L.2 : Novel laser surface treatment to enhance inter-granular corrosion resistance of type 304 stainless steel

A laser surface melting (LSM) treatment has been developed for enhancing inter-granular corrosion (IGC) resistance of type 304 stainless steel (SS). IGC is the main corrosion problem experienced by austenitic stainless steel components operating in nuclear fuel reprocessing and waste management applications and also, in many chemical industries using nitric acid as the process fluid. The basic cause of IGC of austenitic SS is "sensitization" involving inter-granular precipitation of Cr-rich carbides when exposed to temperature range of 773-1073 K. It is accompanied by development of Cr-depleted zones adjacent to grain boundaries leading to IGC.

The results of the present study, performed in collaboration with BARC and IIT, Mumbai, demonstrated that LSM treatment of type 304 SS sheet brought about significant improvement in its IGC resistance.

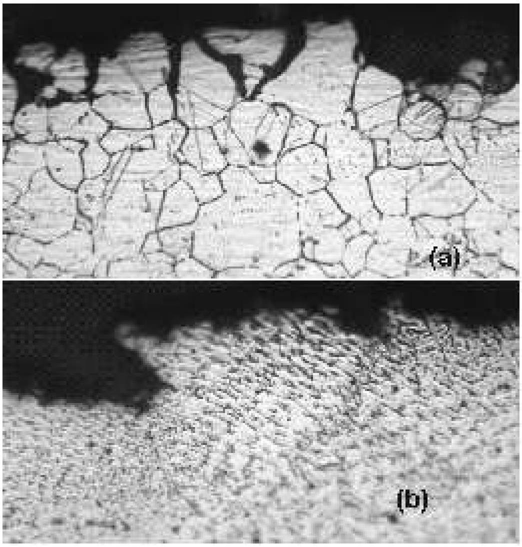

Fig.L.2.1: Comparison of surface microstructures of substrate and laser melted specimens after exposure to sensitization heat treatment & IGC test ASTM A262 Pr. B - (a) substrate with IGC attack and (b) un-attacked laser melted surface.

Figure L.2.1 compares near surface micro-structures of substrate and laser melted specimens after undergoing sensitization heat treatment (923 K / 9 hrs) and IGC test ASTM A262 Pr. B. The results of double loop electrochemical potentio-kinetic reactivation (DL-EPR) test exhibited that laser melted specimens, after undergoing sensitization heat treatment, exhibited significantly lower values of degree of sensitization (DOS, ranging from 0.1-1) than that of the sensitized substrate (4.32). Laser melted surface, even after undergoing sensitization heat treatment, possessed comparable or even lower DOS values than that of the substrate in as-received condition.

Figure L.2.2 compares typical DL-EPR curves of substrate and laser surface melted specimens after exposure to sensitization heat treatment. The factors responsible for enhanced IGC resistance of laser-melted surface are: development of sensitization-resistant microstructure involving (i) high fraction of low angle grain boundaries (increased from 0.04 in the substrate to 0.13-0.19 on laser-melted surface) and (ii) presence of numerous austenite δ-ferrite boundaries. Present work represents a novel approach to engineer surface microstructure of type 304 SS for inducing greater immunity against sensitization & IGC. It has strong potential as an in-situ technique for life enhancement of austenitic SS components operating in corrosive environments.

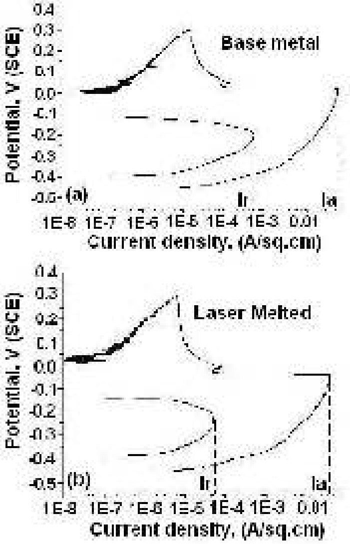

Fig.L.2.2: Comparison of DL-EPR curves for (a) sensitized substrate (DOS = 4.32) & (b) laser melted specimen after exposure to sensitization heat treatment (DOS = 0.106).

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L.3 : Precision processing of silicon with copper vapour laser

Silicon is at the heart of semiconductor, micro-electronics and MEMS technologies. Depending on the nature of the device / sensor, fine structuring (etching, cutting, drilling) varying from few hundreds of nanometers to few hundreds of microns is required to be produced on thin silicon wafers. The UV and visible coherent radiation (~ 250 nm to 600 nm) from a copper vapour laser (CVL) system or second harmonic / sum frequency of CVL are well suited for fast precision processing of silicon.

