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Application of semantic network tools at prototyping stage of electronic packaging

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ABSTRACT: One of the key factors of contemporary reliability engineering in electronic packaging is an ability of quick and efficient access to interdisciplinary knowledge, e.g. material engineering, mechanics, numerical prototyping, etc. The above can be achieved by advanced computer aided knowledge systems. One of the benefits of such system is ability of using and exploration of knowledge from different sources as: databases, documents, web pages, etc. Though knowledge from literature references is very helpful to solve specific problems it seems that precise analysis of wide literature data base is time-consuming and prone to errors. Another factor, sometimes neglected during the literature study stage, is the problem of appropriate determining the correlations and connections between certain facts, information or literature references. The presented research focuses on analysis and application of selected computer aided knowledge systems for semi-automated or automated methods of text processing and language structure analysis referenced as semantic networks. Semantic networks are one of the most promising contemporary knowledge engineering systems. They are based on graphs, which represent relations between nodes. The nodes represent objects or concepts and the links represent relation between nodes. The knowledge analyzed by the semantic networks can be stored in a different form of graphs, e.g. hierarchical layout and require special algorithms to seek out exactly definite information. As an example case of semantic networks application to electronic packaging a comparison of manual and computer literature analysis in relation to whisker formation and growth problem is presented.

1. Introduction

Electronic packaging refers to the packaging of integrated circuits (IC) chips (dies), their interconnections for signal and power transmission and heat dissipation. In electronic systems, packaging materials may also serve as electrical conductors or insulators, provide structure and form, provide thermal paths and protect the circuits from environmental factors such as moisture, contamination, hostile chemicals and radiation. The current technology trend in microelectronics (especially in micro and nano scale) is the rapid development, which can be enhanced by numerical reasoning tools. Nevertheless the key problem is reliable knowledge on material and interface properties and probable failure mechanisms. Unfortunately, the material and failure models of the electronic materials are poorly known and understood. The ongoing trends towards higher reliability, and the same time better thermo-mechanical performance towards components and modules requires on one hand interdisciplinary knowledge and on the second hand the profound literature study. Therefore the current paper focuses on combining the interdisciplinary literature database along with the semantic reasoning tools in order to understand one of the most crucial problems of contemporary electronic packaging, which is whisker formation and growth.

The problem of whisker growth is one of the consequences of solder alloys change from lead to lead free. Whiskers reduce the reliability of electronic components and modules and the understanding of whisker formation and growth could be very helpful. Unfortunately the mechanisms of whisker growth is not clearly understood yet. The whisker of tin grows from the bottom not from the top. They are extruded from the surface relieving stress on the matrix on which they grow. The crucial observation that may help to understand mechanics of growth is that whiskers have a nature of the screw dislocation phenomenon. Understanding this phenomenon may help to resolve the problem of whisker growth. There are many aspects of technological developments required for the establishment of lead-free soldering in the electronics industrial field. The structural integrity of solders and soldered circuits is one of the great concerns. Most of Sn alloys involving pure Sn, Sn-Ag, Sn-Bi or their ternary alloys form two intermetallic compounds at the interfaces with Cu, i.e., Cu6Sn5 and Cu3Sn. The former reaction layer is much thicker than the latter and the integrity of interface is strongly influenced by the presence of the Cu6Sn5 layer. The Sn-Zn alloy forms

different Cu-Zn intermetallic compounds without Sn at the interface with Cu. These reaction layers degrade the heat resistance of the Sn-Zn/Cu interface.

Whiskers can grow with and without electrical field in vacuum and in atmosphere. The best growth has been reported in temperature 50°C. This is temperature of recrystallization of tin. Good growth has been also observed in range from -40 up to 85°C. Growth rate is rather unpredictable; it may take few days as well as few years. Main factors that are believed to trigger whiskers growth are both internal and external compression stresses. Stresses may be caused by grain size, shape and orientation in case of pure metal film, by irregular thick and fast formation of IMC along the interface between layers, by interaction between substrate, metal thin films and IMC, and finally by bending, scratching and thermal cycling. Applying a thin layer of Ni between Cu and Sn layer may mitigate whisker propensity on the tin surface by forming IMC along the boundary of Ni and Sn layers. Nevertheless it can be concluded that the problem of whisker formation and growth is an interdisciplinary problem and thanks to semantic network tools can be understood better and more profoundly.

2. Problem of whisker growth

Whiskers are crystalline structures that grow from the surfaces of pure metal. Whiskers commonly appear as strands of metal, similar to whiskers, hence its name. There are many kinds of whiskers, which can be basically classified by metal of which they are built. Whiskers can be made of Sn, Zn, Cd, Au or Ag. Whiskers can be also classified by shapes, , as shown in the figure 1. They can grow as kinked, bent or striated needles or may take odd shapes. They can grow from several micrometers to several millimeters length and they are typically several micrometers in diameter, excluding gold whiskers, which are hundreds nanometers in diameter.

