Invited Paper

THE MICROWELDING TECHNOLOGIES AND THEIR APPLICATIONS

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Abstract: *The practice-oriented definition of the term "microwelding" concerns all those welded joints, which are suitable for the welds of thin sheets, wires and built-in layers, which thickness or diameter is less than 0.5 mm or the cross section of joint is less than* 0.5×0.5 *mm*^{2}*. Resistance micro-spot and microprojection welding, micro-plasma welding, micro-TIG welding, laser beam, electron beam and ultrasonic microwelding procedures compose the main group of microwelding.*

There are few industrial application examples for automotive discharge lamp and high-pressure gas discharge lamp production, which are presented in the paper. High precision positioning and parameterization are needed in the area of the development of coronary stents. Stents are special intravascular implants, which produced by resistance micro-spot welding in Hungary for ten years.

Keywords: *microwelding, resistance welding, laser beam welding, TIG welding, coronary stents*

1. Introduction

The expression mentioned in the title more often and often appears in the welding literature. One of the searching programmes of the Internet used every day nowadays finds many thousands hits for the searching word "microwelding". For example in the middle of November there were 35700 hits on Google: only 696 German version, their number in French are 400, there were found 22 by the Romanian "microsudura" and finally 31 word-forms in Hungarian language. The domain of microwelding exists in technical terminology for a long time, as two welding processes – micro-plasma welding and resistance micro-spot welding were in use for ages.

The meaning of "microwelding" is rather undefined in technical language. The conceptual definition is very important because of the respect that in many welding processes can be meet this phrase and it can be lead to misunderstandings easily. Furthermore, last years a new prefix "nano" turned up in materials science and because of it all the users the expression microwelding can also meet some new questions. Perhaps is there a nanowelding, too? In the case of thinking about word-magic one must open the above-mentioned working tool, Internet and can find 552 hits in connection with the phrase "nanowelding".

On the basis of these circumstances it is not out of place to try to give a drawing up like a definite interpretation, which is not too stiff, still less discriminative, but a bit *makes familiar with the orientation and makes the interpretation not depend on the linguistic skills or on the fantasy. Must to overstep the definition of the microwelding based on the original circumstances which says that microwelding is not other than a traditional fusion welding completed with microscope like an aid equipment trying to produce minimal weld pool. Addition to this the definition like this was given in connection with the laser beam microwelding and it is not concerning the many processes of the pressure welding.*

It is justified to extend the notion of microwelding over the formation all those welded joints, which are suitable for one or other following groups or maybe at the same time for more of them.

a) *The junction welding of sheets with thickness less than 0.5 mm to a sheet with any thickness with the joint having less than 0.5×0.5 mm^2 cross section;*
b) *The junction welding of a wire with diameter less than 0,5 mm to a material with optional size with a joint less than 0.5×0.5 mm^2;*
c) *Producing of the joints with diameter less than 0.5×0.5 mm^2 with overlay welding;*
d) *By the more strict definition only the fusion zone with 100×100 μm can be admitted as microwelding [1].*

2. Types of microwelding processes

The main characteristic of the above drafted definition is the following: because of being free from process it can afford (even inspire) completing the welding task with different welding procedure. For the achievement of microwelding can be adopted a grate number of welding procedures, but first of all there are the following are in use:

- *Resistance micro-spot welding, resistance microprojection welding;*
- *Micro-plasma welding;*
- *Micro-TIG welding;*
- *Laser beam microwelding [2,3];*
- *Electron beam microwelding;*
- *Ultrasonic microwelding (this procedure satisfies to the definition of microwelding practically in every case) [4];*
- *Electrochemical discharge welding [5].*

From the side of the application circles different procedures can be very different in the respect of universality and that point of view how they are specific at the industry. Electron beam microwelding and ultrasonic welding first of all are the joining technology of microelectronics industry. Resistance micro-spot welding and resistance micro-projection welding most of all are widespread in the lamp producing industry, as at those products there is necessary the welding of the large choice of thin wires, thin sheets and foils. The application circles of micro-plasma and micro-TIG welding are more extensive: beside the above mentioned they get very important role in the production of medical devices. Certainly the favourite one is still the laser beam microwelding or more generally the micro-machining: this laser considered only useless at the beginning of 1960s nowadays gains spreads in every territory of the life, so ahead its rate also on the territory of microwelding.

