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# SURDAT - DATABASE OF PHYSICAL PROPERTIES OF LEAD-FREE SOLDERS

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**Abstract**

The results of investigations, carried out since 1998, of surface tension by the maximum bubble pressure method, and of density by the dilatometric method for pure metals, binary and multi-component systems have been used to create an electronic database SURDAT of materials for lead-free solders. The database enables also to compare the experimental data of surface tension with the values calculated from Butler's relation and with the literature data of other authors. The base was published at the beginning of the year 2007 as a monograph including the installation program and may by obtained free from the website www.imim.pl. The present version of the SURDAT database will be introduced on the website of the National Institute of Standards and Technology (NIST) together with the new version of Lead-Free Solders base elaborated by NIST. The work on the database is continued. The SURDAT database will be supplemented with new data of surface tension and density for systems already available in the base as well as for new systems and it will be extended by including the results of meniscographic investigations. In the paper there has been offered the instruction for preparing the data for the authors of studies who would like to present the results of their experimental investigations in the SURDAT database.

*Keywords:* Surface tension, modelling of Pb-free solders

## 1. Introduction

Starting from the year 1998, in accordance with the world wide trend to search for new lead-free solders at the Institute of Metallurgy and Materials Science of the Polish Academy of Sciences (IMIM PAS) there were initiated systematic investigations of the physical properties of binary and multi-component metal alloys,

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able to replace the solders containing lead, widely used in electronics. These investigations were concentrated on experimental determination of surface tension and of the density of metals of binary and multi-component alloys, as well as on modelling the surface tension from the thermodynamic parameters. In the year 2000 the cooperation has been initiated with the Tele & Radio Research Institute (TRRI), Institute of Non-ferrous Metals (INM) and the Warsaw University of Technology (WUT) and in the years 2002-2004 at the IMIM PAS a joint research project for 5-component Sn-Ag-Cu-Bi-Sb alloys was realized.

In the year 2003 the European Commission published an instruction introducing from July 1 st, 2006 a total prohibition of using lead and other harmful substances. This introduction made it necessary to undertake actions intended to replace the traditional tin-lead solders by lead-free materials. The undertaken systematic investigations resulted in the selection of IMIM PAS as the only representation of Poland in the international network ELFNET in the years 2004-2006. The collected rich experimental material was used to elaborate the SURDAT database, and, which is essential, it made our work concentrate on two groups of solders based on the eutectics Sn-Ag and Sn-Ag-Cu, widely accepted as substitute materials, and on new solders on the basis of alloys with the composition close to the Sn-Zn eutectic with Bi and Sb additions. Investigations of these alloys are carried out by three institutes: IMIM PAS, TRRI, INM within the project: "Advanced soldering materials". There are carried out physico-chemical, thermodynamic and meniscographic investigations. In Table 1 there are presented the metals and alloys subjected to experimental investigations and inserted in SURDAT database.

## 2. Description of SURDAT database

The base consists of two parts. The first contains the description of the experimental methods and the Butler method of modelling

*Table 1. Metals and alloys subjected to experimental investigations*

| **Metals** | **Binary Systems** | **Ternary Systems** | **Quaternary Systems** |
|---|---|---|---|
| Pb<br>Sn<br>In<br>Ag<br>Bi<br>Sb<br>Cu<br>Zn<br>Al<br>Au | Pb – Sn<br>Ag – Sn<br>Ag – In<br>Bi – Sn<br>In – Sn<br>Ag – Bi<br>Sb – Sn<br>Sn – Zn<br>Ag – Sb<br>Cu – Sn<br>Cu – Sb | $(Sn\text{-}Ag)_{eut}$ +In<br>$(Sn\text{-}Ag)_{eut}$ +Bi<br>$(Sn\text{-}Ag)_{eut}$ +Cu<br>$(Sn\text{-}Ag)_{eut}$ +Sb | $(Sn\text{-}Ag)_{eut}$ +Cu+Sb<br>$(Sn\text{-}Ag)_{eut}$ +Cu+Bi |

