QCOALA - Quality Control of Aluminium and Copper Laser-welded Assemblies

QCOALA was an innovative collaborative project funded through the European FP7 programme. It had the objective of improving the laser welding of highly reflective materials, through the development of a fully integrated dual wavelength manufacturing work cell. The project developed a new fully integrated manufacturing system for automated high yield, laser welding of copper and aluminium (0.1-1.5 mm thickness) for car battery (Figure 1) and solar cell electrical interconnections (Figure 2). Welding strategies were developed to suit these types of applications and materials, and were integrated with process monitoring and non-destructive inspection sensors.

The main technologies developed include:

- A dual wavelength (‘GreenMix’) laser system, which has been developed and commercialised.
- A dual-wavelength laser platform for welding copper and aluminium for electrical connections in solar cell and battery applications, using fixed and scanning optics.
- A weld process monitoring system.
- An in-line, post-weld, eddy current and digital radiograghy defect inspection systems.

The project focused on energy-efficient, environment-friendly and agile manufacturing, through feed-back of in-line-monitoring and inspection information into the production line, allowing process control and continuous quality improvement and waste reduction. Whereas the concept of the project, aimed at smarter and more energy-efficient manufacturing, the applications that were addressed in the project were categorised in the 'green' alternative energy market.

Figure 1 Image of super-capacitor battery type (Image courtesy of Volkswagen).

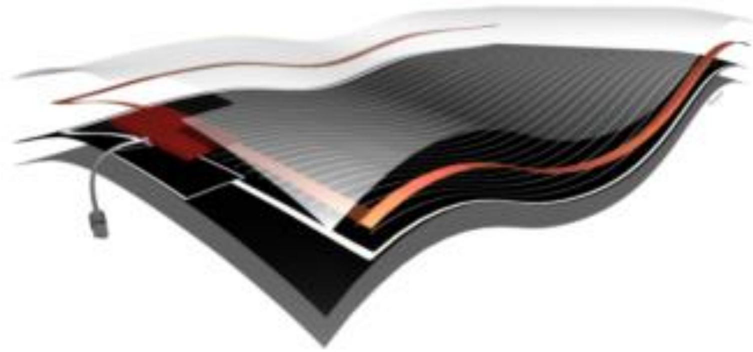


Figure 2 Image of flexible solar cell (Image courtesy of Flisom).

The super-capacitor battery (Figure 1) comprised a ‘bank’ or ‘stack’ of batteries, which were interconnected using copper busbar terminals. Laser welding offered the advantage of high-speed, low heat input and low-distortion.

Flexible organic and inorganic solar cells are increasingly becoming important as an alternative source of energy (Figure 2). Although solar cells are a proven concept / product, many challenges remain in the production process of these flexible thin-film solar cells. As part of the QCOALA project, flexible metal tabs or foils, made of aluminium or copper, were welded to the cells to form modules. This allowed an accurate, low heat input process within the solar cell, which is a very important aspect, since PV cells on <100μm thick foils are extremely fragile and sensitive to mechanical, chemical and thermal stress. Laser welding offered the advantage of a low chemical, thermal and mechanical impact (due to its temporally and spatially selective energy input) compared with ultrasonic welding and conductive adhesives.

The integrated QCOALA technologies were successfully demonstrated on both the solar cell and battery applications.

Results achieved include:

- A dual wavelength (combined 532nm and 1μm wavelengths) laser test platform prototype for thin sheet welding (Figures 3, 4 and 5), tested on thin copper and aluminium electrical interconnections.

Figure 3 Dual wavelength test platform for solar cell application (Courtesy of LASAG)

