High capability, high reliability ultra-slim diode for welding applications

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Abstract A new family of high capability, high reliability ultra-slim diodes has been developed with particular care to high current welding machinery.

At now the first product of the family is a 55 mm diameter device that is already available on the market coded ANSALDO - AUS601 and with rated blocking voltage up to 200V at 190 C.

The 55 mm diameter silicon disk is brazed on both sides to two molybdenum disks by an innovative pressure soldering process at temperature lower than standard brazing process [1].

Thanks to its ultralow thermal resistance AUS601 rated current reaches 13kA at a case temperature of 85C.

Purpose of this work is to present the electrical and thermal characterization of AUS601 together with the result of operating thermal cycling tests performed with typical welding conditions.

Moreover preliminary data on a 75 mm 15kA device under development will be presented as well.

Keywords : ultra-slim diode, welding applications, thermal cycling

1. INTRODUCTION

High power welding machinery are nowadays requiring diodes with more and more current performances in order to reduce the number of paralleled devices and to properly work with increased frequency.

Since silicon wafers arent waited to strongly improved performances (some perspectives are linked to a new material, silicon carbide

[2], not yet available on the market at a competitive cost) the unique answer to these growing demand requires a dramatic reduction of diodes thermal impedance, that can be obtained taking off the ceramic housing so reducing the global thickness between anode and cathode poles and also eliminating the resistance contacts.

Figures 1 and 2 show two typical welding circuit topologies, the first one based on medium frequency the other on net frequency; in this first case diodes recovery behaviour hardly influences global machine efficiency and reliability.

The combination of parameters as peak current, welding on time and off rest time (toff = T-ton) determines the temperature cycle stress on diodes junction.

Owing to typical severe trade off of above parameters and also to the necessity to effectually cool the electrodes, liquid cooling systems are universally used on welding applications.

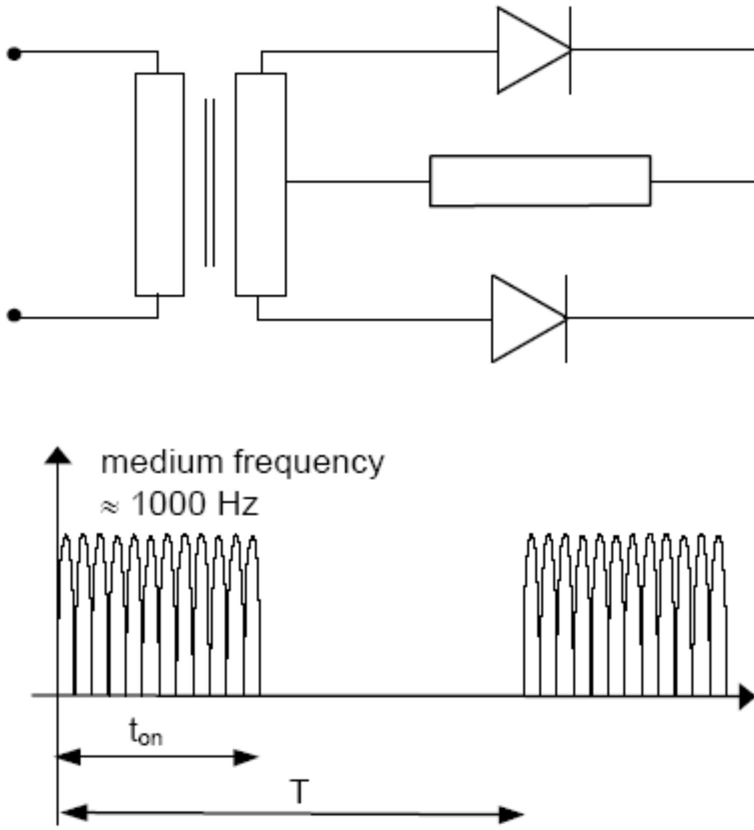

Fig. 1. Typical M2 welding circuit for medium frequency application.