At the industrial application of precision micro-spot welding it has become determinant the direct current producing current generators with precise electronic control. Besides electronic parameters the welding time and force regulation also can be controlled *very accurately (100 μs and 0,1 N resp.) and with the exact registration of the effective welding parameters it can be improved also the quality assurance conditions of the production process. Micro-plasma welding and micro-TIG welding are applications in a close relationship and there are combined machines also can be fined in the supply of the main device producers and thanks to these machines all the two of these applications can be executed [6]. The precision of microwelding from the side of power supply is provided with the fine and precision control. Current and time first of all at micro-plasma application can be controlled until small units of measurement (50-100 mA welding current, 5 ms welding time and 1 Hz to 10 kHz impulse frequency respectively).*

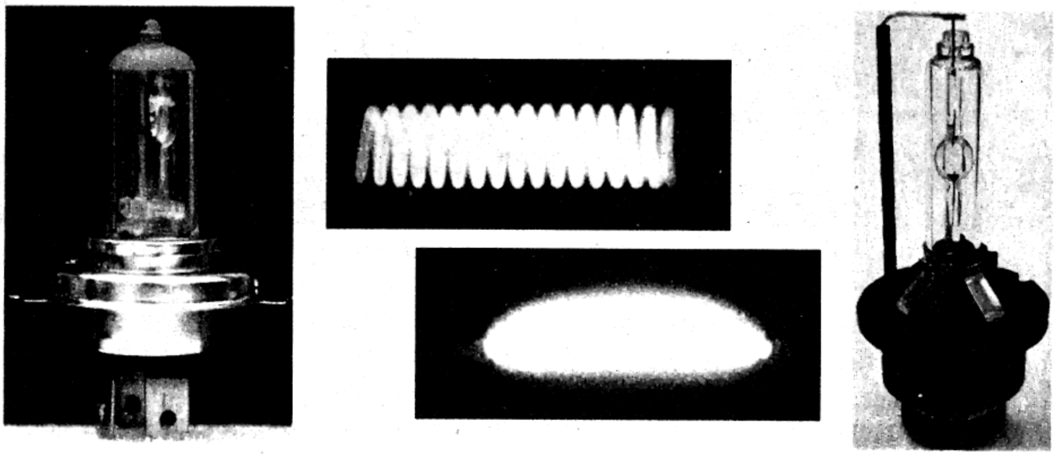
Simply it is impossible provide such a fine regulation conditions if the tungsten electrode tip geometry doesn't suit the strictest/the most demanding/the most exacting requirements. Experiences show that troubles of the welding process were has been caused by the surface preparation defect, wear and pollution of the W-electrode. Micro-plasma welding is much less sensitive to changes of arc length and the energy density is three times larger [7].

Quick spread of laser beam microwelding – in a wider sense micro-mechanic (cutting, hard facing, spraying) – was promoted by automotive industry, electronics (especially mobile telecommunications) and by medical device producing industry. In these areas were increased considerably the circle of those welding tasks where the welding of thin sheets, wires, foils, often in very different material quality is necessary.

High density, focussability of laser beam and intense automatic ability of the equipments and their becoming cheapest practically marked out the widespread of the process treatment.

3. Application examples

After the above generally sketched out statements, in the following can be seen few examples, which are industrial applications or are in connection with R&D resolutions.

