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FRAMES FOR INTEGRATED SYSTEMS OF LARGE-SCALE INTEGRATION, (U)
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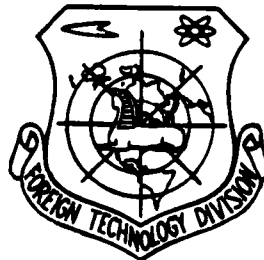


FRAMES FOR INTEGRATED SYSTEMS
OF LARGE-SCALE INTEGRATION

by

Krystyna Jakubowska

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FRAMES FOR INTEGRATED SYSTEMS OF LARGE-SCALE INTEGRATION

Krystyna Jakubowska

The present advances in the technology of integrated systems are directed mainly at increasing the element packing density and improving the quality. This determines to some extent the choice of the type of frame, both in terms of technical parameters and the price of individual frames.

Since the cost of an individual structure has gone down, the main component in the price of the complete element is now its frame and the cost of assembly. Therefore, the producers of frames, aside from optimizing the frame construction, are conducting intensive studies aimed at lowering the costs of the frames and devising the least expensive ways of assembling them.

The frames of integrated systems may be divided into two classes according to the material: plastic and ceramic. At present, both have their enthusiasts and it is difficult to state categorically which is better, taking into account both technical parameters and the cost. Frames made of man-made materials are cheaper, but less reliable. The reliability of plastic frames has been recently greatly improved by the use of masking layers of silicon nitride or glaze and appropriate design of the semiconductors. In addition, the number of defects during hermetization has decreased since new epoxy resin went into use (so-called Polyset B produced by Morton Chemical Co., USA).

Some companies in their effort to lower the price of the finished elements have used man-made materials for hermetization of systems which even contain MOS type elements. In 1971, at Texas Instruments, MOS elements went into production in plastic frames with 40 leads which resulted in a 25% decrease in cost compared with ceramic hermetization [1].

Ceramic frames are more expensive. The price of a plastic frame for systems of large scale integration is on the order of 25-40 cents, and that of ceramic frame, 95 cents [2]. This simple price comparison does not, however, reflect the full cost, i.e., it does not take into

account the differences in the cost of assembly and in the savings obtained for each type of frame. At the same time, ceramic frames are more reliable and may be used under the most difficult conditions.

Plastic frames.

The widely used method of imprinting hermetization for man-made materials in the case of systems of large scale integration does not fulfill the necessary requirements. Defects of wire leads (for higher levels of integration one has to deal with dozens of connections), separation of layers of the material which does not adhere sufficiently to the assembly, poor resistance to humidity, corrosive atmosphere and temperature changes are the principal drawbacks of the conventional plastic frames.

The optimization of such frames and future prospects are represented by hardened resin of appropriate shape (plastic cavity package). In the U.S., such frames are produced by 5 companies. Two of them-- North American Rockwell Microelectronics and MOS Technology, produce frames for their own use, whereas U. S. Electronics Services, Wells Plastics (formerly Interbound Systems) and Semiconductor Components Substrates sell such frames.

There are several more interesting structural solutions which are worth discussing [2,3,4]. The frame USES (Figure 1) is composed of a plate of material pressed together with the assembly line bent in such a way that the ends of the leads are located at the plastic surface. The plate obtained is covered with a metal layer by chemical methods with a layer of Ni of 1.25 μm thickness and a 1.5 μm layer of Au.

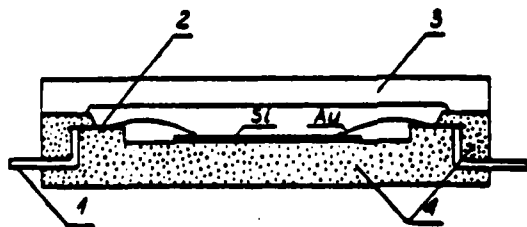


Figure 1. Frame of the USES firm: 1-assembly line, 2-metalization, 3-cover, 4-epoxy resin.