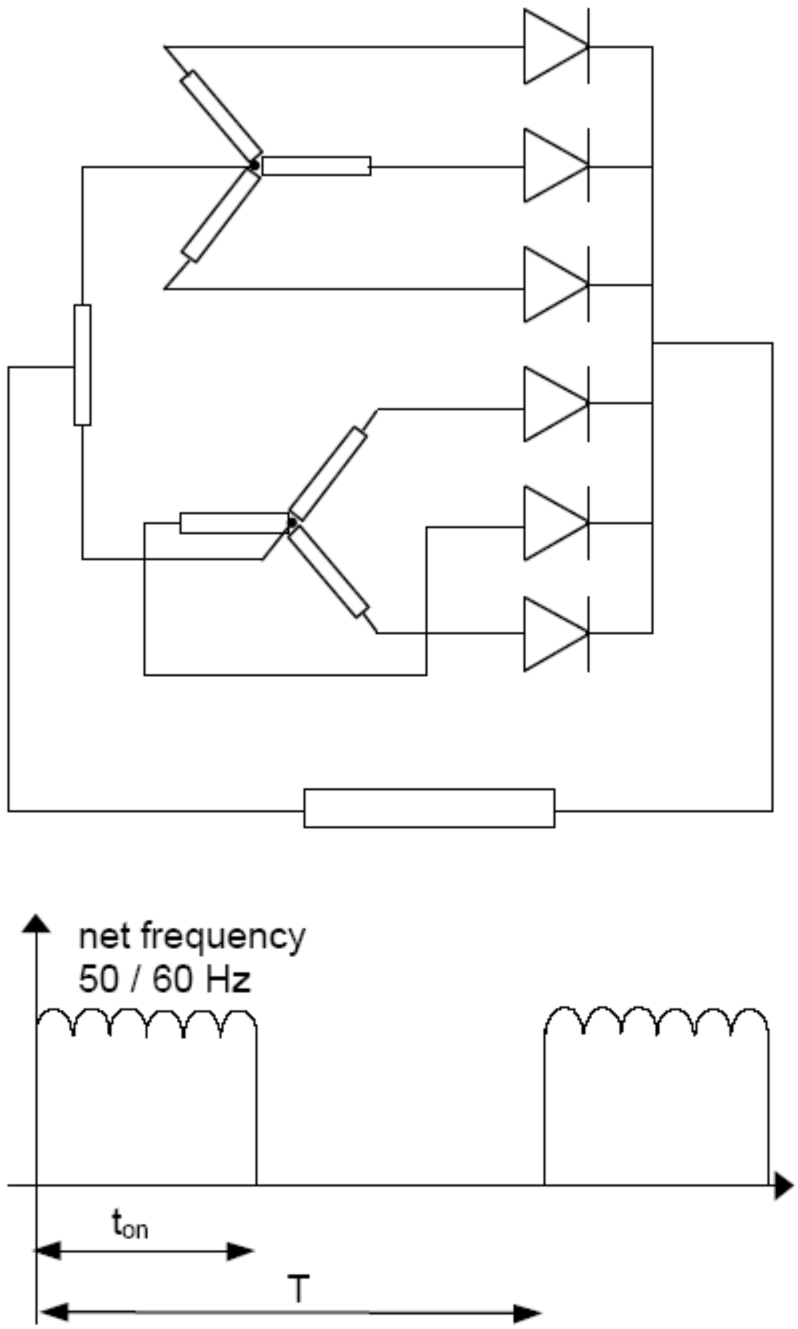

Fig. 2.Typical three phase welding circuit based on double star with interphase inductance configuration

Thus, summarizing, a diode involved in high power welding application must have a very good trade off between static and dynamic characteristics, also considering that it must work for several million welding cycles (expected cycles life).

Weight itself is not a negligible aspect since these devices are usually mounted on moving arms.

2. DEVICES DESIGN AND REALIZATION In order to match at best above requirements Ansaldo has developed and longely tested a new family of rectifier diodes based on a process of silicon-molybdenum low

temperature brazing.

Basing the devices diameter choice on welding market requirements two different diodes size have been individuated, corresponding to 55mm?and 75mm?respectively.

Basically the ultraslim diode is composed by a sandwich of one 200mm thickness, P Ni N+ diffused silicon wafer between two molybdenum disks.

The silicon wafer is alloyed, throughout a low temperature and high pressure process, on both side, to two molybdenum disks with an intermediated layer of silver past.