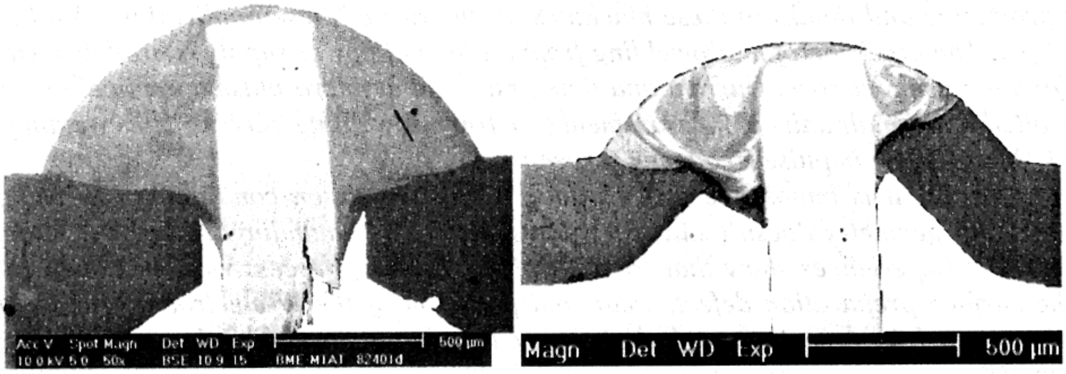


a) b)

Fig.1. Automotive lamps and their light source: H4 lamp.(a) and D2S lamp (b)

In the last few years the development of D1 and D2 type (xenon plasma discharge) automotive lamps has been the most important result. These lamps replace the tungsten filament containing H4 lamps and they have significantly higher lighting performance. In a

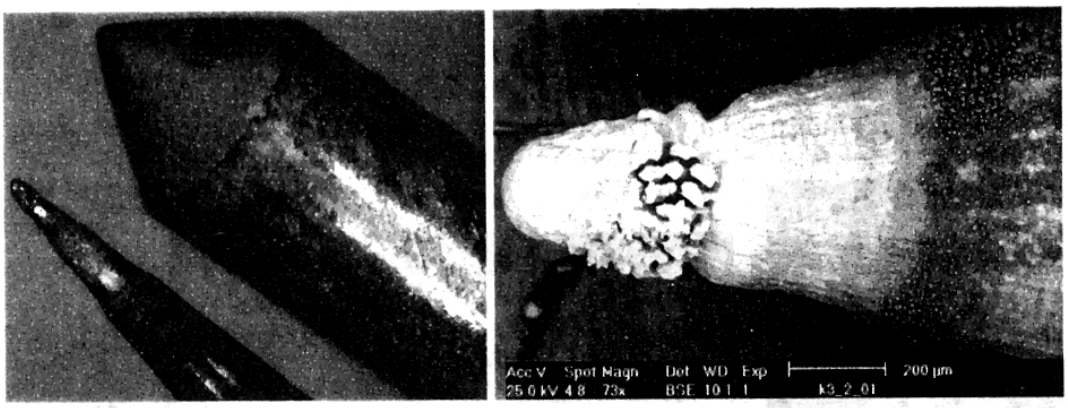
D2S lamp are more than 10 welded joints, which are produced by resistance micro-projection welding, laser beam micro-spot welding and micro-TIG spot welding. The materials to be welded are tungsten, molybdenum, nickel alloys and austenitic stainless steel.



a) b)

Fig.2. The same heterogeneous weld on two different D2S lamps

Back-scattered electron images in Fig.2 show the microstructure of the same arc-spot weld of thin stainless steel sheet and molybdenum wire in two different xenon plasma discharge lamp, produced by micro-TIG welding (Fig.2a) and laser beam micro-spot welding (Fig.2b). Using micro-TIG welding, the wear of the tungsten electrode plays a very important role, because significantly influences the arc ignition security. Figure 3 shows tungsten electrodes after different wear tests.