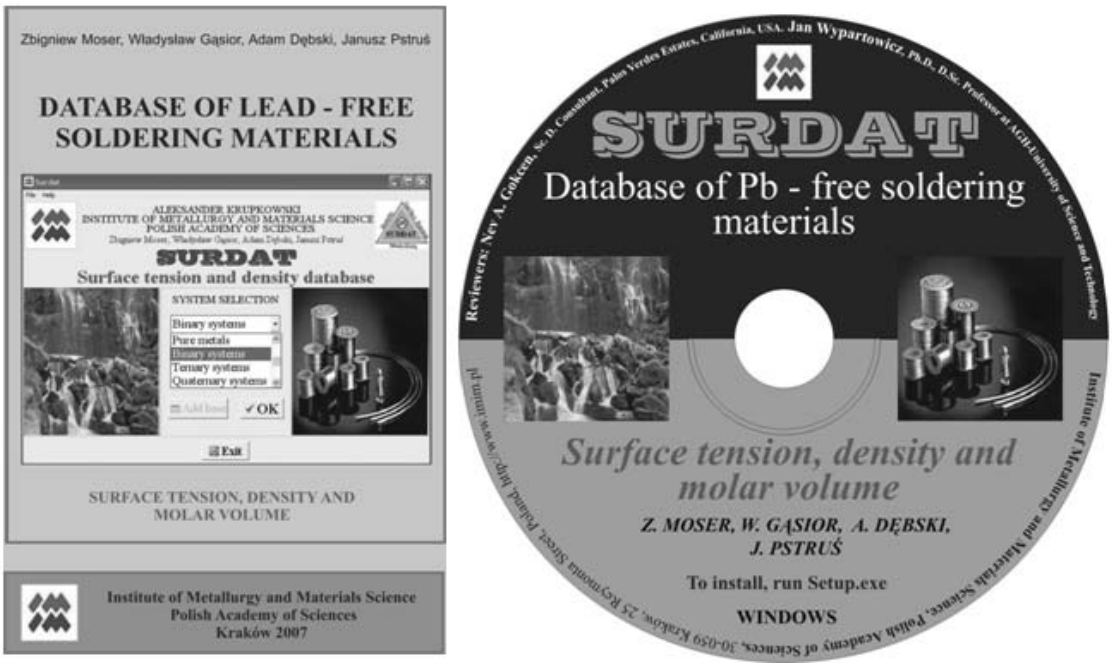


*Fig. 1. SURDAT database published as a monograph together with the installation program*

the surface tension, while in the second part the instruction for installation and the way of using the base are presented.

The first version of the SURDAT database was presented at the conference CALPHAD XXXIII [2] and published in a special issue (Archives of Metallurgy and Materials) dedicated to this conference [3]. Its successive modifications were presented at the conferences CODATA 2004 [4], "InfoBase 2005 of Data Base for Science" [5] and discussed during THERMO INTERNATIONAL in Boulder, Colorado [6]. The latest modification of the SURDAT database was published as a monograph [7] together with the installation programme and inserted on the website of the Institute of Metallurgy and Materials Science of Polish Academy of Sciences www.imim.pl. The database was also presented at the conference: Progress in the soldering technologies [8].

## 3. Discussion

The SURDAT database has been published as a monograph including the installation programme. It is the first database concerning the lead-free solders published in the electronic version. The SURDAT database is free of charge and it may by taken from the web site IMIM PAS and from the Polish website: www.elfnet.pl in the form of a monograph and with an installation programme. The database is the additional contribution of IMIM PAS both to the programme COST 531 and to international network ELFNET.

It should be noted that the database has become the object of interest of the National Institute of Standards and Technology in USA and it will be presented on the website of the NIST together with a new version of the database of lead-free solders. Plans of further development of the SURDAT

database comprise:

- Supplementing the SURDAT database with new data of surface tension, density and extension of the systems available in the base, among others, by including these found in Table 2 which is already realized as shown in Fig.2.
- Extension of the calculation of viscosity and the molar volume of liquid alloys from the thermodynamic properties.
- Inserting in the database the meniscographic data which will be presented in the form of tables (Fig.3) or diagrams (Fig.4).

## 3. Conclusions

The SURDAT database has been published as a monograph with the installation program included. To enable further development of the database there has been prepared an instructions for preparing the experimental data for lead-free solders for the authors who would like to insert the result of their investigations in the SURDAT database. The instruction comprises two parts. The first refers to density and surface tension, and the second - to the meniscographic investigations.

*Table 2. New systems in the SURDAT database*

| Binary Systems | Ternary Systems | Quaternary and Quinary Systems |
|---|---|---|
| **Ag – Cu**<br>**Au – In**<br>**Au – Sn**<br>**Bi – In**<br>**Cu – In** | **Au – In – Sn**<br>**Bi – Cu – Sn**<br>**Bi – In– Sn**<br>**Bi – Sb– Sn** | **Bi – Cu – Sn – Zn**<br>**Bi – Sb– Sn – Zn**<br>**$(Sn\text{-}Ag)_{eut}$ +Cu+Bi+Sb** |