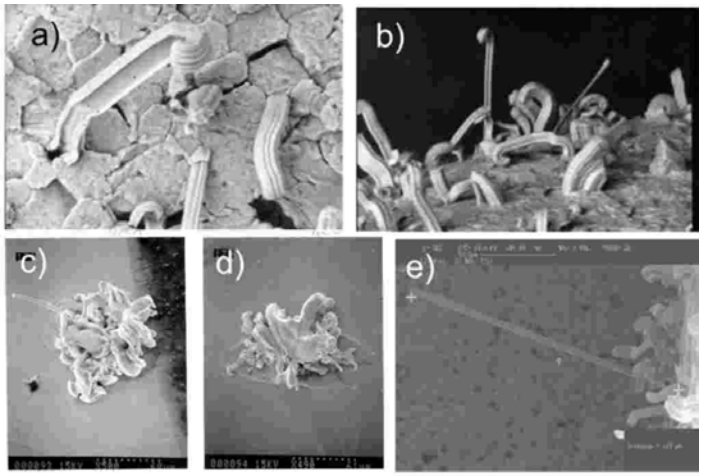

Figure 1. Various whisker shapes a) bent, b). kinked, c), d) odd-shaped, e) needle whisker [6].

Whiskers are conductive structures, so they are very dangerous in electronic industry. They can make stable intrusion short circuits in low voltage leaded to leak few dozen milliamps of current. If the leak current exceeds the fusing current of whisker, the circuit breaks down and the whisker open. There are known many cases of damages caused by whiskers, especially in space industry. There are a couple of examples in commercial telecommunications satellites when there were broken down due to whiskers.

Whiskers problem have been known since 40s of the last century, so phenomenon of their growth have been studied for many years. First time whiskers problem was observed in electrical elements made of cadmium, especially in channels filters used for multi-channel transmission lines produced by Bell Telephone. They caused many repeated failures because of electrical shorts. This problem was resolved temporary by withdraw cadmium from electronics. Electroplated cadmium was replaced by electroplated tin. In the 50s of the last century researchers gave interesting facts of whiskers growth. They proved that whiskers grow not only on Cd surfaces but also on Sn, Ag, Zn, Al materials. They observed that whisker was being formed from material added to its base, not of material added to tip of whisker. This observation is fundamental and it is still accepted today. Next facts were being based on dislocation theory, but there has not been yet any experimental evidence of mechanism described by researchers in 50s of the last century. The crucial discovery was made in 1954 by researchers from U.S. Steel, who pointed at compressive forces as determinant of accelerated whisker growth. In the end of 50s S.M. Arnold from Bell Labs suggested to alloy tin films with lead, which reduce the internal stresses within the tin film and inhibit whisker growth.

The next decades of the last century brought also some interesting facts, especially some recommendation to reduce whisker growth. But solution of alloying tin with lead made research on whiskers not expansive. At the beginning of 21st century studying on whiskers problem became. Interesting in whiskers phenomenon drastically grow up, when some countries all over the world introduced resolutions, which as in e.g. the European Union has definitely forbidden using lead in electronic devices, because of their harmful influence on human beings. Researchers received hard task to solve whiskers problem without annoying lead to tin surfaces. Their obstinacy was showed in many transactions, more than in previous 60 years. Modern measurement techniques, like focused ion beam (FIB) microscopy and micro-focus X-ray diffraction (XRD) have given possibility to gain insight into tin film microstructures and measure internal stress level. Most of research rested on measurement inside stress level of tin films in different environments. Some test samples were submitted by annealing, some were subjected to electrical bias, in some of them crystalline structure was being changed. Even The Integrated Theory for Whisker Formation and Growth was come into being. It is set of observation made by scientist, which have probably the most influence on whiskers growth.

Piece of history information about whiskers phenomenon show, that there is no inevitable solution solve whisker formation and growth problem. There are many theoretical and some practical solution which reduce or accelerate whisker growth, but experiments were leaded in certain period of time and in certain environments. Because of very long time of experiments and very different factors influenced on environment, researchers haven't enough time to lead all tests. Secondly, mechanisms of whiskers growth are not only connected with certain type of knowledge. Scientists must join together all information included in many articles and transactions from many different domains of knowledge. It is very helpful to solve specific problems, but it is time-consuming and often prone to errors. Also during the literature study stage a problem arises of appropriate determining the correlations and connections between certain facts, information or interdisciplinary knowledge.

3. Computer program for semantic analysis of whisker growth

The processing of large quantities of scientific data has always been a problem for researchers. Especially today, when the number of scientific publications is constantly increasing and the required knowledge has interdisciplinary character, the literature study becomes more and more difficult. One of such examples is the problem of whisker formation and growth. The first publications concerning whisker growth appeared in late 50s and especially in recent years the number of publications has grown significantly, which is mainly due to problem known as green electronics. Despite of a huge number of publications and research activities in that area the mechanisms of whisker formation and growth is not fully understood. Therefore the profound analysis of interdisciplinary publication databases supported by contemporary computer reasoning algorithms and tools such as semantic networks might be very helpful.