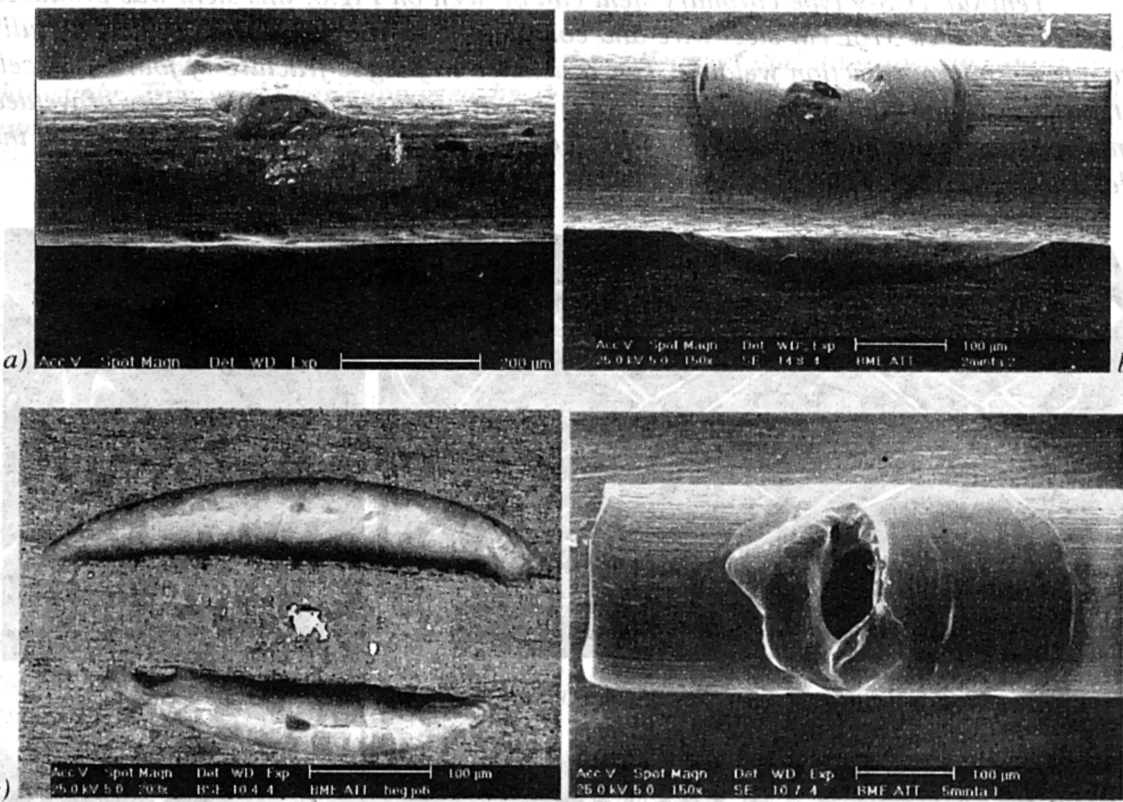
a) b)

Fig.3. Wear of tungsten electrodes after many hundreds micro-spot welding cycle

The D1 and D2 lamps contain some welds between 0.25 mm W-wire and 0.1 mm Mo-foil, which welded joints are seen in figure 4. Components of weldability of these dissimilar welds differ at resistance microprojection welding (Fig.4a) and at laser microwelding (Fig.4b). Both welding procedures have their own advantage and disadvantage concerning to crack sensitivity, maintenance frequency and productivity.