The metal layer forms the base for making wire connections and on the other side it touches the bent leads of the line. Next, a layer of plastic with an opening at the center is applied and connected to the base of the frame. After metallization of the area designated for the crystal, the frame is ready for assembling the structure of integrated system. A cover is glued on top. This frame is characterized by a very high impermeability, especially because metal paths are applied on plastic rather than introducing the ends of assembly line into the frame. This construction of course, requires the knowledge of how to achieve metallization of man-made materials. This metallization is characterized by better adhesiveness to plastic than the assembly line which results in higher impermeability of the frames.

A disadvantage of such a frame is the necessity for making the connections by the ultrasound method, although recent studies have confirmed the possibility of applying thermo-compression using epoxy resin and somewhat thicker metal paths.

FRAME "WELL" (Figure 2). In this frame we have an aluminum plate embedded under the assembly line; this plate serves as an underlay for the structure during ultrasound connection of the wires. The plate is oxidized anodally such that the consecutive leads of the assembly line are isolated from the "island" with the semi-conductor structure. The upper cover is connected with the frame by epoxy resin.

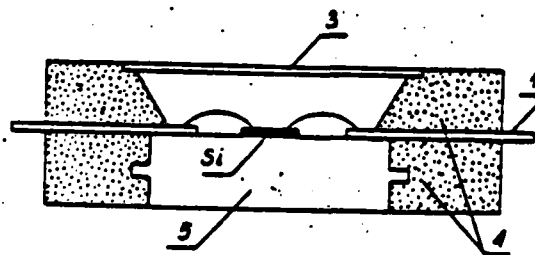


Figure 2. Frame of the WELL Company: 1-assembly line, 3-cover, 4-epoxy resin, 5-anodized aluminum plate

By using an aluminum plate, this frame makes it possible to make the connections by the ultrasound method. In addition, the aluminum

plate increases the mechanical rigidity of the frame. A similar construction is used by the SCS firm, as shown in Figure 3. According to catalog data, a guaranteed impermeability of these frames is 10^5 cm³/min for helium and in practice, it is 10^7 - 10^8 cm³/min for helium.

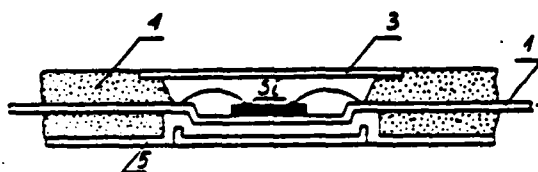


Figure 3. Frame of the SCS firm: 1-assembly line, 3-cover, 4-epoxy resin, 5-anodized aluminum plate

FRAME "NRMEC" (Figure 4). Structures assembled in these frames are masked by a layer of silicon nitride (protection against chemical and ion contamination) and by a layer of silicone rubber (protection against mechanical damage, shorts and corrosion of the connections).

The structures are soldered onto a gold-plated underlay which is glued to a depression having the shape of the plastic with the assembly line. Both the underlay and the cover are glued with epoxy resin.

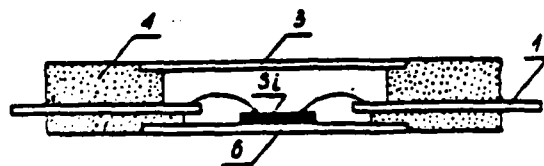


Figure 4. Frame of the NPMC firm: 1-assembly line, 3-cover, 4-epoxy resin, 5-metal plate

FRAME "MOS Technology" (Figure 5). This frame is made in two operations of resin pressing. In the first a similar shape is obtained as in the other frames with a pressed assembly line. This shape is made of silicone resin. After the crystal is soldered and wire leads are made, covers are applied from above and below and the entire structure is hermetized using pressing technique with epoxy resin.

This combination of silicone and epoxy resin increases the resistance of the frames to humidity, corrosive atmosphere (salt mist) and resistance to bending. Also, the price is low, 20 cents for a frame with 40 leads, only a few cents more than for complete frames [4].