Laser System Engineering Division of RRCAT has carried out precision etching of bulk Si using 2 W average power CVL (510 nm) radiation (divergence angle of ~60 µrad and pointing angle < 10 µrad). The CVL beam was focussed onto the Si substrate with a lens of 5 cm focal length. The substrate was mounted on a precision 3-axes workstation. The resolution of the workstation was 2 µm. During laser irradiation, the substrate was moved in a predetermined fashion to generate the desired etching pattern. Figures L.3.1a and b show two such results. These pictures were taken by imaging the laser processed Si substrate on a CCD using 100X magnification.

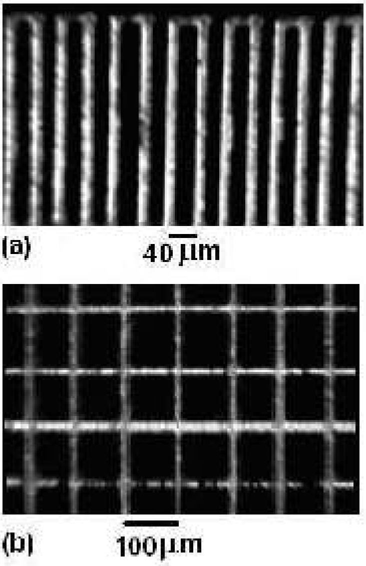

Fig. L.3.1 : Precision etching of silicon with CVL (510 nm) radiation

Laser processing of silicon naturally creates a hazy residue of re-deposited silicon particles. The white tracts, as seen in Fig.L.3.1, are the representatives of this debris. The laser made etched channel is embedded in the debris and is of width much less than 10 µm. The minimum separation achieved between consecutive channels achieved is of the order of 20 µm. In the present experiment, no effort was made to clear the debris. Much higher resolution and cleaner channels are expected in future by utilizing UV radiation and debris cleaning arrangement.

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L.4 : Generation of super-Gaussian beam in a high power transverse flow CO_2 laser

A novel graded phase mirror (GPM) resonator has been designed and developed to generate the lowest order super-Gaussian beam (SGB) with a large user defined waist in a high power transverse flow CW CO_2 laser. The main problem of poor beam quality and inferior focussability in high power TF CO_2 laser is, thus, circumvented by suitably designing an aspheric GPM resonator which efficiently extracts the laser power in single lowest order super-Gaussian mode. The phase profile of the aspheric GPM (Fig.L.4.1) has been designed by using the Fresnel-Kirchhoff's diffraction formulation for wave propagation in an optical resonator and has been fabricated on a copper substrate using a single point diamond turning machine (Nanoform 250, make Taylor-Hobson, USA, available at C.S.I.O., Chandigarh). A thin protective coating of HfO_2 was then applied on the diamond machined aspheric surface.

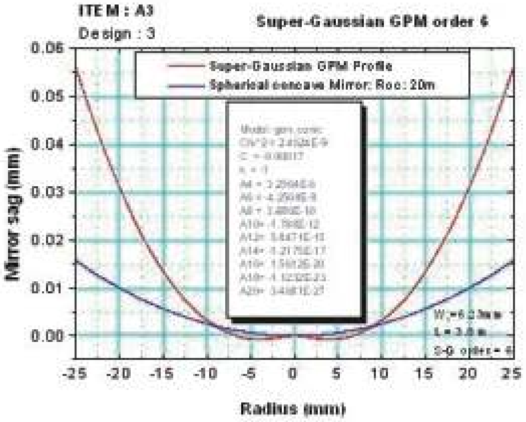

Fig.L.4.1 : Phase profile of the GPM

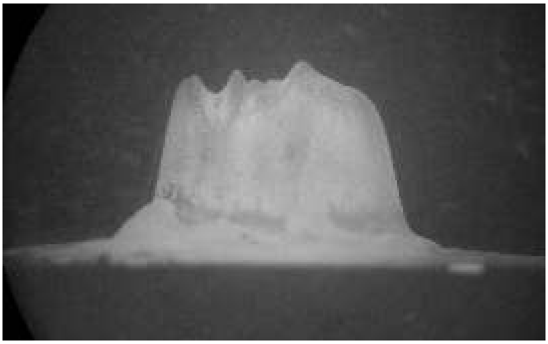

Fig.L.4. 2 : Near-field intensity of SGB

Experiments with the stable super-Gaussian GPM resonator have been carried out in a 3 kW transverse flow CW CO_2 developed at the ICL section, RRCAT. Near field intensity distributions produced by this custom GPM