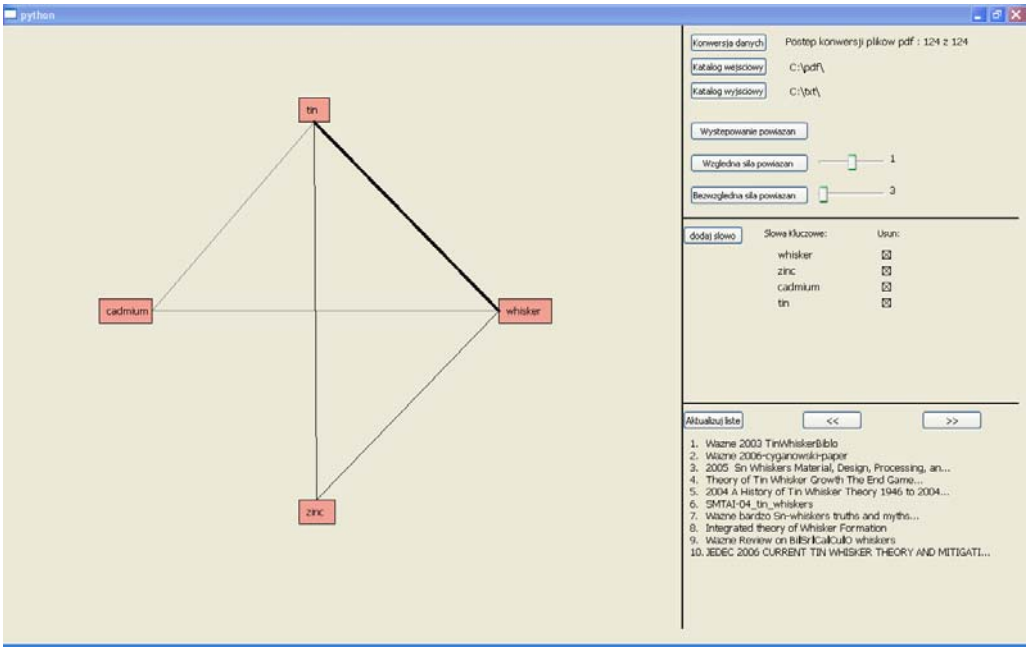

Figure 2. The developed computer program for semantic analysis of whisker growth.

As the first step towards development of the semantic network tool a computer program was developed, which is presented in figure 2. The program was written in Python language and contains a number of helpful reasoning functions and algorithms implemented. So far the program is focused on simple but efficient statistical analysis of publications. As the publications are mainly stored in pdf format, they must be at first converted from pdf to text format. The implemented reasoning algorithms is based on user defined keywords. The selected graphical representation of the results is of a graph including node and links. Nodes represent the keywords while links between them represent the identified statistical correlation. The thicker the line the stronger is the correlation. Currently there are there three reasoning algorithms implemented in the program. The first algorithm identifies the relationship of separate words for the existence of their pairs. The second algorithm identifies the relative number of links between keywords while the third algorithm is its simplified version.

The developed program was tested on a set of 127 interdisciplinary publications in PDF format, which seemed to be less or more relevant to the whisker formation and growth problem. On of the benefits of the developed program is the ability of presenting the sorted list of analyzed publications according to the applied algorithm and its results. In figure 2 an example analysis results are given with the following keywords: whisker, zinc, cadmium and tin. The achieved results highlight the most important links of the defined keywords. The statistical analysis enables to draw the conclusions on the most essential statistical interaction between the defined keywords and thus the underlying phenomena. According to the achieved results the highest statistical correlation is between whisker and tin. At the same time the correlation between zinc and cadmium seems to be the lowest. Additionally the statistical correlation between tin and cadmium is lower than for of tin and zinc. It should be underlined that the goal of the presented program is to assistant the expert during the stage of literature study and analysis. In fact it is not meant to replace the expert. The results only help to identify the most probable interactions between the keywords and afterwards select the most interesting publications using the their sorted list. Though the current development stage of the program allows only the statistical analysis of the defined keywords and to identify the essential interactions it is meant to implement at the next stage the language structure analysis referenced as semantic networks.

4. Conclusions

The current paper focuses on the problem of interdisciplinary knowledge exploration concerning whisker formation and growth with the help of semantic network algorithms and tools. Despite of the so far achievements, the further research is required and will be focused on improving the reasoning functionality. Solution based only on searching keywords in texts doesn't give possibility to determine if two publications, in which the same keyword appear, concern the same or similar domain of knowledge. Reasoning can be made by using semantic network as core of itself. Semantic Networks (SN) are knowledge representation structure using nodes and links between nodes. The nodes represent objects or concepts and the links represent relation between nodes. Simple SN have one (is-a) or several type of relation. Complexly of SN can be determines first of all by number of relation types, but also by number of nodes. The links are directed and labeled so semantic network is a sort of a directed graph. Existing popular semantic networks like WordNet or ConceptNet describe commonsense knowledge. Moreover idea of ConceptNet base on ambiguous concept. Ambiguous is useful in inference about common life, but it is inadvisable in inference about technical issues, which must be definite precisely and unambiguously. This can be solved by using logical description of knowledge and logical deduction, which will be issue of the followed up research.

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