"Complete" frames. Some producers of integrated systems with large scale integration still use 40-lead frames manufactured by the conventional pressing technique. For instance, Texas Instruments hermetizes more than half of its production by this method, including MOS type systems. However, the semiconductor structures are then specially prepared, i.e., covered with glaze before hermetization (except for systems with very short switching time). In contrast to the plastic shapes discussed previously, in the case of "complete" frames silicone resin is universally applied, and most recently, the epoxy resin Polyset B of the Morton Chemical Co., USA. This resin is free from ionic impurities and is characterized by high compression during solidification which assures good adhesiveness to the assembly line, the crystal and the wires. The temperature of the resin change, i.e., the temperature at which the expansion coefficient of the plastic increases abruptly, is more than 150°C and for those generally used until now, it is $110^{\circ}\text{--}120^{\circ}\text{C}$.

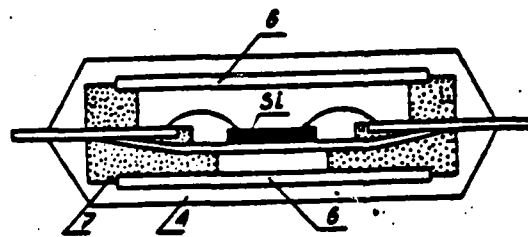


Figure 5. Frame of the firm MOS Technology: 4-epoxy resin, 6-metal cover, 7-epoxy resin

Ceramic frames.

The frame DIP (eng. dual in plug), produced using the so-called CER-DIP technology [5] is a ceramic frame generally used for hermetization of integration systems. Usually, these are frames with 8, 14,

16 or 24 leads. The frame is composed of two rectangular shapes of alundum ceramic (for special applications beryllium ceramic is used) in which depressions are formed (Figure 6). The ceramic shapes are made by pressing in the cold the dry ceramic powder in presses with 10-20T pressure. Small amounts of wax or another organic glue are added to the powder in order to bind the shape mechanically.

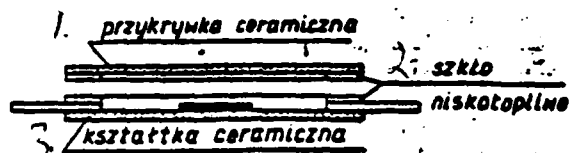


Figure 6. Frame of CER-DIP type. Key: 1-ceramic cover, 2-low melting glass, 3-ceramic shape.

The ceramic prepared in this way is called "green". The shapes obtained have very low mechanical resistance and can be broken even by hand.

After baking, the ceramic shapes are covered by low-melting glaze of 0.25-0.4 mm thickness. The semiconductor structures are assembled directly on the assembly line, similar to the procedure for plastic frames, which is made of alloy 42 (42% Ni, 58% Fe) of 0.15-0.3 mm thickness. The assembly bands are galvanically covered with gold, silver, nickel or aluminum. The choice of the covering material is decided here on the basis of economy. Over the last few years the cost of silver bath has increased from \$1.293 per ounce to \$2.565 and then stabilized at \$1.60-2.00 [6]. During the same time the cost of gold has fluctuated between \$35 and \$42.25 per ounce. At present, it is \$40.25. Taking into account the reliability of the final elements, the best results are obtained by gold plating of the bands and using gold wire for the connections with the structure. Frequently, the gold covering of the band is replaced by silver. A good quality of the connections can then be obtained only by using thermocompression by gold wire. Using bands that are covered with aluminum, because of easy oxidation of the covering, it is necessary to use the ultrasonic

technique for making the connections. The advantage of this choice of covering metal combination (Al on band--Al wire--metallization Al on semiconductor structure) is the increased reliability of the finished elements (absence of purple disease and white disease, absence of connection potential when various metals are connected), as well as considerable lowering of the cost of the frame and assembly (assuming the price of aluminum for the unit cost of using silver is 66 and for gold, 1580) [6].