Compared with standard one this innovative alloy process offers some important advantages:

1. Reduction of defects introduced inside silicon during standard joining process

2. No thermal mismatch between the two materials (silicon and molybdenum) with consequent higher thermal cycling capability and the possibility of silicon disk joining to moly on both sides without mechanical tensions or distortions

3. As above direct consequence the diode can avoid any housing since molybdenum surfaces reach optimised levels in terms of roughness and planarity, so getting the aim of a dramatic improvement of thermal resistance.

The total thickness of the final structure is 2.3mm for AUS 601 and 5.2 mm for AUS701; gold metallization of external diodes surfaces leads to an optimised thermal and electrical resistance. (see fig. 3).

Finally a rubber O-ring on the external board for pollution protection complete the devices

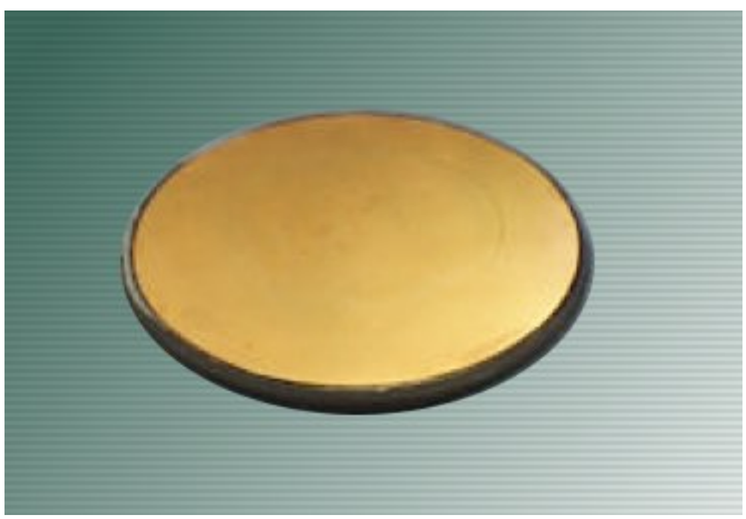

Fig. 3 Picture show AUS601 sample (cathode view)

3. DEVICES CHARACTERIZATION

A complete electrical and thermal characterization has been performed. As result Table 1 reports some main features of the two diodes:

		AUS601	AUS701
Si diameter	[mm]	55	75
thickness	[mm]	2.3	5.2
V_{rrm}	[V]	200	200
I_{tav}/T_c=85°C	[kA]	13.3	15.4
V_{fo}	[V]	0.73	0.7
rf	[mohm]	0.035	0.033
Rthj-c	[°C/kW]	4	3.5
T_J max	[°C]	190	190
weight	[gr]	50	200

Tab. 1. ultraslim diodes features

Forward voltage (fig.4) and recovery (fig.5 and 6) characteristics of both devices at maximum junction temperature have been pointed out as hereafter reported:

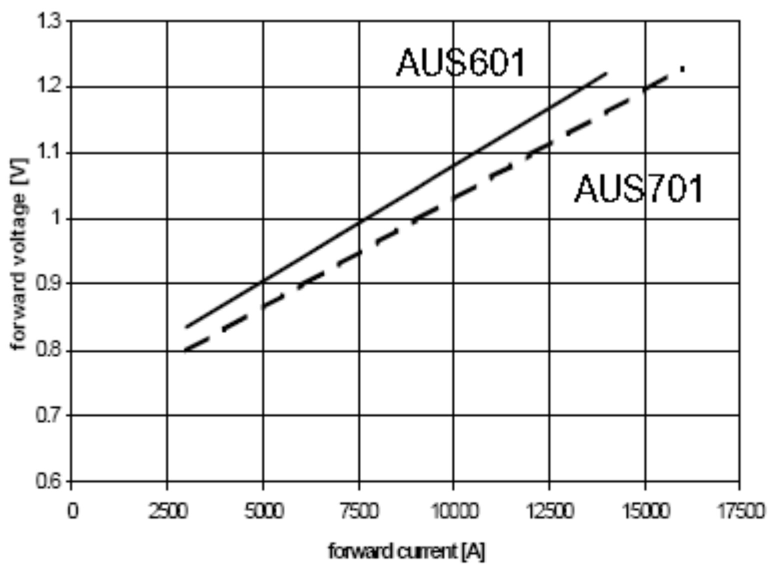

Fig.4. Ultraslim diodes forward characteristics.

