# Material microscopy

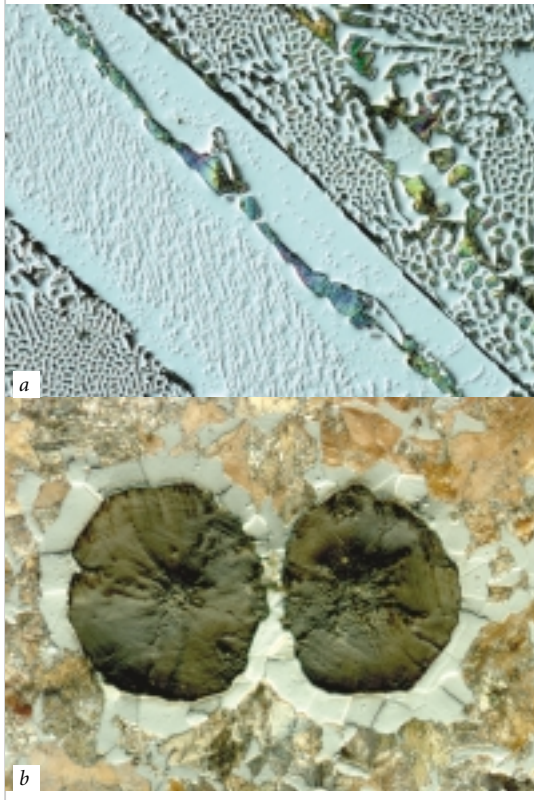
## Joining processes under inspection

Joining different or similar materials through welding, brazing, or soldering is required for the construction of all sizes of components, from the hull of a ship to a microchip. Technical joining questions are thus significant for practically all areas of mechanical engineering and plant construction, in particular in power plants, vehicle and ship construction, aeronautics, space travel and electrical engineering.

The Institute for Welding Engineering, Technical University of Braunschweig, deals with a wide range of topics in this specialized area in research and teaching. In addition to training students in materials engineering and metallography, the Institute for Welding Engineering is involved in the development and control of joining and cutting processes. For example: the optimization of arc welding processes or the welding of aluminum and magnesium alloys. The department of metallographic analysis under the direction of Dr. Helge Preis plays a central role in the work of the institute. The department staff carries out materials testing for quality of welded joints and failure analysis. The goal of the testing is the determination of macroscopic features based on the material's microstructure. This analysis requires modern methods and techniques to answer a variety of questions, along with the search for a microscope solution, which meets these requirements.

*Elke Helmke, laboratory director at the Institute for Welding Engineering (ifs), Technical University of Braunschweig, in conversation with Dr. Brüne Venus, system specialist with Carl Zeiss.*

**Classical material samples with modern techniqes**




*a) White cast iron, primary cementite $Fe_3C$ and ledeburite, hypereutectic pig iron. Etching: Nital (EC Epiplan-Neofluar 20x/0.50 HD DIC; contrasting technique C-DIC).*

*b) Gray cast iron, sphaero cast. sphaeroliths with ferrite envelope and pearlitic ground mass. (EC Epiplan-Neofluar 50x/0.80 HD DIC; contrasting technique C-DIC).*

**Innovative light microscopy techniques in metallography and materials testing**

# Welds

### Focus on welds

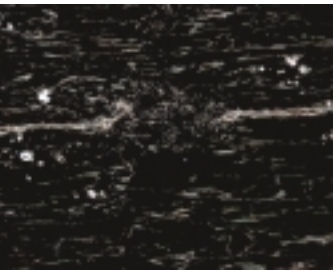
The quality of welded joints is critical for the integrity of designs and structures of all types. Light microscopy examinations provide important information about the structures of welded joints. They shed light on the structural quality of the weld and the basic material as well as on phases and structure. The joining process can be assessed through good sample preparation and a high-performance microscope.

