



**Particle Physics Division
Mechanical Department Engineering Note**

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Title: Water Desorption from Various Materials

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Abstract Summary: The following note is a summary of the results of trying to determine the amount of time it would take in order for water adsorbed on the surface of a material to fully desorb.

Applicable Codes:

The purpose of this note is to determine the amount of time, and the rate at which it would be possible to remove water from a system that includes stainless steel, Teflon, and FR4 fiberglass reinforced epoxy. To provide a little background in the area, when a material is exposed to ambient air, it will naturally absorb some of the water vapor that makes up a percentage of air. In many systems, the water becomes an unwanted side effect of manufacturing and assembly of the system.

One source stated that the amount of water adsorbed on a surface could be as high as several hundred monolayers, in other words, several hundred molecules thick; however, this is a very difficult thing to measure with any sort of accuracy...one cannot simply take a micrometer and measure the thickness of the water adsorbed on the surface. The adsorbed layer of water cannot necessarily be assumed to be a constant thickness over the entire surface, either. Each of the materials absorbs a different amount of water, as a result of differing material properties.

There are three main methods of removing adsorbed water from a material and most of the analysis of these methods was done under vacuum conditions, not atmospheric, like this system. These methods are bake-out, UV irradiation and running a dry gas through the system.

Bake-out: Standard conditions for bake-out usually require temperatures somewhere in the range of 125-250°C. Based on the other materials present in the system, it is not feasible to use these temperatures for a bake-out procedure. With an allowable temperature range of 20-50°C, we can assume that the bake-out time will be reduced slightly using the highest possible temperature, but it will be a good deal longer than if standard bake-out temperatures were used. There was no information that could be found that gave a set value for the amount of time it would take or any equations that would provide a way of determining a set time. One source did provide an example of experimentally determined times for a very narrow range of thicknesses, geometries and materials (Fig. 1). An equation was also provided with this graph; however, with no knowledge of the diffusivity constant or the diffusion at the temperatures present in our system, activation energy could not be calculated. Activation energy differs for each application, so the time of diffusion cannot be directly determined.

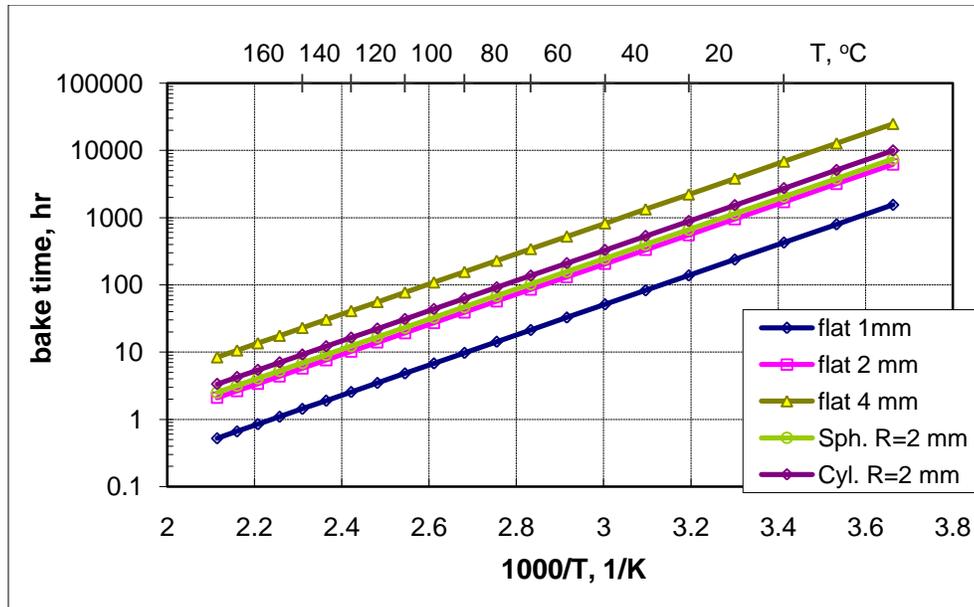


Figure 1: Calculated temperature dependencies of moisture bake-out times for packages of different size and shape (for Plastic Encapsulated Microcircuits)

A thermodynamic approach to the bake-out method could be utilized to determine the difference in thermal energy that would be necessary given this range of temperatures, but with no way of knowing how much water the energy needs to be transferred to, it would not be possible to set a value for desorption time. Another issue with this approach is that the amount of energy required for each layer and molecule is different from the next. One source stated that the molecules bonded directly to the stainless steel, Teflon, or FR4 fiberglass reinforced epoxy would have a set bonding energy (which is different for each material), and all of the layers adsorbed on top of this initial layer would have different energies resulting from van der Waals forces and hydrogen bonding between the molecules. This bonding energy differs for each additional layer of water, with the outermost layers having the lowest bonding energy.

UV irradiation: the basis of this method is that the ultraviolet waves provide additional energy to the water molecules, which allows them to overcome the bonding energy with other molecules. The problem with this method is that it only works at pressures around and below 1 torr (0.0013 atm/0.133 kPa/0.019 psi). The reason for this ineffectiveness is that at pressures above 1 torr, the energy from the UV radiation is dissipated in the other molecules and it has little to no effect on the water on the surface of the system.

Dry gas fill: a dry gas is run through the system as a means of using the kinetic energy of the molecules to “knock off” some of the adsorbed water. This method is effective at reducing the time to remove the water from the system, but, as with the other methods, it is difficult to determine a set time that this will take due to several other variables and limited information on the topic.

The bottom line of the analysis is that using argon in the system in addition to heating the system to the highest possible temperature will help to decrease the time it takes for full water removal, but a specific time cannot be determined based on the information that was collected. There is a very limited, very general amount of information on rates and time of water removal from stainless steel and most of this information pertains to systems that are under vacuum conditions. Information on the subject was even more difficult to find regarding Teflon and FR4 fiberglass-reinforced epoxy. Ultimately, the best way to ensure the fastest time of water removal would be to limit exposure to high-humidity air and moisture during the manufacturing and assembly stages, fill the system with a dry gas and heat the components as high as the parts will allow.

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