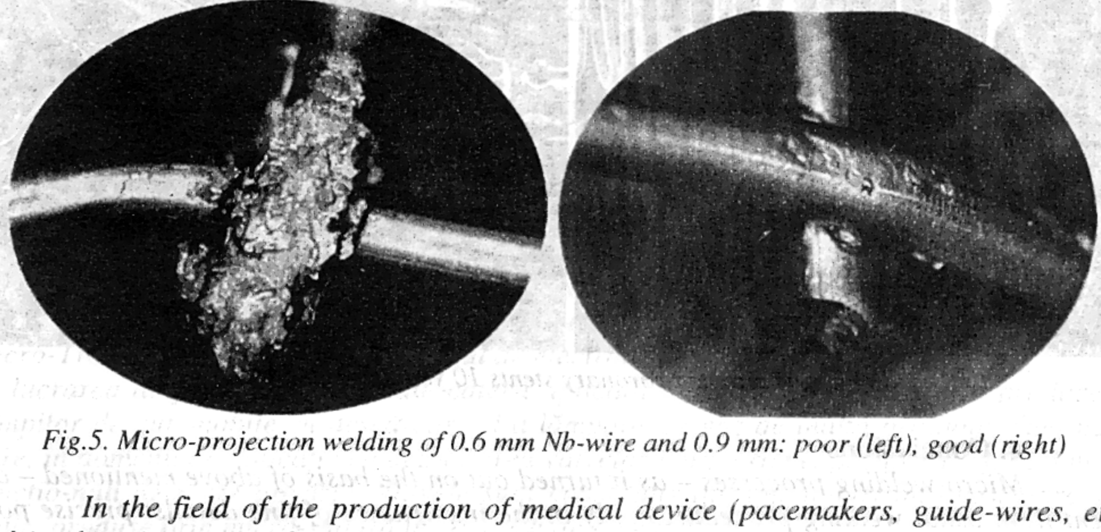
In the high-pressure discharge lamps can be found many welded joints between dissimilar metals and alloys (i.e. niobium, nickel alloy, tungsten, molybdenum), which thermo physical parameters are very different. Besides optimizing of welding parameters, the surface cleaning and metallurgical properties – possible formation of brittle inter-

metallic phases – play very important role. 0.6 mm Nb-wire and 0.9 mm Ni-Mn alloy wire were joined with un-optimised (Fig.5a) and optimised (Fig.5b) welding parameters of resistance micro-projection welding.



a) b) c) d)

Fig.4. Welded joint of 0.25 mm thick W-wire and 0.1 mm Mo-foil



a) b)

Fig.5. Micro-projection welding of 0.6 mm Nb-wire and 0.9 mm: poor (left), good (right)

In the field of the production of medical device (pacemakers, guide-wires, etc.) and implant (stents, grafts, etc.) microwelding is a frequently used technology. Coronary and peripheral stents are special net shaped intravascular implants, which have been pro-

duced by resistance micro-spot welding in Hungary for ten years. In Hungary and Russia the different generations of TentAur stents (gold, gold-coated stainless steel, uncoated but surface treated 316LVM stainless steel) were applied very successfully.

TentAur TCS-9 type coronary stent can be seen on Fig.6; this stent was produced from 0.14 mm thick 316LVM steel wire and contains 17 joints, which were welded by fully automatised microprojection welding. The resistance to fatigue fracture of joints is excellent. Nowadays the Hungarian stent developments are focused on the flexibility of welded stents and starting of the production of laser beam cutted stents. Figure 7 shows few of the oldest and newest laser cutted coronary stents.