Assembly lines with assembled semiconductor structures are deposited on ceramic shapes on top of a heater at about 350°C for several dozens of seconds and the band is mechanically pressed onto a layer of glaze. At this temperature the glaze is softened and connected to the band. At present, primarily recrystallizing glazes are used with the composition $\text{PbO-ZnO-B}_2\text{O}_3$, which crystallize as Pb-Zn borates. The typical glazes are CV97 of the Owens-Illinois Company or Corning 7583. After application and preliminary heating during the connection time of the ceramic with the assembly band, the glaze remains amorphous and begins to crystallize only during the final heating of hermetization. This gives connections which are twice as good as those for non-crystallizing glazes. The process of crystallization is very critical and should take place under conditions of maximum fluidity and highest rate of crystallization and thus at maximum temperature, somewhat lower than the temperature of secondary melting of the glaze. The use of crystallizing glazes gives several advantages, but it requires a very detailed thermal processing of the glaze, both during the preliminary heating and the hermetization of the frames. Thus, for the glaze CV97, the temperature of softening is 350°C (temperature of baking of the glaze on ceramic), the temperature of crystallization is 489°C (temperature of hermetization of the frames) and the temperature of secondary melting is 533°C and is the maximum temperature of the frames. Exceeding it causes deterioration of the properties of the glaze. The temperatures listed may vary depending on the rate of heating, the type of surrounding atmosphere and the temperature distribution in the oven. In order for crystallization to occur only during hermetization of the frames, and in order to avoid secondary

melting of the glaze, in practice, it is necessary to use ovens with very exact temperature distribution for hermetization. Also, for given conditions of operation, it is necessary to determine the characteristic temperatures for the glaze being used each time, e.g., by the method of differential heat analysis (eng. DTA) [7,8]. Thus, the ceramic shape with attached assembly band and semiconductor structure, covered by a second ceramic shape, is hermetized in a graphite cassette, usually in a band-type oven at the crystallization temperature of the glaze.

Another type of frame is shown in Figure 7. It consists of a plate of alundum ceramic, to which the assembly band is attached together with the second ceramic plate with a rectangular opening at the center.

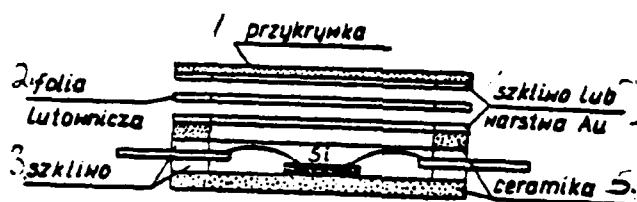


Figure 7. Ordinary ceramic frame of DIP type. Key: 1-cover, 2-soldering foil, 3-glaze, 4-glaze or layer of Au, 5-ceramic.

The frame prepared in this manner is ready for the assembly of elements, following which it is hermetized from above by a ceramic or metal cover. The attachment of the cover can be achieved by glaze or eutectic alloy, e.g., 80% Au, 20% Sn (now the alloy 78-22% is recommended). Frames of this type are very expensive and not utilized in practice for systems of small and intermediate integration scale.

The widely used frame type DIP leaves a lot to be desired in terms of shape and mechanical resistance, especially for systems with a large number of leads. Therefore, for ceramic frames a totally new concept has been developed, namely the edge mount package in which the assembly band has been replaced by metallization on the ceramic and an external edge connector, Figure 8. For the first time these frames