### Application 1:

**Two copper sheets connected by ultrasonic welding (Cu 99.9%).**

Etching: Ammonium persulphate. The joint was viewed in brightfield reflected light, darkfield and with C-DIC. (EC Epiplan-Neuofluar, 50x/0.80 HD DIC). The new C-DIC (Circular DIC) is an ideal supplement to traditional reflected-light contrasting techniques, such as brightfield, darkfield, and DIC. This optical technique was introduced for the first time with the new materials microscope Axioskop 2 MAT. Because it works in circular rather than linear polarized light, C-DIC can solve a familiar imaging problem. With this innovative technique, sample structures that used to be visible only in a certain direction can now be seen in their entirety – regardless of their orientation and without rotating the sample stage. The result: visible, complete sample information, distinctly greater contrast and significantly improved efficiency.


*Brightfield*
*In the conventional reflected light technique, the structure in the welded joint area and in the material can only be recognised with difficulty.*



*Darkfield*
*Diffusely dispersed structures such as cracks, voids, and grain boundaries can be more easily identified on a dark background.*

*C-DIC*
*Turbulence in the material being welded, which can only be suspected in brightfield, is clearly highlighted in C-DIC.*

### Application 2:

**Welded joint test of a chassis. Light vehicle manufacturing. Material AZ 61.**

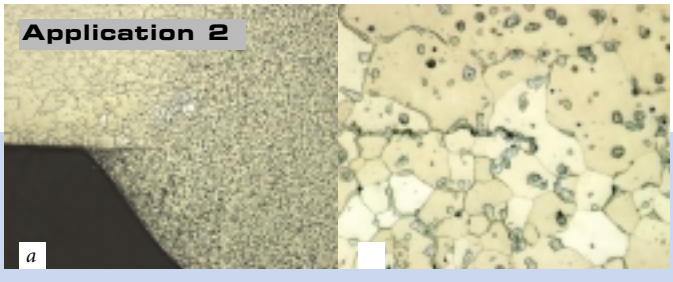
Etching: picric acid mixture. This welded joint was tested in brightfield reflected light at 50x and 500x magnification.

### Application 3:

**Materials for construction of the power plants. Compounded joined laser welding.**

The structure of a mixed joint can only be viewed through traditional etching processes. The welded joint was observed in circular differential interference contrast (C-DIC) at low magnification. (EC Epiplan-Neofluar 50x/0.13HD DIC).


*Laser weld of a mixed joint of highly alloyed materials. The transition between the welded material and the basic material is tested. In the DIC contrasting technique, the internal structures of the welded material and the basic material are highlighted particularly well.*




*a) A 50-fold magnification gives a good overview of the formation of the weld and the heat influence zone. A dark line is visible in the transition area. But it is not clear whether there is a crack or overlapping, or whether new phases have been formed in this zone (brightfield, EC Epiplan-Neofluar 5x/0.13 HD DIC)*

*b) Under high magnification, it becomes clear: there is no crack but a collection of $Mg_{17}Al_{12}$ precipitation and eutectics (EC Epiplan-Neofluar 50x/0.80 HD DIC)*

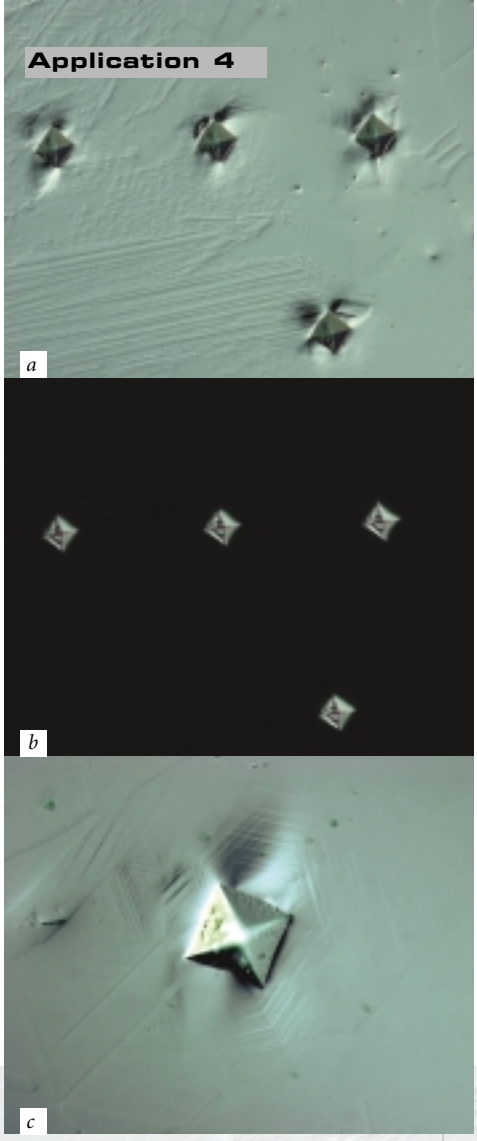
**Application 4:**

**Determination of the microhardness of the materials being welded and the basic material as well as determination of the hardness variation over the weld.**

Information about the structure and the quality of the welded joint can be gained from measurements of hardness and hardness variation.