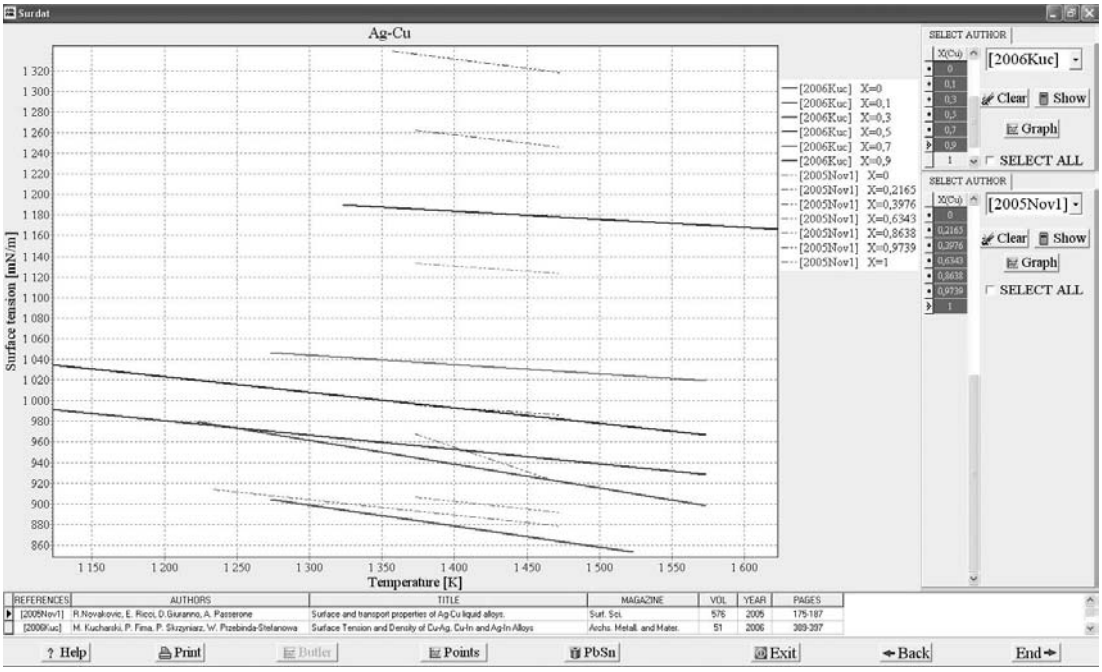


*Fig. 2. Temperature dependences of surface tension of liquid Ag-Cu alloys, compared for two authors of studies*