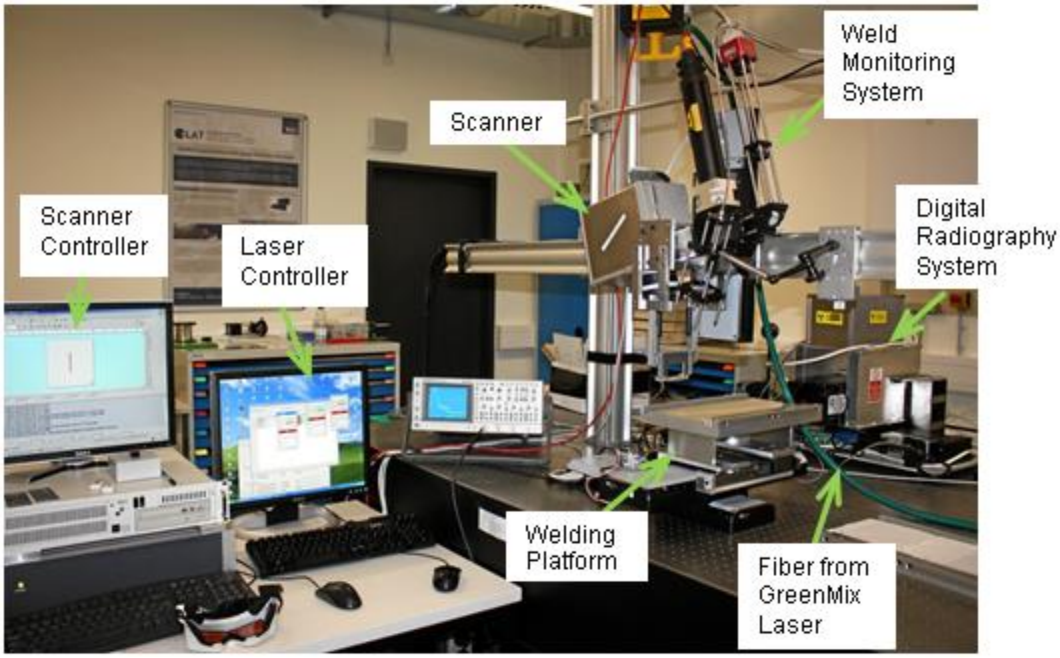


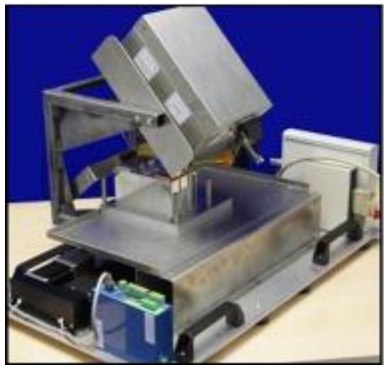
Figure 4 Dual wavelength test platform for solar module application (Courtesy of RUB).


Figure 5 Dual wavelength test platform for battery application (Courtesy of TWI and Precitec).

- A prototype weld Monitoring System (WMS) for 532nm and 1µm laser wavelengths, was developed for the in-line quality monitoring of high quality laser welds in thin-gauge aluminium and copper (Figure 6a). Weld features and defects that could be detected included weld pool geometry, lack of fusion/penetration.

- Post-weld in-line digital radiography (Figure 6b) and eddy current (Figure 6c) technologies were developed to detect small defects (up to sizes of a few tens of nm) in thin-gauge aluminium and copper interconnections, using modelling and experimental work. Defects that could be detected included porosity, cracks and surface blow holes.

a)



b)

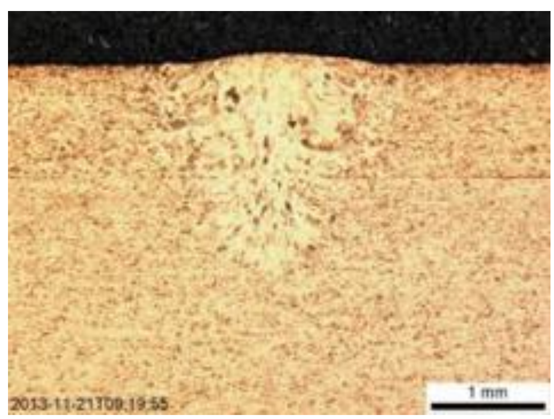
c)

Figure 6

a) Prototype Weld Processing/Monitoring Head (Courtesy of Fraunhofer/ILT);
b) Digital radiography (Courtesy of CIT);
c) Eddy current (Cortesy of TWI) prototype systems.

- Laser welding processing platforms investigated at combined 1µm and 532 nm wavelengths, for the joining of: aluminium to aluminium, copper to copper and aluminium to copper material configurations. Processing parameters investigated include wavelength, spot size, beam quality, pulse length, average and peak power, and repetition rate (Figures 7 & 8).

a)



b)

Figure 7 Micrographs of weld top-bead:
a) Transverse cross-section;
b) Cu (1mm) to Cu (4mm) lap-welded sample, representative of a high quality weld (Photo: TWI).

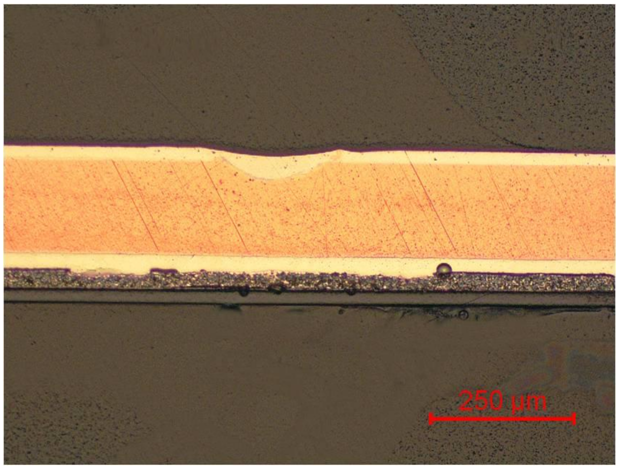


Figure 8
Micrographs of weld cross-section Cu busbar to flexible solar cell module, representative of a good quality joint.

Benefits and Impact of QCOALA technology

- Over 30 events attended and/or presented.
- 4 IPR outputs (2 patents, 1 ™, 1 Design).

The above results will facilitate the introduction of advanced laser automation into mainstream manufacturing of products requiring high yield, small-scale joining and interconnect. This has the potential of increasing productivity by 50-100% and process yields by 2-10%.

The technologies being developed for thin sheet aluminium and copper welding have the potential of being scaled to larger joint sizes and applied to other applications requiring automation, in-process control and monitoring.

Acknowledgement
The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 260153.