Sample preparations in metallography are involved. The piece to be examined is sawed, ground while wet, polished, and then etched. In only a few cases can the components of the structure be recognized after polishing through different coloration. Usually the structure has to be developed by etching. Microhardness determination, however, requires an unetched, flat, finely polished material surface. The exact positioning of the indentations is difficult to observe.

The new EC Epiplan-Neuofluar lens, together with the innovative C-DIC contrasting technique, dramatically increases image information gathering without etching.




*a) C-DIC*

*Together with the C-DIC contrasting technique, the EC Epiplan-Neofluar lens supplies considerably more information. Material: Inconnell 625; unetched. Even in an unetched condition, the dendritic coagulation of the welded material (left area) can be clearly distinguished from the basic material (right area). The advantage is obvious: hardness indentations can be positioned specifically on the melting line. With no etching, hardness indentations remain undamaged, guaranteeing exact determination of hardness. (EC Epiplan-Neofluar 20x/0.50 HD DIC).*

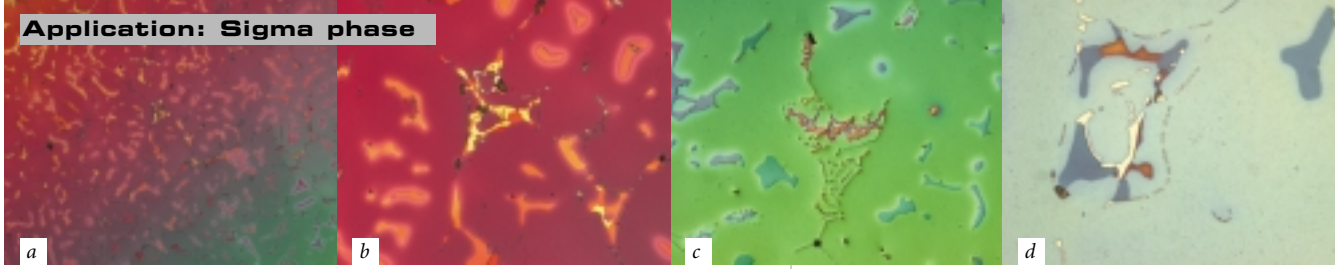
*b) Darkfield*

*Darkfield is ideal for automatic image analysis evaluation of hardness indentations. (EC Epiplan-Neofluar 20x/0.50 HD DIC).*

*c) C-DIC*

*Vickers hardness indentations in the basic material. With C-DIC, the zone influenced by plastic deformation can be imaged particularly well. Important in setting hardness curve lines (EC Epiplan-Neofluar 20x/0.50 HD DIC).*


*Microhardness tester MHT 10. The microhardness sensor is simply mounted on the nosepiece. The testing strength lies between 0.5 and 400 p (MHT 4: 0.05 to 200 p). The diamond indentation tip is pressed into the sample by a plunger located in a magnetic field. A transmitter controls the strength during indentation. The sensor can be fitted optionally with Vickers or Knoop diamonds. The diagonals are measured and the hardness determined.*




## Focus on inter-metallic phases

Accompanying elements that get into materials during the smelting process are usually undesired ancillary components. Some of them, however, are added deliberately to influence material properties.

## Application: Sigma phase

**The Sigma phase is a material-embrittling inter-metallic phase – an undesired ancillary effect of highly alloyed materials.**

The example here is a cast material (G-X5 CrNiMoNb 18 10), electrolytically etched with lead acetate. Process: brightfield and C-DIC.