As effect of enlarged silicon area and higher thickness, AUS701 shows a lightly softer recovery against AUS601.

Finally note that weights reduction against standard packaged diode (weight ratio 4) helps to compact the total design of the equipment that is particularly useful for moving welding systems.

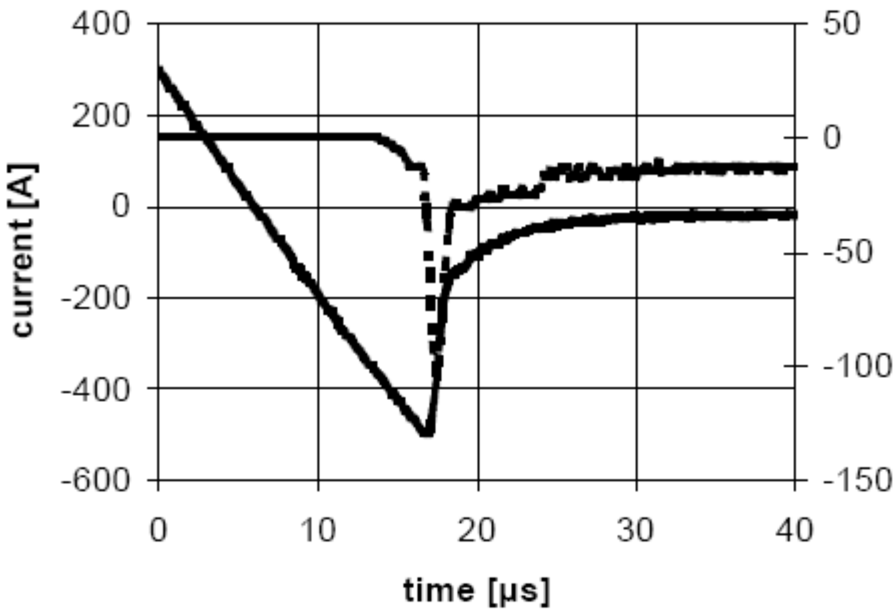

Fig. 5. Typical AUS601recovery waveform at Tj = 190C,Ipk = 3kA, di/dt = 50A/msec, Vr = 10V

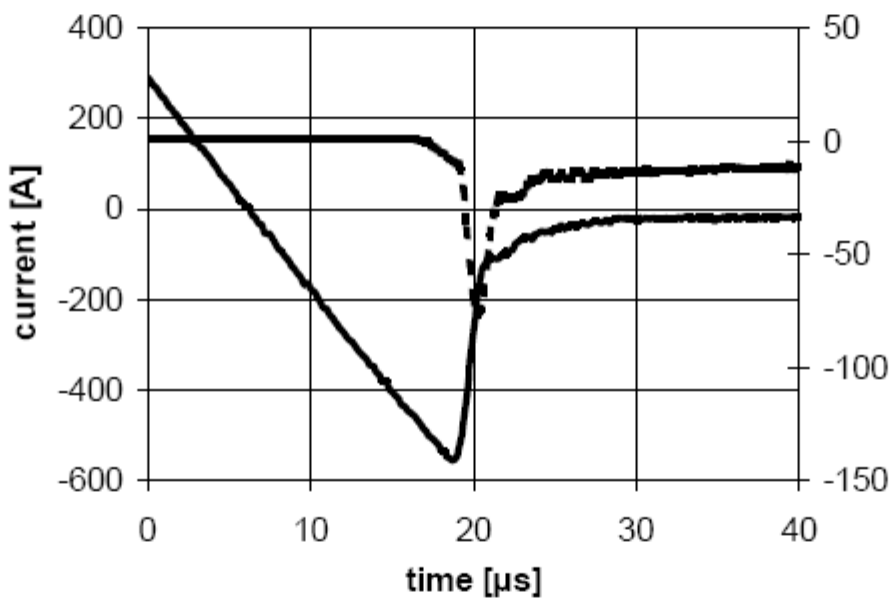

Fig. 6. Typical AUS701recovery waveform at Tj = 190C,Ipk = 3kA, di/dt = 50A/msec, Vr = 10V

At now AUS601 has been fully tested and is already available on the market, in the meantime AUS701 is carrying out its development and qualification process.

