces can be used to alter efficiency. By carefully selecting which materials are in contact, ideal interfaces can be maximized. For example, a layered palladium-nickel material has been shown to generate excess heat under certain conditions, so by alternating palladium and nickel as the materials deposited in the inter-layered structure, the overall interfacial area can be increased as opposed to simply layering one after the other in the same pattern.

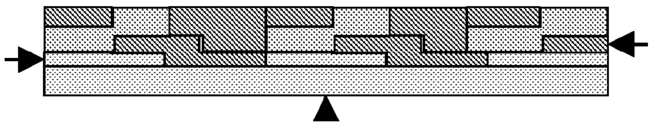


Figure 3: Depiction of inter-layered structure using a dynamic stencil and multiple materials