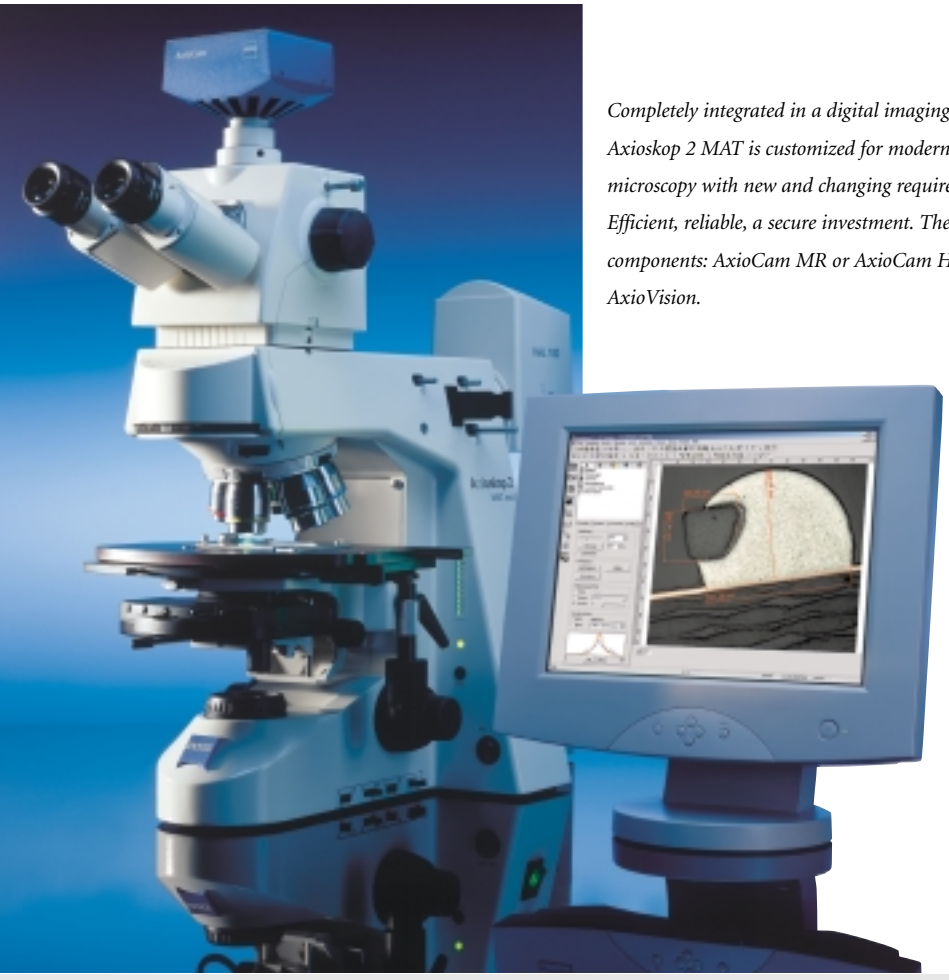
*a) Overview shot after the etching process of the curve colours of the cast material. (brightfield: EC Epiplan-Neofluar 5x/0.13 HD DIC)*

*Detail shots of the various areas from a):*

*b) Orange: delta ferrite. Yellow: Sigma phase. White-yellow: NbC (brightfield; EC Epiplan-Neofluar 20x/0.50 HD DIC).*

*c) Blue: Delta ferrite. Red: Sigma phase. White-yellow: NbC (C-DIC; EC Epiplan-Neofluar 20x/0.50 HD DIC).*

*d) Blue: Delta ferrite. Rust-red: Sigma phase. White-yellow: NbC (brightfield, EC Epiplan-Neofluar 50x/0.80 HD DIC).*



*Completely integrated in a digital imaging platform, Axioskop 2 MAT is customized for modern materials microscopy with new and changing requirements. Efficient, reliable, a secure investment. The system components: AxioCam MR or AxioCam HR and AxioVision.*

## Conclusion

The Axioskop 2 MAT is an outstanding, well-designed microscope with straightforward operation, ergonomic design, and a wide variety of imaging software. Above all, this microscope features two impressive innovations: the newly developed lens series EC Epiplan-Neofluar, which supplies substantially more visible information, and the C-DIC contrasting technique that, for the first time, makes all image information visible without stage rotation, in addition to providing greater contrast and image clarity.

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