4. RELIABILITY TEST CAMPAIGN

With reference to AUS601 qualification campaign, it has been subjected to a set of tests aiming to verify its global reliability in severe work conditions.

Table 2 shows adopted reliability tests plan:

Reliability test	Test conditions	Test results
Passive thermal cycling	Tmin = -40°C, Tmax = 130°C Time cycle = 2h, Nc = 10	No failure
Active thermal cycling	Ion = 3000A, ΔTcase = 75°C, time cycle ≈ 130sec, actual Nc = 100K	No failure, test in progress
Hot blocking life test	Tj = 190°C, Vhb = 160V (80%Vrrm), time 1000 hours	No failure

Tab. 2. test plan performed in Ansaldo Laboratory facilities

Thanks to their ultralow thermal impedance this kind of diodes can work with high ΔTcase that is truly useful for welding cycle.

During Active Thermal Cycling test the equipment control commands diodes current cut off when case temperature reaches 110C, enabling again current flow when that temperature drops down to 35C.

Test waveforms are reported in Fig. 7

Long term active thermal cycling test is still in progress in order to reach expected theoretic results, foreseen in about 200K cycles for ΔTcase = 75C [3].

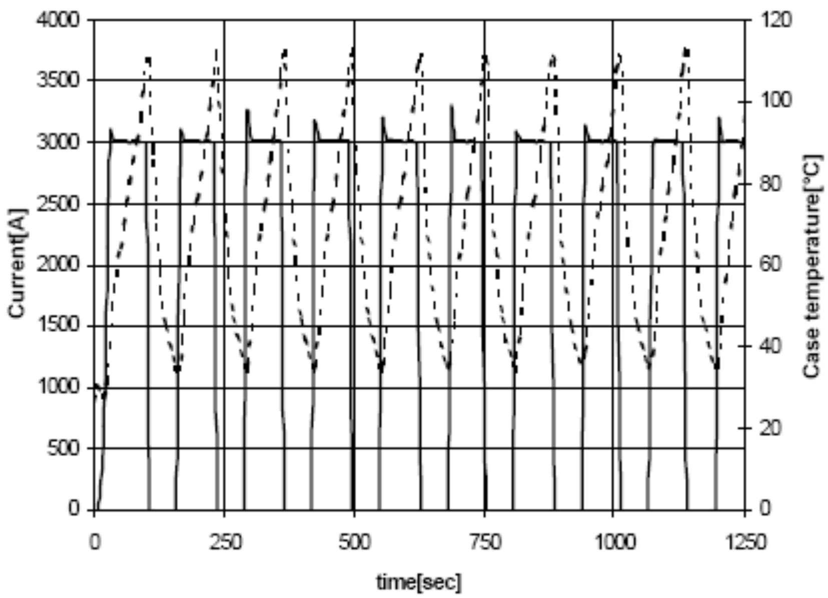

Fig. 7. The graphs report a view of the active thermal cycling test .Diodes current and diodes case temperature (discontinued line) are shown.

In addition on above laboratory characterization, some on field tests in cooperation with welding systems manufacturers have been performed.

An example is shown in table 3:

Reliability test	Test conditions	Test results
Welding cycling	M2 circuit, f =1kHz, 2 diode // per arm, Idc=35KA, ton =0.5sec, toff=4sec, actual Nc = 1000K	No failure, test in progress

Tab. 3. real welding cycles test results

5. CONCLUSION

A new family of rectifier diodes expressely devoted to welding application has been

presented.

Due to their capacity to avoid ceramic packaging, thanks to an innovative low temperature brazing tecnique, these diodes show very low thermal impedance so that highest current performances can be

matched.

A plan of electrical characterization and reliability qualification, both in laboratory and on field, has been also carried out.

Key qualities for welding machinery, as robustness and mechanical-electrical reliability, found full confirmation by above tests campaign.

REFERENCE

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