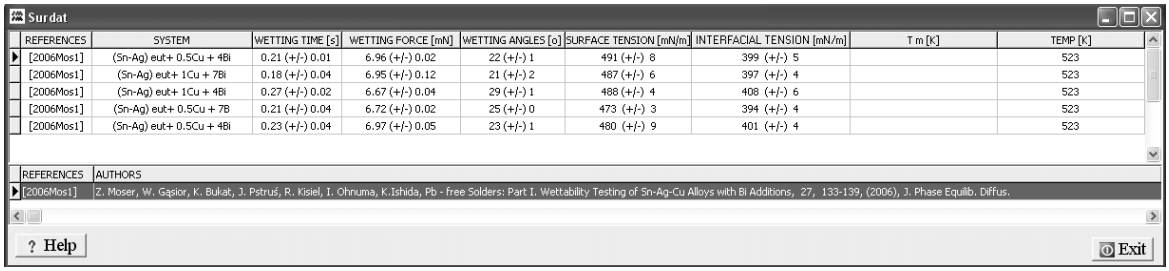


*Fig. 3. Results of meniscographic investigations for the system Ag-Bi-Cu-Sn*

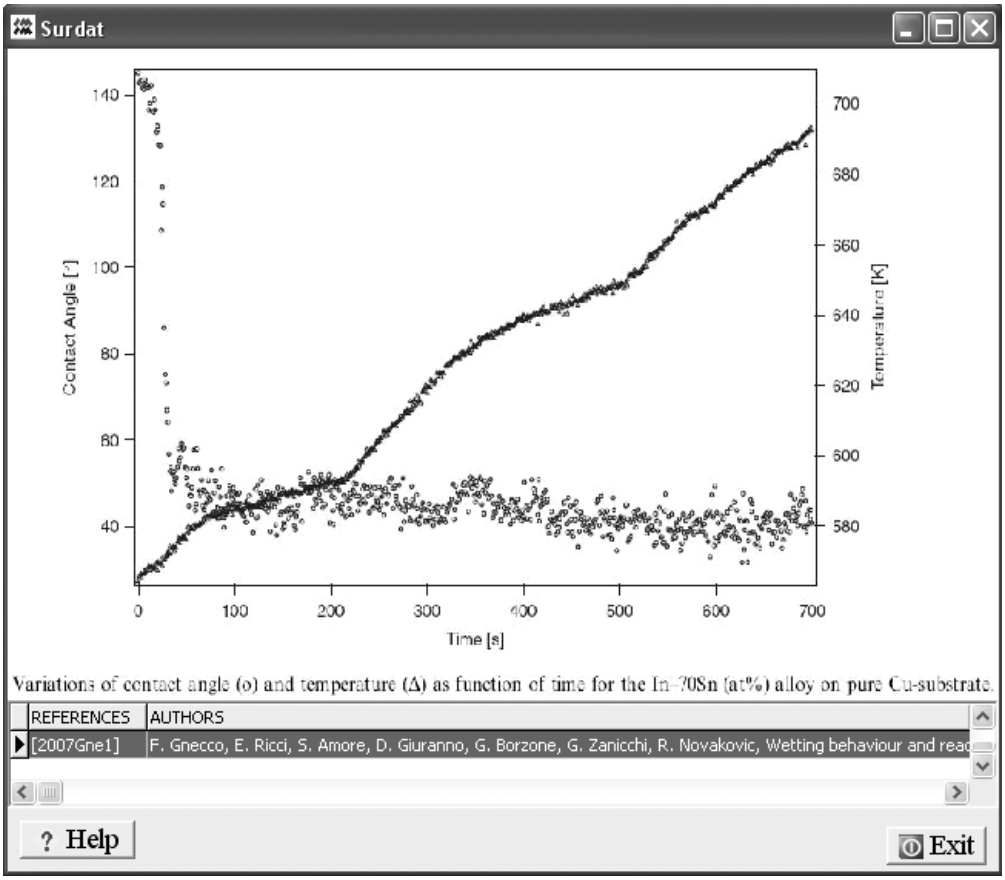


*Fig. 4. Dependence of the wetting angle on time for the system In-70Sn*

***Density and surface tension***

- Publication in electronic or copy form- information introduced into the database: authors of the publication, title of the study, journal, volume, year of publication (see example below).

*[2006Mos1]:* Moser Z., Gasior W., Bukat K., Pstrus J., Kisiel R., Ohnuma I., Ishida K., Pb - free Solders: Part I. Wettability Testing of Sn-Ag-Cu Alloys with Bi Additions, J. Phase Equilib. Diffus., 27, (2006), 133-139.

- Elaborated equations of temperature dependences:

$$\rho = a + bT$$
$$\sigma = a + bT$$

where:
ρ - density,
σ - surface tension
a, b -linear equations parameters,
T - temperature,
X - mole fraction.

| System | Properties | $X_{Sn}$ | a | b | Temperature Range |
|---|---|---|---|---|---|
| Ag-Sn | ó | 0,962 | 586 | -0,09 | 600-1200 |
| | | 1 | 583 | -0,083 | 500-1200 |

### *Meniscographic studies*

- Publications in electronic or copy form (authors, title, journal, volume, year, pages).

- Numerical data or as a plot (if are published) including: wetting time, wetting force, contact angle, interfacial tension, surface tension, range of temperature, melting point, substrate, flux.

- Temperature range for each of the examined concentrations.

$T_m$- Melting point,
Temp - Range temperature,
Sub - Substrate,
Atm - atmosphere (air, protective atmosphere).

## References


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5. W. Gasior, Z. Moser, A. Debski, InfoBase 2005 of Data Base for Science. Materials of 4th Scientific Conference, p. 144 *(in Polish)*.
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7. Z. Moser, W. Gasior, A. Debski, J.Pstrus, Database of Lead - Free Soldering Materials, Institute of Metallurgy and Materials Science Polish Academy of Science, OREKOP, Kraków 2007.
8. A. Debski, Z. Moser, W. Gasior, J.Pstrus, Progress in the Soldering Technologies. 2nd International Scientific-Technical Conference. Conference on Soldering. Wroclaw Poland, 24-26 September 2007, p.41 *(in Polish)*.


| References | System | Wetting Time [s] | Wetting Force [mN] | Wetting Angles [°] | Surface Tension [mN/m] | Interfacial Tension [mN/m] | $T_m$ [K] | Temp [K] | Sub | Atm | Flux according to PN-EN 61190-1-1: 2004 IEC 61190-1-1: 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| [2006Mos1] | $(Sn-Ag)_{eut}$ | 0.038 (+/-)0.03 | 5.38 (+/-)0.18 | 47 (+/-)1 | 518 (+/-)6 | 436 (+/-)5 | 494 | 523 | Cu | Air | ROL 1 |