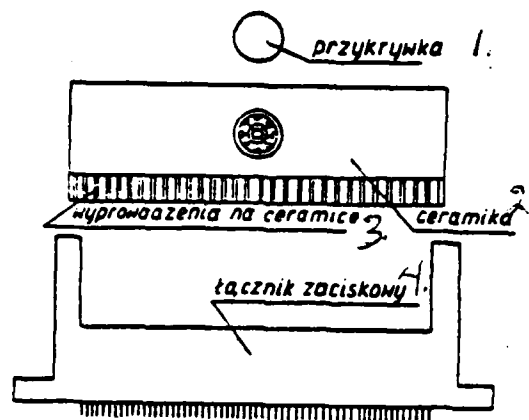


Figure 3. Ceramic frame with edge mount and edge connector. Key: 1-cover, 2-ceramic, 3-leads on the ceramic, 4-edge connector

have been constructed by the firm Coors Porcelain, Golden, Colorado, in collaboration with American Micro-Systems, Santa Clara, California. At present, they are produced by many American companies, e.g., Met Ceram, American Lava Co. According to many users, such as, e.g., Fairchild Co., these are the frames of the future.

A frame of this type consists of an alundum ceramic plate, onto which metal conducting paths are deposited, usually of metals such as Mo or Mn and, additionally, covered with nickel [9,10]. The ends of the paths and the area under the crystal are covered with a gold layer of about 2 μ m thickness. This plate is covered with a layer of alundum ceramic with a center opening. The ceramic is covered by glaze or by a metal necessary for hermetization, as in conventional frames. For frames with a large number of leads often several layers of ceramic with metallization are used. The edge connector is made primarily of nylon with glass filling and the contacts are springs of beryllium bronze with gold covered ends.

The main advantage of the edge mount package is its high density of element packing and better heat removal (the elements are mounted perpendicularly to the assembly stage), as well as the lower cost of the frame. In the case of damage and change of element, the edge connector remains the same which gives a saving of approximately half

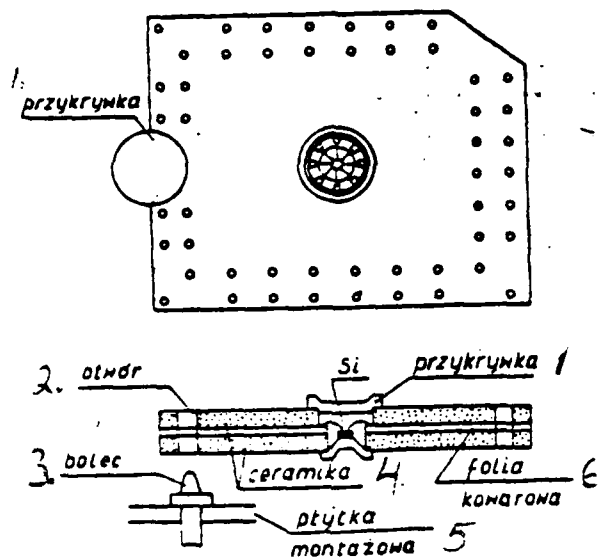


Figure 9. Ceramic frame of DIACON Company of San Diego.
Key: 1-cover, 2-opening, 3-bolt, 4-ceramic, 5-assembly plate, 6-foil.

the cost of the entire frame. The cost of edge mount package is 55¢ and that of an edge connector is 45¢.

A similar design of a frame without leads is the frame of Diacon Company of San Diego (Figure 9). This frame has an assembly band of about 25 μ m thickness between two ceramic plates. The ceramic plates have openings which let the bolts of the assembly plate pass through, cutting through the foil. In this manner, points on the assembly plate are connected to the leads of the integrated system. The largest frames of this type have 51 leads at present [11].

CONCLUSIONS

We can now distinguish the most promising solution for the frames:

1. Ceramic frame with edge mount package and edge connector,
2. ceramic frame without leads for assembly plates with bolts,
3. plastic frame of DIP type made of plastic shapes.

Taking into account the fact that the cost of a frame is much higher than the cost of the structure and assembly, it is important to analyze in depth the economy of any given frame for its choice. We should also remember that an eventual later change in the frame type leads to high expenses related not only to the production of frames, but also to the assembly of semiconductor elements. The requirements of the users and the possibilities of acquiring a given type of frame are also important. Frequently, a frame is chosen because of the future possibility of its local production. This last consideration accounts for the fact that many companies tend to use plastic frames since they are the easiest to produce and thus allow the company to become independent of outside suppliers.

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