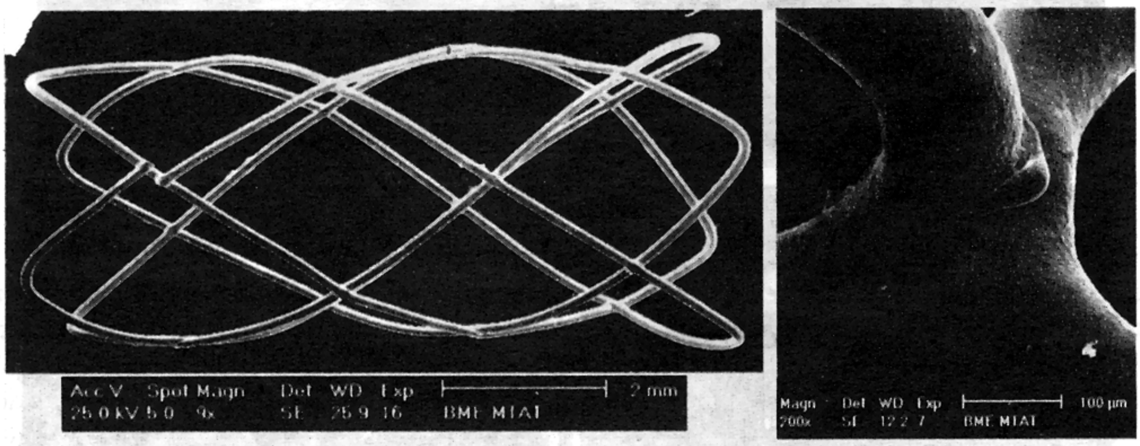


Fig.6. TentAur TCS-9 type coronary stent and one of his welded joints

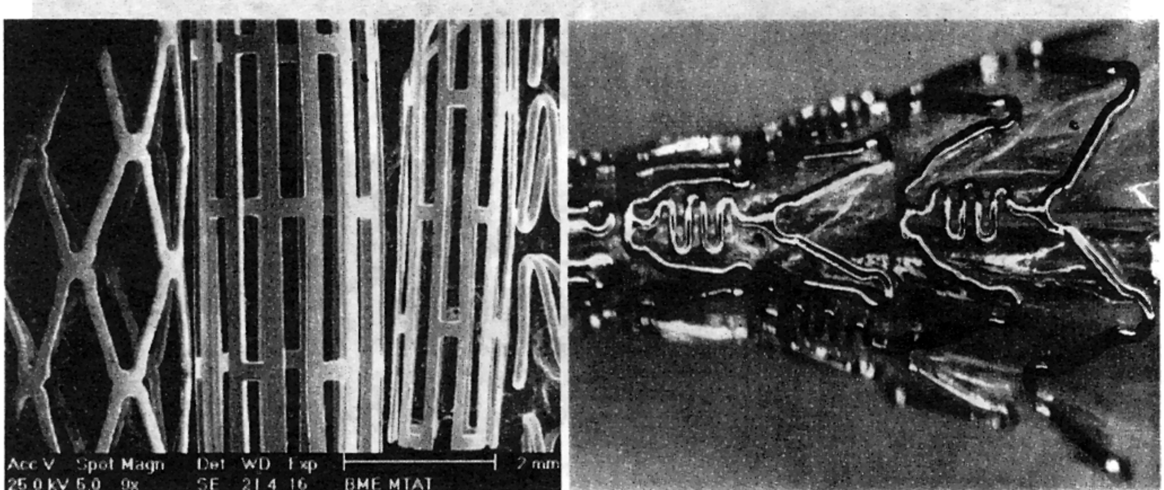


Fig.7. Laser cutted coronary stents 10 years ago and today

4. Conclusions

Micro-welding processes – as it turned out on the basis of above mentioned – different from usual welding procedures only in the importance of fine details: precise positioning, fastening and motion systems, precision mechanics control and measuring technology. As the specific value of the products produced by microwelding – and so the welded joint in them – is characteristically much higher than the value of great steel structures (a *gas-discharge light costs 40-50 Euros, a coronary stent costs 200-3000 Euros), the attention directed to microwelding cannot be proportioned with the cross section of the joint for example: especially can't be in engineering training.*

5. Acknowledgements

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6. References

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TEHNOLOGIILE DE MICROSUDURĂ ŞI APLICAŢIILE LOR

Rezumat: *Definiţia orientată spre aspecte practice a termenului "microsudură" ("microwelding") priveşte toate îmbinările sudate, care sunt adecvate sudării tablelor subţiri, a firelor şi semi-fabricatelor a căror grosime sau diametru este mai mică de 0,5 mm sau a căror arie a secţiunii asamblării este mai mică de 0,5×0,5 mm². Principalul grup de tehnici de micro-sudură este constituit din: sudarea cu micro-proiecţie, cu micro-plasmă, micro-TIG, cu fascicul laser, cu fascicul de electroni, respectiv ultrasonic.*
În lucrarea de faţă sunt prezentate câteva aplicaţii industriale referitoare la producerea lămpilor de automobile cu descărcare şi a lămpilor cu gaz de înaltă presiune. Sunt necesare, în domenii de aplicaţie ca dezvoltarea valvelor coronariene, poziţionări şi parametrii funcţio-nali de mare precizie. Valvele sunt constituite din implanturi intravasculare speciale, produse prin micro-sudură în Ungaria de zece ani.